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Reverse Logistics Inventory Control

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Abstract: Reverse Logistics has received more and more concerns and the inventory management is the key of the process of reverse logistics management. In the light of this, this study researches the inventory problems in the businesses that do the reverse logistics activity. In order to determine the optimal inventory volume, the manufacturing/remanufacturing model is established on the base of some assumptions. The objective in this model is to minimize the total cost per time unit for ordering remanufacturing lots and holding returned and new remanufactured items in stock. Then, the adoption of numerical example shows the effectiveness of this model.

Key words: EPQ, reverse logistics, inventory

INTRODUCTION

As the increasing awareness of environmental protection, shortage of resources and other factors, more and more attentions have paid to reverse logistics. Because implementation of the reverse logistics can save natural resources, increase the enterprise' image, reduce the burden on the environment and so on. Reverse logistics inventory management is extremely important in the reverse logistics management, because the warehouse is the main venues to control the recovery products and recovery product inventory controlling also plays an important role in the operation of enterprises performance. However, that the reverse logistics itself is not controllable and the methods of finishing inventory replenishment are optional makes inventory management issues become exceptionally complex.

This study studies that there exist recovery inventory and the finished product inventory at the same time in the enterprises implementing reverse logistics by means of establishing a simplified reverse logistics inventory model. Assuming that each cycle includes only one manufacturing process and one remanufacturing process, the expression of the total inventory costs is identifies then, finally the minimum total inventory cost per unit time is obtained by the derivation of the expression of the total inventory costs.

SIMPLIFIED INVENTORY MODEL

Products randomly return to manufacturing plants through recycling network, then they create inventory in storage after products return to the factory, waiting further processing. Here assumes that the products after remanufacturing have the same quality as the new products and all of them can directly enter the market to meet customer needs. If the formal equipment manufacturers (original equipment manufacturer, OEM) engage in the recycling of waste products manufacturing at the same time, it forms a manufacturing/remanufacturing hybrid systems of reverse logistics, as shows in Fig. 1 (RI is short for Recovery Inventory; FI is short for Finished Product Inventory).

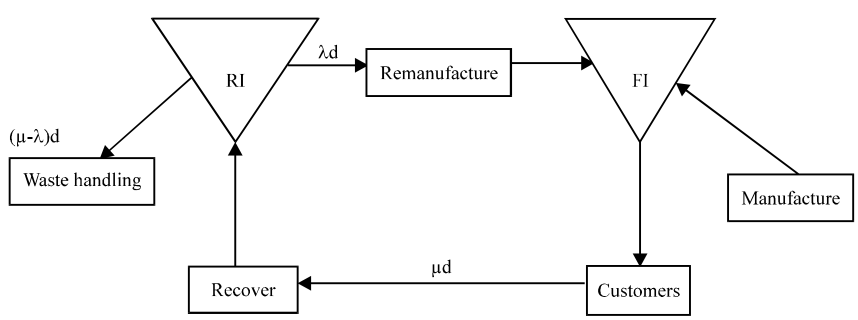

Fig. 1: Simplified inventory model

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In the following model, there are a recovery inventory and a finished product inventory. The recovery products will be put into recovery inventory to wait for further being remanufactured and then the products in the published products can be straightly output to meet customer's needs.

MODEL DESCRIPTION AND DERIVATION PROCESS

Some scholars have made some researches about the problem of the inventory controlling in reverse logistics (Dai and Ma, 2006; Li and Da, 2006; Koh *et al*., 2002), some of which are not realistic or cannot be used in the production practice and some of which are not so intuitive or the calculation process is too complex, which makes readers difficult to understand.

Then to make the analysis simple and clear, the article only studies the production activity that is organized around one manufacturing process and one remanufacturing process, the result of which applies to the M manufacturing or R remanufacturing process and the derivation process is more intuitive.

Before analyzing the problem, some assumptions must be made as followings, that is:

- The demand rate d and the recovery rate are continuous and determined; also it assumes that λ is remanufacturing coefficient and μ is recovery ratio, $0<\mu<1, 0<\lambda<\mu$
- Manufacturing productivity rate and remanufacturing productivity rate are continuous and uniform and manufacturing productivity rate is p_m and remanufacturing productivity rate is p_r and both of them are more than demand rate d
- Manufacturing quantity is Q_m, biggest volume of recovery inventory is Q_r and remanufacturing quantity is Q'_r, thus the volume of waste is Q_r-Q'_r
- Remanufacturing cycle is t_r, manufacturing cycle is t_m and inventory cycle is t
- Storage fee in unit time and unit recovery product is h_r and storage fee in unit time and unit finished product is h_s; ordering fee of each manufacturing and each remanufacturing are separately are K_m and K_r
- The shortage is not allowed and the supplement process takes some time

The analysis is intended to identify the volume of new product manufacturing quantity and the recovery remanufacturing quantity, making unit time inventory total cost the smallest (Hu, 1998). The changes about the volume of the recovery inventory and the finished products inventory are showed as Fig. 2.

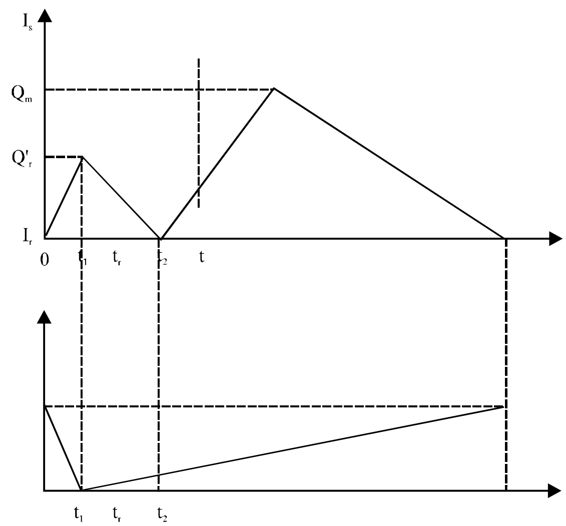

Fig. 2: Changes about finished product inventory and recovery inventory

It can be seen from Fig. 2 that $Q'_r = (p_r\text{-}d).t_1 = d.(t_r\text{-}t_1)$ Thus:

$$t_1 = \frac{d \cdot t_r}{p_r}$$

Similarly, $Q_m = (p_m\text{-}d).(t_2\text{-}t_r) = d.(t\text{-}t_2)$:

$$t_2 = \frac{p_m \cdot t_r + d \cdot t_m}{p_m},\ Q_m = (p_m - d) \cdot \frac{d \cdot t_m}{p_m}\ c$$

In the recovery inventory:

$$Q_r = (p_r - \mu d) \cdot \frac{d \cdot t_r}{p_r}$$

so, the average invent volume of finished product is $(Q'_r/2+Q_m/2)$, then the sum of the ordering fee and storage fee of finished product is:

$$C_1 = K_r + h_s \frac{Q'_r}{2} t_r + K_m + h_s \frac{Q_m}{2} t_m \qquad (1)$$

the average volume of recovery inventory is $Q_r/2$, so the storage fee of the recovery product in the storage cycle t is:

$$C_2 = h_r \frac{Q_r}{2} t \qquad (2)$$

Therefore, the total inventory cost per unit is:

$$C = \frac{C_1 + C_2}{t} = \frac{K_r}{t} + \frac{h_s(p_r - d)dt_r^2}{2p_r t} + \frac{K_m}{t} + \frac{h_s(p_m - d)dt_m^2}{2p_m t} + \frac{h_r(p_r - \mu d)dt_r}{2p_r} \quad (3)$$

Because the remanufacturing coefficient is λ, the ratio of remanufactured product in finished inventory is λ, that is:

$$\frac{t_r}{t} = \lambda, \frac{t_m}{t} = 1 - \lambda$$

Therefore, Eq. 3 can be simplified as follows:

$$C = \frac{K_r}{t} + \frac{h_s(p_r - d)d\lambda^2 t}{2p_r} + \frac{K_m}{t} + \frac{h_s(p_m - d)d(1-\lambda)^2 t}{2p_m} + \frac{h_r(p_r - \mu d)d\lambda t}{2p_r} \quad (4)$$

t is derivative in above formula, ordering:

$$-\frac{K_r}{t^2} + \frac{h_s(p_r - d)d\lambda^2}{2p_r} - \frac{K_m}{t^2} + \frac{h_s(p_m - d)d(1-\lambda)^2}{2p_m} + \frac{h_r(p_r - \mu d)d\lambda}{2p_r} = 0$$

The optimal inventory cycle is obtained as:

$$t^* = \sqrt{\frac{2(K_r + K_m)p_m p_r}{h_s(p_r - d)d\lambda^2 p_m + h_s(p_m - d)d(1-\lambda)^2 p_r + h_r(p_r - \mu d)d\lambda p_m}} \quad (5)$$

So:

$$t_r^* = \sqrt{\frac{2\lambda^2(K_r + K_m)p_m p_r}{h_s(p_r - d)d\lambda^2 p_m + h_s(p_m - d)d(1-\lambda)^2 p_r + h_r(p_r - \mu d)d\lambda p_m}} \quad (6)$$

$$t_m^* = \sqrt{\frac{2(1-\lambda)^2(K_r + K_m)p_m p_r}{h_s(p_r - d)d\lambda^2 p_m + h_s(p_m - d)d(1-\lambda)^2 p_r + h_r(p_r - \mu d)d\lambda p_m}} \quad (7)$$

$$Q_m^* = \frac{(p_m - d)d}{p_m} \cdot t_m^* \quad (8)$$

$$Q_r'^* = \frac{(p_r - d)d}{p_r} \cdot t_r^* \quad (9)$$

$$Q_r^* = \frac{(p_r - \mu d)d}{p_r} \cdot t_r^* \quad (10)$$

Table 1: Information system levelsd

d	λ	μ	p_m	p_r	K_m	K_r	h_r	h_s
200	0.8	0.3	1000	800	100	25	3	5

A NUMERAL EXAMPLE

The simulation calculation is proceeded through the parameters listed in Table 1 to verify the validity of the above derivation process.

The results can be obtained according Eq. 5-10 as follows:

$$t = 0.64, t_r = 0.19, t_m 45$$

$$Q_m = 72.1, Q'_r = 29.0, Q_r = 30.9$$

The optimal total inventory cost per unit time is C = 388.43.

Although, this article only studies the situation that only exist one manufacturing process and one remanufacturing process, it can be extended to M manufacturing process and R remanufacturing process, only corresponding increasing M or R batches in the calculation of storage fee. It is worth noting that, in more than one manufacturing or remanufacturing processes, the batch calculated might not be positive integers, which only need to be adjusted accordingly.

CONCLUSIONS

In this study we consider the complexity of reverse logistics inventory to of the inventory and establish the simplified model, then derive the optimal manufacturing batch and remanufacturing batch that is effective testified by the example. The results can play a certain theory-guiding role on the inventory controlling in the enterprises implementing reverse logistics.

This model could be referenced to adjust the manufacturing and remanufacturing volume quantities to achieve the smallest units in the enterprises implementing reverse logistics, which can reduce inventory total costs, thereby reducing to some extent the costs of implementation of the reverse logistics and to a certain extent it is possible to make enterprises to implement reverse logistics activity.

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