ISSN : 0974 - 7435 Volume 10 Issue 15

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(15), 2014 [8489-8494]

# Inventory control strategies for multi-types emergency resources of maritime traffic accidents

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## ABSTRACT

The emergency resources of maritime traffic accidents can be divided into two main categories, one is routine emergency resource another is professional emergency resource. For maritime accidents, replenishment time of emergency resource affects the inventory cost and shortage fee dramatically. This article analyzes the influence and takes account of characteristics of different emergency resource consumption. Both EOQ model and [s, S] inventory management model are used to explore the optimal inventory replenishment mode and inventory control strategy.

## KEYWORDS

Inventory; Emergency resources; Maritime accidents.

## INTRODUCTION

In recent years, the security situation of global maritime shipping is looking blue. The number of tremendous devastating accidents and serious accidents has increased year by year, although the total number of accidents is decreasing. With the rapid development of large ships and modern transport, the ship results in greater economic losses and more casualties for each accident in average. How to take effective measures to control maritime shipping risk and improve capacity for emergency response has been a maritime research hotspot.

Maritime traffic accident emergency resources are the essential premise for emergency rescue and important basis for emergency management. However, the excessive inventory of emergency resources will inevitably lead to idle and waste of resources, On the contrary, too low inventory of emergency resources cannot meet the needs of accident rescue. Therefore, rational inventory control of emergency resources is to guarantee the implementation of rescue timely and effectively. It’s also an effective way reducing life and property loss and marine pollution. Scientific inventory control strategy will enhance the utilization efficiency of emergency relief supplies, and save financial expenditure.

On random inventory management, Kuojung Yuan[1]presents a basic inventory buffer management method through monitoring real-time inventory, the establishing two stock horizontal lines, a green horizontal line (the largest inventory) and a red horizontal line (safety inventory); Based on Kuojung Yuan’s research, DIAO Ye guang and REN Jianbiao[2]add another stock horizontal line in order to adjust inventory size and reduce order costs timely and effectively. On emergency replenishment management, Zhang yi[3]proposes relief supplies inventory model based on the optimal goal of timeliness, and analyzes the effects of random demand puts on relief inventory supplies; Accordance to the acquisition costs, raise the difficulty, timeliness and other requirements, Wu Yu[4]divides the relief supplies into four categories, and makes different inventory policy reasonably based on the characteristics of muti-types relief supplies; Mao Duohua and Wang Jian[5]consider three materials simultaneously segment needs, using the EOQ model to get the best purchases times and minimum storage capacity; Combined with the consumption characteristics of emergency recourses, Zhang Yanchun[6]focus on inventory changes and adopt the improved [s, S] strategy model to get the optimal order point and order quantity of emergency resources.

Currently, on emergency resources inventory management, existing literatures focus on random demand management and safety stock management. However, the research about replenishment time differences of muti-types emergency resources is very less. Moreover, emergency resources replenishment time could affect the inventory cost, especially for those emergency resources with high requirements of timeliness, The replenishment time even affect the stock losses. Right now, the research on this field is now basically empty.

The emergency resources of maritime traffic accident can be divided into two main categories, one is routine emergency resource another is professional emergency resource. For maritime accident, replenishment time of emergency resource affects the inventory cost and shortage fee dramatically. This article analyzes the influence and takes account of characteristics of different emergency resource consumption. Both EOQ model and [s, S] inventory management model are used to study the optimal inventory replenishment mode and inventory control strategy.

## THE CLASSIFICATION OF MARITIME TRAFFIC ACCIDENTS EMERGENCY RESOURCES

Maritime traffic accidents emergency resources are of different kinds. According to the characteristics of emergency resources consumption, emergency resources can be divided into routine emergency resources and professional emergency resources. Routine emergency resources are used for routine water safety monitoring and early warning, regardless of whether the maritime traffic accident occurs or not, they consume regularly, such as coast guard boat, VHF, security lighting and so on. While professional emergency rescue resources are utilized only when maritime traffic accident occurs, which used in rescuing in order to reduce the loss of life and property, such as, dispersants, fire extinguishers, emergency kits, booms rope.

The consumption characteristics of routine emergency resource are similar with commercial resources. The consumption rate is stable; the average demand follows a normal distribution; inventory costs associated with the average inventory. Thus, the EOQ model can be used for routine emergency resource inventory management, ordering a reasonable amount of order point, determining the safety stock. Once the maritime traffic accident take place, professional rescue emergency resources start to consume. The process of consume is instant. So, emergency inventory change is intermittent. Besides, the time of the accident and demand are difficult to forecast, so it’s more reasonable and scientific to apply [s, S] inventory management strategy through monitoring real-time inventory.

## THE ROUTINE EMERGENCY RESOURCE INVENTORY CONTROL MODEL BASED ON EOQ MODEL

During the emergency resources inventory management, ordering lead time is very important in decision making. As ordering lead time is relevant with the difficulty to raise together, the difficulty for muti-types emergency resources are different and different types of emergency resources have varies ordering time cycle. In this way, if the emergency resources supply is sufficient in the market, the raising cycle is shorter. Conversely, more longer. Such as VHF and emergency lighting is easier to raise, while coast guard boat is relatively difficult.

If we make orders for each routine emergency resource separately, it is not economic obviously. So, it is possible to classify all the routine emergency resources roughly, dividing the ordering lead time into two levels, $LT_1$, $LT_2$, supposing $LT_1 < LT_2$.

Supposing the ordering lead time of routine emergency resource which is relatively easy to obtain (herein referred to Class A emergency resources) is $LT_1$, while the ordering lead time of that is relatively difficult to raise (herein referred to Class B emergency resources) is $LT_2$.

To simplify the study, assume that the unit purchase price and storage costs of Class A and B emergency resources are equal. They are both ordered in emergency logistics center at one time. The library time is negligible and every ordering is of the same size. It's not allowed to be lack of stock. As the amount of safety stock does not affect the size of the order, so the storage fees are not included in the total cost of inventory.

The variables involved in the model are defined as follows:

*D:* the total demand of routine emergency resources for a season;
*d:* the demand of routine emergency resources for unit time
*Q:* the size of ordering;
*K:* The cost for ordering;
$Q_s$: Safety inventory
$C_1$:Unit purchase price of routine emergency resources;
$C_2$ : Unit storage fees of routine emergency resources;
*TC:* the total cost of inventory routine emergency resources emergency for a season;
*ROP:* optimal order point
$LT_1$: the order leading time of A class emergency resources;
$LT_2$: the order leading time of B class of emergency resources;

For a clear understanding of the influence by ordering lead time, the Class A and B emergency resources inventory changes are shown in Figure1 and 2 respectively. Comparing the two Figures, It's easy to get the emergency resources lead time is longer, the greater the optimal reorder point, but the ordering size of emergency resources does not affected.

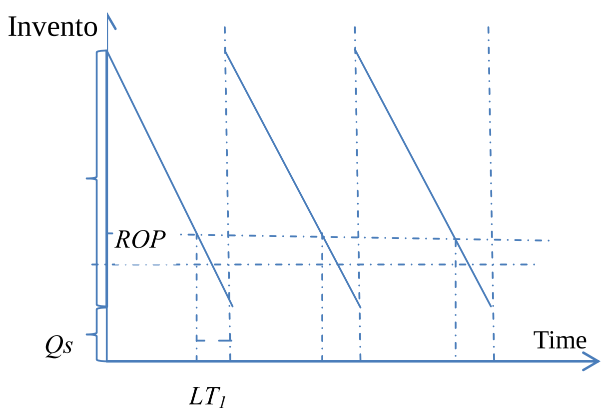


**Figure 1 : Inventory Change of Class A Emergency Resource**

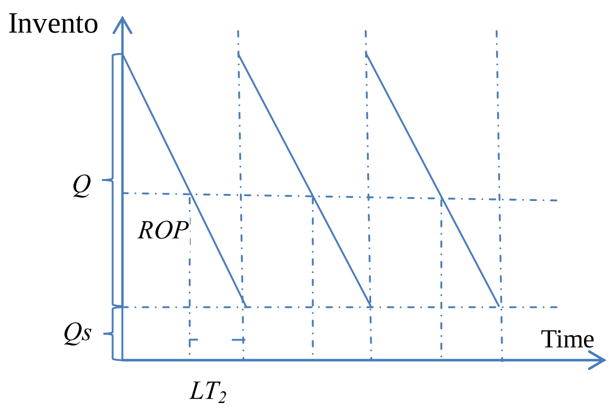


**Figure 2 : Inventory Change of Class B Emergency resource**

**The Optimal Order Quantity of Routine Emergency Resources (Q)**

The total inventory cost *(TC)*of routine emergency resource, includes three parts, the average storage costs, procurement costs and ordering costs namely:

$$\mathrm{TC} = \frac{1}{2}QC_2 + DC_1 + \frac{D}{Q}K \quad \textbf{(1)}$$

Hence, the total cost of inventory *(TC)* 's partial derivative with respect to order quantity *(Q)* is :

$$\frac{\mathrm{d(TC)}}{dQ} = \frac{C_2}{2} - \frac{DK}{Q^2} \quad \textbf{(2)}$$

By setting formula (2) to zero, the optimal order quantity *(Q *)* of routine emergency resources is as follows:

$$Q^* = \sqrt{\frac{2DK}{C_2}} \quad \textbf{(3)}$$

Namely, the optimal order quantity of class A and B emergency resources are both $\sqrt{\frac{2DK}{C_2}}$.

**The Optimal Order Point of Routine Emergency Resources (ROP)**

If the dynamic demand are not taken into consideration, the best order point of class A and B are $ROP(A) = LT_1 * d$, $ROP(B) = LT_2 * d$ respectively. However, as the random characteristics of emergency resource demand may lead to the situation demand exceeds inventory, resulting in stock loss. To avoid the cases there are not enough inventory to meet the emergency resources needs of the maritime traffic accident point resources, reduce stock loss, it is necessary to increase inventory. Thus, except for the inventory quantity to maintaining regular consume, it's necessary to add additional inventory to meet demand due to random disturbances of the ordering speed and time, to ensure the cash supply capacity.

Take class A emergency resources for example, assuming that the demand per unit time *(d)* of class A emergency resource follows a normal distribution, that is $\mathrm{d} \sim \mathrm{N}(\mathrm{d}, \sigma^2)$. During the ordering lead time $LT_1$, the demand $d(LT_1)$ follows normally distributed $\mathrm{d}(\mathrm{LT}_1) \sim \mathrm{N}(\mathrm{d} * \mathrm{LT}_1, \sigma^2 * \mathrm{LT}_1)$.

Therefore, the best reorder point *(ROP)* should satisfy:

$$\frac{ROP - \mathrm{d} * \mathrm{LT}_1}{\sigma\sqrt{LT_1}} \sim N(0,1) \quad \textbf{(4)}$$

Let *Z* as stock safety factor, the class A emergency resources safety stock $Q_s$ can be expressed as:

$$\mathrm{Q}_s = \mathrm{ROP} - \mathrm{d} * \mathrm{LT}_1 = \mathrm{Z} * \sigma\sqrt{LT_1} \quad \textbf{(5)}$$

Then get the optimal order point of Class A emergency resource is: $\mathrm{ROP(A)} = LT_1 * d + \mathrm{Z} * \sigma\sqrt{LT_1}$
Similarly, the optimal order point of Class B emergency resource is: $\mathrm{ROP(B)} = LT_2 * d + \mathrm{Z} * \sigma\sqrt{LT_2}$

## THE INVENTORY MANAGEMENT STRATEGIES OF PROFESSIONAL EMERGENCY RESOURCE BASED ON [S, S] MODEL

The most typical characteristic of professional emergency resources consumption is the time of consumption depends on whether maritime traffic accidents occur. Besides, the consumption speed is very quick, and the demand of consumption is random. The inventory cost of professional emergency resources includes inventory shortage cost. and The shortage costs not only associate with the existing inventory, and also with the time.

Compared with routine emergency resources, there is no ordering lead time in professional emergency resources inventory management. In general, after the maritime emergencies, the inventory will be checked, consumption checking, decide whether to order resource or not. The size of ordering is related with the existing inventory. The replenishment cycle of professional emergency resource (including the raising, purchasing, transporting time) will affect inventory costs (including storage charges, stock charges). Therefore, as is similar to routine emergency resources, the replenishment cycle of professional emergency resource can divided into two levels $t_1$, $t_2$, supposing $t_1 < t_2$.

The replenishment cycle of professional emergency resources (herein referred to class C emergency resources)whose replenishment is relatively easy can be set to $t_1$. The replenishment cycle of professional emergency resources (herein referred to class D emergency resources)whose replenishment is relatively difficult can be set to $t_2$.

To simplify the study, in the event of maritime accidents, professional emergency resource consumption, instantaneous, the time of consuming is negligible. If the amount of resource consumption is rather small, they remain size of inventory is in the range [s, S],the storage fee and shortage fee can be seen as the same. When the inventory level drops below s, the changes of storage fee and shortage fee have to be taken into consideration. In an inventory cycle, replenishment happens at least one time.

In this section, the meaning of the parameters $K$, $C_1$ is the same with that in section 2). In addition, there are some other parameters involved in this part. They can be defined as follows:

*r:* demand of professional emergency resources, the probability density of which is *p (r);*
*x:* current inventory of professional emergency resources;
*S:* The largest inventory of professional emergency resources, that is, $x + Q = S$;
s:The order point, decide to order when professional emergency resource stock is less than s;
*T:* the inventory cycle;
*Q:* The order quantity of professional emergency resource, which is a variable;
$C_2$: Storage costs for unit professional emergency resource in a time unit;
$C_3$: storage fee for Unit professional emergency resource in a time unit;

After the maritime emergencies, the inventory will be checked, consumption checking, decide whether to order resource or not. When the current inventory $x < s$,order is necessary; when the current inventory $x \geq s$,ordering is unnecessary. For a clear understanding of the influence by replenishment cycle, the Class C and D emergency resources inventory changes are shown in Figure3 and 4 respectively.

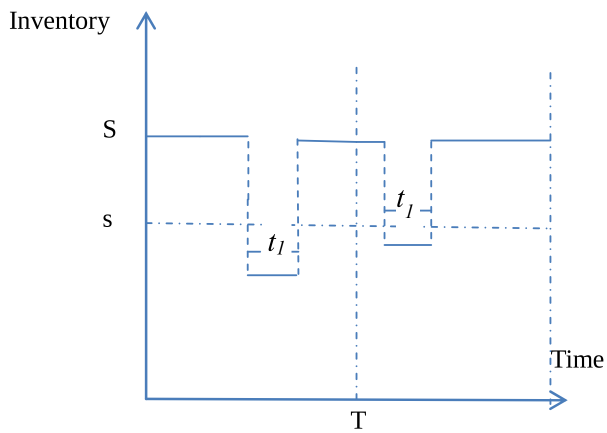


**Figure 3 : Inventory Change of Class C emergency Resource**

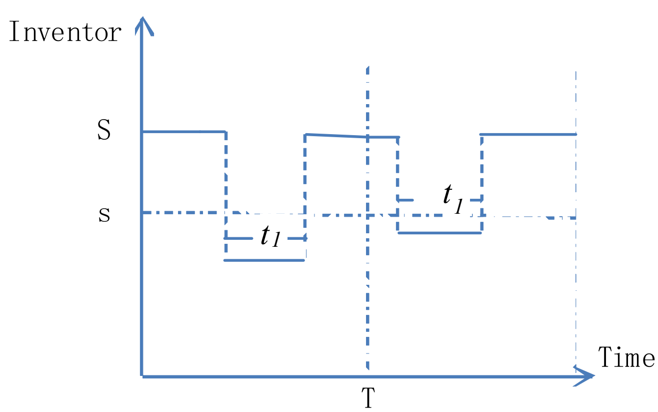


**Figure 4 : Inventory Change of Class D Emergency Resource**

**The Maximum Inventory of Professional Emergency Resource (S)**

According to the requirements of *[s, S]* inventory management model, when the initial inventory $x > s$, the order quantity $Q = 0$; when $x < s$, $Q > o$. Making the minimum of total cost in a inventory time as the objective, we can get the target solution *S,* s.

Taking the class C emergency resources for example. When $Q > o$, the total inventory costs of professional emergency resources in a inventory cycle include ordering costs, professional fees emergency resource procurement, ordering professional emergency resources during storage fees and shortage costs, non-professional emergency resources during the ordering and storage fees out costs, namely:

$$\mathrm{C(Q)} = K + \mathrm{C}_1 Q + C_2(ST - Qt_1) + C_3 T\int_S^{\infty}(r-S)p(r)dr + C_3 t_1\int_{S-Q}^{S}(r-S+Q)p(r)\,dr \quad \textbf{(6)}$$

When $Q = 0$, due to emergency resources and reserves and shortage costs are the same with that when maritime traffic accidents do not happen, we can suppose there are no maritime accidents.

In the case that $Q > 0$, when total cost of inventory $C(Q)$ reaches a minimum value, the $Q$ is the optimal value, so setting $dC(Q)/dQ = 0$ we can get:

$$\int_0^S p(r)dr = 1 - \frac{C_1 + C_2 T - C_2 t_1}{C_3 T} \quad \textbf{(7)}$$

**The Reorder Point of Professional Emergency Resources (s)**

If we decide to order professional emergency resources, the inventory cost in the period of $T$ is :

$$\mathrm{J} = \mathrm{K} + C_1(S - \mathrm{x}) + C_2 S\cdot T + C_3(T - t_1)\int_S^{\infty}(r-S)p(r)\,dr + C_3 t_1\int_x^{\infty}(r-x)p(r)\,dr \quad \textbf{(8)}$$

If we don't order professional emergency resources, the inventory cost in the period of $T$ is :

$$J' = C_2 x\cdot T + C_3 T\int_x^{\infty}(r-x)p(r)\,dr \quad \textbf{(9)}$$

Obviously, due to the order cost, the inventory cost $J$ must be higher than $J'$. namely:

$$C_2 x\cdot T + C_3 T\int_x^{\infty}(r-x)p(r)\,dr \le \mathrm{K} + C_1(S-\mathrm{x}) + C_2 S\cdot T + C_3(T-t_1)\int_S^{\infty}(r-S)p(r)\,dr + C_3 t_1\int_x^{\infty}(r-x)p(r)\,dr \quad \textbf{(10)}$$

*Thus,s* is the maximum value when the above inequality formula makes sense. We can get:

$$\int_0^s p(r)dr = 1 - \frac{(\mathrm{T} - t_1)(C_1 + C_2 T - C_2 t_1)}{C_3 T} \quad \textbf{(11)}$$

## CONCLUSION

We conclude by summarizing our main results. We developed different Inventory control strategies for Muti-types emergency resources of maritime traffic accidents.

For routine emergency resource, the optimal order quantity is $Q$ *,when the ordering cost is higher and the storage fee is lower,the optimal order quantity will become larger. The best reorder point and safety stock is related with ordering lead time of different resources. For professional emergency resource, the maximum inventory and the reorder point of professional emergency resources are related with replenishment circle of different resources.

However, we just try to make a tentative study on Inventory Control Strategies for Muti-types emergency resources. For future research, the influence how the replenishment time and ordering lead time affect the Inventory timeliness need to be discussed.

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