Atlantis Highlights in Intelligent Systems, volume 2
Proceedings of the 2021 International conference on Smart Technologies and Systems for Internet of Things (STS-IOT 2021)

Analysis of (r,Q) and (s,S) Spare Parts Ordering Strategy under Maximum Inventory Constraints

Ou Qi[1], Lei Zhang[2] and Jiuchao Li[1*]

[1]*Army Academy of Armored Force, Beijing, China*
[2]*NO.2 Military Representative Office in Changchun of Shenyang Military Representative Bureau, Changchun, Jilin, China*
[*]*Corresponding author. Email: 247658766@qq.com*

ABSTRACT
Aiming at the limited maximum inventory in actual storage, the advantages and disadvantages of (R, q) and (s, s) spare parts ordering strategies are analyzed. Through the storage cost modeling, the optimal cost parameters of the two strategies are determined. Under the condition of cost optimal parameter control, the (R, q) and (s, s) ordering strategies are compared by sections, the cost maximum inventory relationship curves of the two strategies are obtained, and the calculation method of cost control critical point is given, which improves the practicability of spare parts ordering strategy under the condition of maximum inventory.

Keywords: *Inventory system, (R, q) strategy, (s, s) strategy, Inventory cost, Discrete demand*

1. INTRODUCTION

The selection of spare parts ordering strategy is a key link in the supply management of non-repairable parts in the equipment field. In order to minimize the ordering cost of spare parts under specific constraints, scholars at home and abroad have carried out a lot of research.

Considering that the ordering of spare parts is constrained by the ordering quantity and inventory, Li Wu establishes the minimum expected cost per unit time (R, q) optimization model between two adjacent orders. The model overcomes the disadvantage that the traditional (R, q) model is too sensitive to the demand distribution and improves the robustness of the ordering strategy. Ling Liuyi [1] established the cost calculation model of (R, q) ordering strategy based on BOM on the basis of (s-1, s) strategy, and gave the global optimal solution of ordering strategy. For the cost optimization problem of multi-level inventory system, Wanjie [2] established arena simulation model, determined the retailer's optimal order point and order batch, and realized the retailer's supply chain inventory cost control.

A two-level distribution[3] system whose demand obeys Poisson, and obtained the optimal inventory allocation strategy of the system through policy iteration. An example shows that the strategy can significantly reduce the overall cost of the system. The problems of high demand uncertainty is aimed at and large shortage loss of spare parts in the traditional rigid spare parts ordering strategy of electromechanical equipment [4], established the spare parts procurement model by using the binary tree model method, which effectively restrained the demand uncertainty and shortage loss. In order to reduce the inventory cost of spare parts under uncertain demand, a discrete uncertain spare parts ordering model established based on triangular fuzzy number [5], which reduced the unnecessary inventory and inventory cost of large equipment maintenance enterprises [6-7].

The above research optimizes the ordering strategy for specific problems, reduces unnecessary inventory and saves inventory cost. However, the limitation of maximum storage space is considered, which reduces the practicability of the results. In view of the limited maximum inventory in actual storage, the advantages and disadvantages of classical (R, q) and (s, s) spare parts ordering strategies under random demand are analyzed, and the critical points of the two strategies in the application of cost control are given.

2. MODEL CONSTRUCTION CONDITION SETTING

Assuming that the process of generating demand for each kind of spare parts is a stochastic stationary process, if the expected value of annual demand for a certain spare part is, the probability of generating K demands in any time t (year) conforms to Poisson distribution:

$$p(k,\lambda t)=\frac{(\lambda t)^t}{k!}e^{-\lambda t} \quad (1)$$

In order to facilitate the establishment of calculation models, it is assumed that:

The storage space of spare parts is limited, and the maximum is Smax;

Spare parts demand is a discrete variable, but the annual demand λ is expected to be constant

The unit price of spare parts is k, the storage cost per unit time is C1, the shortage loss cost is C2, and the cost of each order is C3. Demand r is a discrete random variable. The values of demand r are r0,r1,…, rm, and its probability is P(r0), P(r1),…, P(rm), and $\sum_{i=0}^{m}P(r_i)=1$

This model allows stock outs to occur

3. (R,Q) POLICY PARAMETER DETERMINATION

(r,Q) assume that the demand isr, single order quantity is Q, Under this condition, there are three kinds of expenses

When the supply exceeds the demand, the expected value of the storage cost of spare parts is

$$\sum_{r=0}^{Q}C_1(Q-r)P(r) \quad (1)$$

In case of short supply, the expected value of shortage loss cost is

$$\sum_{r=Q+1}^{m}C_2(r-Q)P(r) \quad (2)$$

When ordering each time, the expected value of ordering cost and spare parts purchase cost is

$$C_3+KQ \quad (3)$$

Then the total cost in a cycle isf

$$C(Q)=\sum_{r=0}^{Q}C_1(Q-r)P(r)+\sum_{r=Q+1}^{m}C_2(r-Q)P(r)+C_3+KQ \quad (4)$$

The best Q is the ordering strategy to minimize the cycle cost, that is

$$C(Q)\le C(Q+1)$$
$$C(Q)\le C(Q+1) \quad (5)\ (5)$$

Substitute the above formula into the above formula

$$\sum_{r=0}^{Q-1}P(r)<\frac{C_2}{C_1+C_2}<\sum_{r=0}^{Q}P(r) \quad (6)\ (6)$$

Note that all the results satisfying the above formula are Q^*

4. (S,S) POLICY PARAMETER DETERMINATION

Considering an order cycle, the initial inventory is I. at the beginning of the cycle, it is necessary to determine whether to order in this cycle. Assuming s is the order point, if I > s, no order will be made; If I ≤ s, it is necessary to order and supplement the inventory to s, that is, the order quantity in this cycle is S-I.

When I > s, no order is placed, and the total cost is the sum of storage cost and shortage loss cost

$$C(s,S)=\sum_{r\le I}C_1(I-r)P(r)+\sum_{r>I}C_2(r-I)P(r) \quad (7))(7)$$

When I ≤ s, order and replenish the inventory to s. The total cost is the sum of ordering cost, storage cost and shortage loss cost

$$C(s,S)=C_3+K(S-s)+\sum_{r\le S}C_1(S-r)P(r)+\sum_{r>S}C_2(r-S)P(r) \quad (8)$$

The demand r is one of r0,r1,…, rm. Under the condition of never generating periodic inventory redundancy. set $S_i=r_i(i=1,2,...,n)$ the value of S should also be one of r0,r1,…, rm, so that the problem of solving s is transformed into the problem of finding the minimum S_i to meet the following constraints

$$C(S_i)\le C(S_{i+1})$$
$$C(S_i)\le C(S_{i-1}) \quad (9)$$

The second formula is substituted into the constraint conditions

$$\sum_{r\le S_{i-1}}P(r)\le\frac{C_2-k}{C_1+C_2}\le\sum_{r\le S_i}P(r) \quad (10)$$

Take the order quantity S_i of this cycle that satisfies the above formula $S^*=\min(S_i)$, $Q^*=S^*-I$ is called order critical value $N=\frac{C_2-K}{C_1+C_2}$.

Obviously, if the expected cost of not ordering the current inventory is less than the expected cost of ordering, it is appropriate to choose not to order. As can be seen from the above, the expected cost of non-ordering is

$$C(s)=\sum_{r\le s}C_1(s-r)P(r)+\sum_{r>s}C_2(r-s)P(r) \quad (11)$$

The expected cost of ordering is

$$C(s,S^*)=C_3+K(S^*-s)+\sum_{r\le S^*}C_1(S^*-r)P(r)+\sum_{r>S^*}C_2(r-S^*)P(r)$$

$$\Sigma\varepsilon\tau\ C(s)\le C(s,S^*) \quad (12)$$

Substitute $s = r_i$ i=1,2,…,m into the cost constraint, and the first satisfied $C(s) \le C(s,S^*)$ is recorded as s^*

5. STORAGE COST CALCULATION UNDER MAXIMUM INVENTORY CONSTRAINTS

5.1 Model Comparison

Through comparison, it can be seen that $0 < s < S < Q$

Assuming that the maximum inventory of a company is S_0, the cost constraint can be divided into the following cases according to the value of S_0, $S_0 > Q$

When the maximum inventory is $S_0 > Q$, (s,S) the cost expectation of the strategy is $C(s,S) = \min(\underset{I>s}{C(s,S)}, \underset{I\le s}{C(s,S)})$

The (r,Q) cost expectation of the strategy is:

$$C(Q) = \sum_{r=0}^{Q} C_1(Q-r)P(r) + \sum_{r=Q+1}^{m} C_2(r-Q)P(r) + C_3 + KQ$$

□□□It can be seen from the comparison $\underset{I>s}{C(s,S)}$ and $C(Q)$ calculation formula $\underset{I>s}{C(s,S)} < C(Q)$ and $C(s,S) = \min(\underset{I>s}{C(s,S)}, \underset{I\le s}{C(s,S)}) < \underset{I>s}{C(s,S)}$.

Therefore $C(s,S) < C(Q)$, when the maximum inventory limit exceeds the maximum storage space required by the two strategies, the strategy (s,S) is better than the strategy (r,Q).

$$S < S_0 < Q$$

When the maximum inventory is in this interval, the storage limit will affect the (r,Q) optimization effect and increase (r,Q) the required cost. When it is in this interval, it has no impact on the normal operation of the strategy (s,S), so it is also (s,S) better than the strategy (r,Q) in this interval

$$s < S_0 < S$$

In this range, due to the limit of maximum inventory, set $Q = S_0$ in (r,Q) and $S = S_0$ in (s,S). Therefore, when S_0 is in this range,

the cost expectation of the strategy (r,Q) is

$$C(S_0) = \sum_{r=0}^{S_0} C_1(S_0-r)P(r) + \sum_{r=S_0+1}^{m} C_2(r-S_0)P(r) + C_3 + KS_0$$

(s,S) cost expectation of the strategy is

$$C(s,S_0) = \min(\underset{I>S_0}{C(s,S_0)}, \underset{I\le S_0}{C(s,S_0)}) \tag{13}$$

Due to the limitation of maximum inventory, the situation cannot happen, so the cost expectation of the strategy is

$$C(s,S_0) = \underset{I>S_0}{C(s,S_0)} \tag{14}$$

Considering that the average cost of individual spare parts is equal, make

$$\frac{C(s,S_0)}{S_0 - s} = \frac{C(S_0)}{S_0} \tag{15}$$

Can be obtained

$$\sum_{r=0}^{S_0} (S_0 - r)P(r) = \frac{C_3 - C_2}{C_1 - C_2} \tag{16}$$

Note that at this time, because it is always a positive number, it exists and is unique. When $S_0 > S_0^*$ and $C(Q) > C(s,S)$,the strategy (s,S) has advantages; On the contrary, when $S_0 < S_0^*$, strategy (r,Q) has advantages.

$$0 < S_0 < s$$

When the maximum inventory is in this range and the maximum inventory is lower than the order point, the strategy (s,S) cannot work normally; Although the limitation of maximum inventory leads to a significant increase in storage costs, the strategy (r,Q) can still meet the requirements of the system under this condition.

5.2 Cost comparison

Install components that can be completely decomposed into various levels. The failure of each level is caused by the failure of one of its subordinate components. The repair of field replaceable unit (LRU) components is completed by replacing replaceable unit (SRU) and other components in subordinate workshops. The non-decomposable repairable parts are directly repaired, and the non-repairable parts are directly discarded.

Each installation is deployed at a site, and various pieces are stored at the site. The time of accessing each piece is ignored, that is, the model only analyzes the case of a single site.

MTBF of each non decomposable component is known, and the demand rate of decomposable component is equal to the sum of the demand rates of all subordinate components of the component:

$$\lambda_{\sup} = \sum_{i=1}^{l} \lambda_i n_i \tag{17}$$

Where: $\lambda_i = t_U / MTBF_i$ is the annual average demand rate of spare parts in i; n_i is the number of the spare parts installed in the superior parts; t_U is the average annual service time of equipment.

The meanings of some variables in this paper are as follows: MTTR is the average repair time of faulty parts, MTTR is the inventory level of repairable parts, and Bo is the current shortage of repairable parts at the guarantee station; E80 is the expected shortage of repairable parts at the guarantee site, R is the reordering and purchase point of non-repairable parts, q is the quantity of non-repairable parts ordered each time, and it is the ordering time of non-repairable parts; G is the unit price of non-repairable order; A_s is supply availability for equipment, A_0 is the inherent availability of equipment; A is the availability of equipment.

6. CONCLUSION

In this paper, under the condition of random demand, the optimal cost parameters of the strategy (s,S) and the strategy (r,Q) are determined. Considering the limitation of the actual storage space on the spare parts ordering strategy, the strategy (s,S) and the strategy (r,Q) are compared by sections. The results show that when the maximum storage space is not obviously limited to the spare parts ordering strategy, the strategy (s,S) is better than the traditional strategy (r,Q), On the contrary, the traditional strategy (r,Q) is better than the strategy (s,S).

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