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Demand Prediction of LRU Parts with Backorder for SRU

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Abstract—*For the problem that the demand of vari-indenture Recoverable Parts did not submit to the Poisson distribution, put forward the Negative binomial distribution to improve the forecasting accuracy. Used the fill rate to estimate the supply degree of Recoverable Parts, the restricted total security funds and the lowest fill rate as the constraint conditions, searching for the fill rate maximization as the objective function, established the demand forecasting model of Recoverable Parts, through the marginal analysis to solve it. The example proves that the model has good prediction effect.*

Keywords-demand prediction; Recoverable Parts; Negative binomial distribution; vari-indenture

I. INTRODUCTION

For the demand prediction of Recoverable Parts, commonly assume that Recoverable Parts follows the Poisson distribution. But for the demand problem of the vari-indenture Recoverable Parts, the actual probability distribution of Recoverable Parts does not always follows the Poisson distribution, if still use the Poisson distribution to forecast the demand of Recoverable Parts, which will lead to the more higher errors. Actually, the demand of the vari-indenture Recoverable Parts submits to the Negative binomial distribution, this paper studies the application of the distribution on the demand prediction of the vari-indenture Recoverable Parts.

II. MODEL FOUNDATION

A. Assumptions

1) The failed number of Recoverable Parts is independent of each other.

2) No cannibalization.

3) LRU (Line-replaceable Unit) occurs in the base, if currently stock is not 0 then send out one, if not, once shortage of LRU happens. Both cases, no matter what kind, are at the base repairing the failed LRU, while in the repair process finds that its SRU (Shop-replaceable Unit) is failed, replace them if the failed SRU in stock to complete the repair, or once shortage of SRU occurs. Both cases, no matter what kind, are at the base repairing SRU. Each failed LRU only because of a failed SRU, SRU repair will not be delayed for its Recoverable Parts not in stock. This paper mainly studies the two-indenture demand problems that the first indenture Recoverable Parts follows the Poisson distribution, as in [1-4].

B. Fill rate and demand distribution model

The fill rate is the percentage of the contented demand, it is only relevant with the circumstances when the demand occurs, is suitable to measure the supply level of Recoverable Parts.

Set s as the stock, if the demand x is less than or equal to s-1, then the stock of Recoverable Parts meets the demand, which means that once of demand is supplied, and the fill rate increases in the same pace with s, whose model is

$$\mathrm{EFR}(s)=\sum_{x=0}^{s-1}\Pr\{x\} \tag{1}$$

Where, Pr(x) is the steady-state probability distribution of demand x, whose model is

$$\Pr\{x\}=\begin{cases}\dfrac{(\mu)^x e^{-\mu}}{x!} & V=1\\ \dbinom{r+x-1}{x}\, p^x(x-p)^{\,r} & V>1\\ \dbinom{n}{x}\, p^x(1-p)^{\,n-x} & V<1\end{cases} \tag{2}$$

Where, μ is mean of demand x, $x=0,1,2,\ldots$, V is variance-to-mean ratio of Parts' Pipeline.

1) If Backorder of LRU does not occur for its SRU, then the demand of any Recoverable Parts is generally subject to the Poisson process with the average annual demand m, the average repair time T, according to Palm theorem, the steady-state probability distribution of amount of repairing Recoverable Parts, follows the Poisson distribution with mean $\mu=mT$ and V=1, as in [5].

2) If Backorder of LRU occurs for its SRU, then the demand of its SRU still follows the Poisson distribution, but the demand of the LRU follows the Negative binomial distribution with mean $\mu=E(X_0)$ and $V=\dfrac{Var(X_0)}{E(X_0)}$, when $V>1$, so the values of the parameters of the Negative binomial distribution are $r=\dfrac{\mu}{V-1}, p=\dfrac{1}{V}$. $E(X_0)$ and $Var(X_0)$ are namely

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$$E(X_0) = m_0 T_0 + \sum_{j=1}^{J} \mathrm{EBO}(s_{0j} \mid m_{0j} T_{0j}) \tag{3}$$

$$Var(X_0) = m_0 T_0 + \sum_{j=1}^{J} \mathrm{VBO}(s_{0j} \mid m_{0j} T_{0j}) \tag{4}$$

Where, $m_0 = \sum_{j=1}^{J} m_{0j}$, m is one year of demand of the LRU, the subscript 0 is the index of LRU Parts, the subscript j is the index of its own SRU Parts. EBO(s) is the expectation of Pipeline shortage, VBO(s) is the variance of Pipeline shortage.

3) If Backorder of LRU does not occur for its SRU, generally, the demand of any Recoverable Parts is subject to the Poisson process, but for the LRU replaced for the wear and tear failure, which follows the Binomial distribution with mean $\mu = np$ and $V = 1 - p$,as in [6], when V <1, so the values of the parameters of the Binomial distribution are $n = \frac{\mu}{1-V}, p = 1 - V$. Because the LRU, with the wear and tear failure, generally does not replace the SRU, but to replace the whole unit, so this paper do not take into account the vari-indenture problems of these LRU.

C. Model optimization

The optimization objective of demand prediction of Recoverable Parts is to get the total fill rate of Recoverable Parts system highest, under the constraint condition of the determinate total supply costs and the lowest fill rate of each Recoverable Parts, as in [7-12], the optimization model is

$$\left.\begin{aligned} &\max z = \sum_{i=1}^{I} \mathrm{EFR}_i(s_i) \\ &\sum_{i=1}^{I} c_i s_i \le C \\ &E_i \le \mathrm{EFR}_i(s_i) \end{aligned}\right\} \tag{5}$$

Where, c_i is the unit price of the ith Recoverable Parts, C is the total supply funds of Recoverable Parts system, whose unit is million dollars; I is the serial number of Recoverable Parts. In addition, E_i is the lowest fill rate of the ith Recoverable Parts, which is given by the impact on the flight and conditions of finance, as in [13-14].

The lowest fill rate of the Parts is formulated with the main considerations on the two factors, namely the impact on the flight and the conditions of purchase. The Parts, which are greater impact on the flight and more difficult to purchase, are the sticking points of the Parts supply work and the difficulty in prediction, whose lowest fill rate may be formulated slightly higher; the others is gradually reduced in accordance with the impact on the flight and conditions of stock.

The lowest fill rates of the Parts formulated in this paper are:

1) For the Parts that are more important on the flight and more difficult to purchase, whose lowest fill rate is 0.90 to 0.95;

2) For the Parts that are comparatively easier to purchase, whose lowest fill rate is 0.85 to 0.89;

3) For the Parts with a certain influence on the flight, more difficult to purchase, whose lowest fill rate is 0.80 to 0.84;

4) For the Parts with a certain influence on the flight, comparatively easier to purchase, whose lowest fill rate is 0.75 to 0.79;

5) For the Parts with little impact on the flight, then for which do not need to set the minimum fill rate.

D. Model Solution

First, determine the distribution that the demand of Recoverable Parts follows, and calculate its parameters.

Then, according to the optimization model, through the marginal analysis method, calculate the maximum total fill rate and optimization amount of the demand of each Recoverable Parts.

III. SAMPLE

In some base, a LRU has two items of SRU, namely SRU1, SRU2. In the past ten years, the demand statistical data of Recoverable Parts is shown in Tab.Ⅰ. The lowest fill rate of each Parts is same, namely 85%, the variance-to-mean ratio of the LRU is 1.

TABLE I. DEMAND STATISTICAL DATA

Parts	stock	price /(10000 dollar)	repair period /(year)	average demand
LRU	4	2	0.1	6
SRU1	2	1	0.4	3
SRU2	2	1	0.4	2

Because the variance-to-mean ratio of the LRU is 1, so it follows the Poisson distribution. Next, compute the variance-to-mean ratio of LRU' Pipeline, which is 1.2009, obviously, the LRU should be to forecast not by the Poisson distribution but by Negative binomial distribution, the values of whose parameters are r=1.4934, p=0.1673. The fill rates of Parts under condition of different stock are shown in Tab.Ⅱ, the demand prediction results are shown in Tab.Ⅲ.

TABLE II. FILL RATE OF PARTS UNDER CONDITION OF DIFFERENT STOCK

demand amount	fill rate of LRU	fill rate of SRU1	fill rate of SRU2
1	0.0692	0.3012	0.4493
2	0.1553	0.6626	0.8088
3	0.2447	0.8795	0.9526
4	0.3314	0.9662	0.9909
5	0.4125	0.9923	0.9986

demand amount	fill rate of LRU	fill rate of SRU1	fill rate of SRU2
6	0.4866	0.9985	0.9998
7	0.5535	0.9997	1
8	0.6131	1	1
9	0.6657	1	1
10	0.712	1	1
11	0.7524	1	1
12	0.7876	1	1
13	0.8181	1	1
14	0.8445	1	1
15	0.8672	1	1
16	0.8867	1	1
17	0.9035	1	1
18	0.9179	1	1
19	0.9302	1	1
20	0.9407	1	1
21	0.9497	1	1
22	0.9573	1	1
23	0.9638	1	1
24	0.9693	1	1
25	0.974	1	1
26	0.978	1	1
27	0.9814	1	1
28	0.9843	1	1
29	0.9867	1	1
30	0.9888	1	1

TABLE III. DEMAND PREDICTION RESULTS

steps	demand amount of LRU	demand amount of SRU1	demand amount of SRU2	total fill rate	total funds /(10000 dollar)
1	15	4	3	2.786	31.1
2	15	4	4	2.8243	31.2
3	15	5	4	2.8504	31.4
4	15	5	5	2.858	31.5
5	15	6	5	2.8643	31.7
6	15	6	6	2.8655	31.8
7	16	6	6	2.8851	33.8
8	17	6	6	2.9018	35.8
9	18	6	6	2.9162	37.8
10	18	7	6	2.9175	38

If the total cost is 311000 dollars, the total fill rate of Parts system next year will achieve to 2.786, the demand amount of each Parts met next year is (15, 4, 3), the fill rate of each Parts is (0.8672, 0.9662, 0.9526), all higher than 85%.

If the total cost is enough, such as 380000 dollars, the total fill rate of Parts system next year is 2.9175, the demand amount of each Parts met next year is (18, 7, 6), the fill rate of each Parts is (0.9179, 0.9997, 0.9998).

IV. CONCLUSION

In practice, the supply cost of Parts must be restricted, and can not avoid Backorder occurring, but the part of probability not still met may be effectively reduced by the abnormal supply mode, such as urgency translation and order, these measures can further enhancing the fill rate of the Parts. In addition, the model uses LRU and its SRU as a Parts system, through a system approach to forecast the overall demand of the Parts system, the way can optimize the configuration of demand amount so as to get higher supply level.

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