METHOD OF OPTIMAL SPARE ALLOCATION FOR MOBILE REPAIR STATION

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Summary.

Method of finding optimal spare stock for Mobile Repair Station is suggested. Numerical calculations are performed with use of real field data. It showed significant improvement: probability of first fix for suggested variant is 0.967 in comparison with 0.534 for existing variant.

1. Introduction

There is a Service Base (SB) that serves clients' equipment within some zone. A client sends a request for repair to the SB when his equipment has failed. Immediately after a request an available Mobile Repair Station (MRS) is directed to the client. One of he most important index of quality of service is the so-called "fast fix" (FF) that takes just several minutes. FF is possible if there a needed Field Replacement Units (FRU) at the MRS spare stock is available. Otherwise, a special request is sent by MRS to its SB and the needed FRU is delivered to the client only in several hours. (In addition, it involves extra spending of money for restoration client's equipment.)

Equipment of clients can differ by configuration though consists of the same set of components, number of which exceeds several hundreds. Due to natural restrictions, the stock room is nor enough for keeping FRU of all possible types. Thus, the problem of optimal list of spares at MRS stock arises that provides maximum probability of FF under given restriction on the available room for spares.

2. Formulation of the problem.

Denote available space of MRS stock V^*. Let client j , $j = \overline{1, M}$, has equipment with n_k^j components of type k (let's call it component-k). s. Denote failure rate of a component of type k by λ_k, $k = \overline{1, N}$. Then the flow of requests formed by components- k , Λ_k, arriving at the SB can be written as

$$\Lambda_k = \lambda_k \sum_{1 \le j \le M} n_k^j \tag{1}$$

The total flow of requests, Λ, is equal to

$$\Lambda = \sum_{1 \le j \le N} \Lambda_k \tag{2}$$

It is clear that a current failure occurs due to a failure of component-k occurs with the probability

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$$p_k = \frac{\Lambda_k}{\Lambda} \tag{3}$$

Denote available space of MRS stock by V and physical volume of component-k by v_k. If one assumes that there are no multiple instantaneous failures and the probability that the second failure of the same equipment during FRS travel time is negligibly small, than the solution of the problem is very simple: one calculates values

$$w_k = \frac{p_k}{v_k} \tag{4}$$

and then takes first S components that satisfy the following condition:

$$\sum_{1\le k\le S} v_k \le V < \sum_{1\le k\le S+1} v_k \quad . \tag{5}$$

In practice, FRU of different types are approximately of the same volume, i.e. $v_k=v$. It means that instead of ordering values w_k, it is enough to order values p_k.

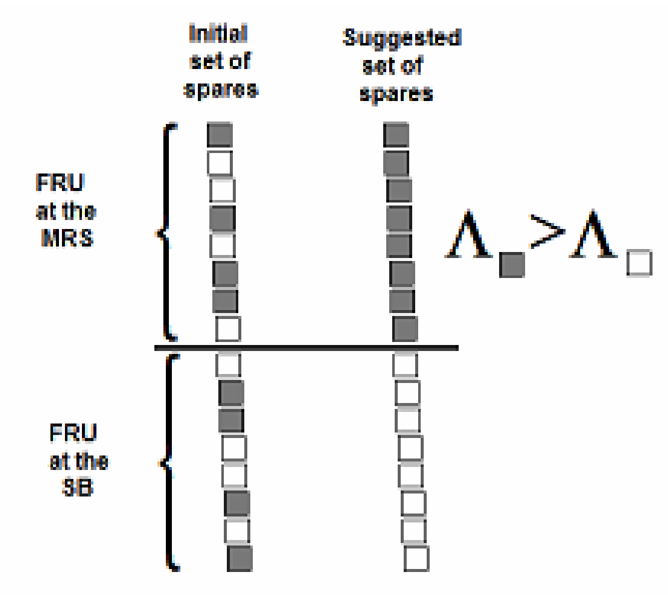

Figure 1. Explanation of the solution.

3. Case study

The following solution has been performed by contract with Hughes Network Systems (Germantown, Maryland, USA) for a maintenance service for ground clients of a global telecommunication system.

In this particular case, the volumes of FRU are approximately the same, so the limitation is for the total number of FRUs that is equal to 51.

Values of Λ_k for various components are given in Table 1. In this table, column “O” (for “old”) contains the number of spares in the initial list and column “N” (for “new”) contains the number of spares in the final list obtained by suggested method. For the sake of shortness, we omitted those types of equipment components, for which both spare lists (initial and suggested) have zero spare units at the MRS stock.

Table 1.

#	Part No.	Rate (per day)	O	N	x x x	#	Part No	Rate (per day)	O	N	x x x	#	Part No	Rate (per day)	O	N
1	30514-2	0.0149	0	1	x	25	30290-1	0.0038	0	1	x	49	20079-1	4.9 E-4	1	1
2	15338-1	0.0118	1	1	x	26	14364-1	0.0035	1	1	x	50	3043-1	3.9 E-4	1	1
3	14364-9	0.0114	0	1	x	27	30812-1	0.0032	0	1	x	51	3511-1	3.6 E-4	1	1
4	17668-1	0.0107	1	1	x	28	15901-1	0.0031	0	1	x	52	15233-1	2.9 E-4	2	0
5	3066-1	0.0103	2	1	x	29	12171-2	0.0025	1	1	x	53	15187-2	2.9 E-4	1	0
6	19847-1	0.0096	1	1	x	30	11836-4	0.0023	1	1	x	54	30491-1	2.9 E-4	1	0
7	11836-1	0.0095	1	1	x	31	19552-2	0.0023	0	1	x	55	12256-1	2.4 E-4	1	0
8	13847-2	0.0093	0	1	x	32	17668-2	0.0023	0	1	x	56	17114-1	2.3 E-4	1	0
9	3514-5	0.0088	1	1	x	33	10111-1	0.0022	0	1	x	57	30510-1	2.2 E-4	1	0
10	12076-1	0.0086	0	1	x	34	92132-4	0.0022	1	1	x	58	93634-8	2.2 E-4	1	0
11	17512-1	0.0077	1	1	x	35	70275-1	0.0021	0	1	x	59	10306-1	1.9 E-4	1	0
12	30038-2	0.0071	1	1	x	36	124364-6	0.0020	1	1	x	60	17132-1	1.9 E-4	1	0
13	16174-1	0.0069	1	1	x	37	110228-1	0.0018	1	1	x	61	30470-1	1.9 E-4	1	0
14	11836-9	0.0057	0	1	x	38	124871-1	0.0018	1	1	x	62	30066-2	1.4 E-4	2	0
15	30290-2	0.0056	1	1	x	39	113061-1	0.0017	0	1	x	63	30206-1	1.4 E-4	1	0
16	17960-9	0.0053	0	1	x	40	110119-1	0.0016	1	1	x	64	30626-1	1.2 E-4	1	0
17	92486-2	0.0053	0	1	x	41	200260-4	0.0015	1	1	x	65	92513-1	1.2 E-4	1	0
18	13847-1	0.0052	0	1	x	42	30330-1	0.0015	1	1	x	66	11667-1	8.6E-5	1	0
19	17960-1	0.0050	0	1	x	43	30467-1	0.0014	1	1	x	67	20228-3	6.7E-5	1	0
20	19847-2	0.0045	1	1	X	44	92428-2	0.0012	1	1	x	68	11485-1	4.2E-5	1	0
21	3727-2	0.0042	0	1	X	45	90096-2	8.6E-4	1	1	x	69	3512-4	1.8E-5	1	0
22	15901-2	0.0041	0	1	x	46	30279-1	8.4 E-4	1	1	x	70	11836-5	1.2E-5	1	0
23	1836-2	0.0041	1	1	x	47	30140-1	6.8 E-4	1	1	x	69				
24	1939-1	0.0039	1	1	x	48	111998-1	5.9 E-4	1	1	x	70				

From the complete list of equipment components (it is not presented), one can find that the total failure rate in the chosen service zone is equal to Λ=0.254 [1/day], i.e. approximately 1 failure in every 4 days. Failures covered by the initial set of spares form a failure flow with rate Λ_k = 0.136, and for suggested set of spares the analogous value equal to $\Lambda_k^{opt} = 0.229$.

It means that the probability of FF has been increased from $p_k = \frac{\Lambda_k}{\Lambda} = \frac{0.136}{0.254} \approx 0.535$ to

$$p_k^{opt} = \frac{\Lambda_k^{opt}}{\Lambda} = \frac{0.229}{0.254} \approx 0.902.$$

Approximate evaluation of expected gain is the following. The entire service system spreading over the USA gets on the average about 44,000 calls a year. MRSs with initial spare stocks made about 44,000×(1-0.535)≈20,500 extra deliveries due to lack of needed spares. The suggested spare stock leads only to 44,000×(1-0.902)≈4,300 extra deliveries, i.e. about 16,500 extra deliveries less. Each visit takes on the average about 4 hrs (round trip) and about 0.5 hr for equipment inspection at the client site. Each visit costs at least $150, so the total gain is about 24.7 million a year.