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(S-1, S) Spare-part Inventory Algorithm for Fleet Maintenance : Valida'ion

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ABSTRACT

Recently, Park [1] proposed an algorithm for the optimum spare-part stock level in an (S-1, S) inventory system for small fleet. This paper reports validative GPSS simulation results and numerical experiences with the algorithm.

1. Introduction

In the operation and maintenance of a fleet of equipments, an (S-1, S) spare-part inventory policy is appropriate when the demand is low but the item is expensive. Park [1] proposed an algorithm for the optimum spare-part stock level in an (S-1, S) inventory system where the size of the fleet is small so that the demand rate for parts is state-dependent.

The algorithm depends on the ratios of

(1) backorder cost to inventory carrying cost, and

(2) failure rate to replenishment rate.

These assumptions are logical since time or money can be measured in an arbitrary scale: replenishment rate and the inventory carrying cost can be set equal to 1 without loss of generality. Also, the algorithm is claimed to be applicable to any replenishment time distribution having the same mean.

To validate the algorithm, three distributions are used in GPSS simulations for the various combinations of fleet size, cost ratio, and failure-replenishment rate ratio.

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Notation

N	number of the specific parts in the fleet
λ	average failure (hazard) rate of part
μ	mean replenishment rate
S	stock level specified
$\$_s/\$_h$	ratio of the backorder cost to inventory carrying cost
$\bar{C}(\cdot)$	average total inventory cost

2. Model

The (S-1, S) inventory system can be modeled as a cyclic tandem queueing system with finite "customers" composed of

(1) N+S initial spare-parts

(2) N-channel queueing stations with exponential service (failure) times

(3) infinite-channel queueing stations with arbitrary service (replenishment) times

as in Figure 1.

The model is simulated using GPSS [2]. The GPSS block diagram in Figure 2 is for the case: N=5, S=3, λ=.001, μ=.003, uniform (333±33) replenishment time distribution. Simulation duration were set to 10^5 unit time, during which approximately $10^5 N\lambda$ failures and $10^5\mu$ replenishments were simulated.

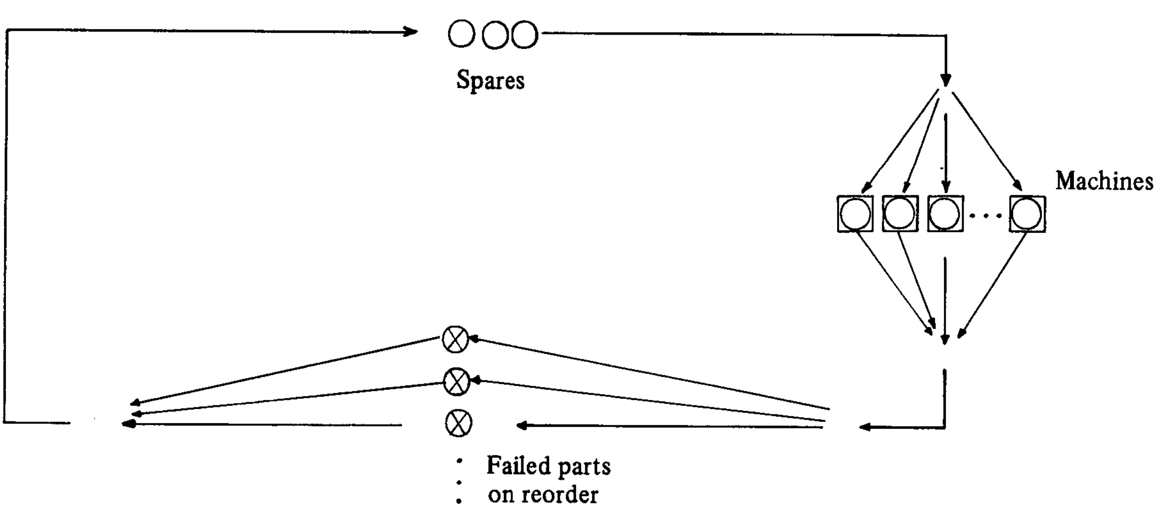

Fig. 1. (S-1, S) Inventory System

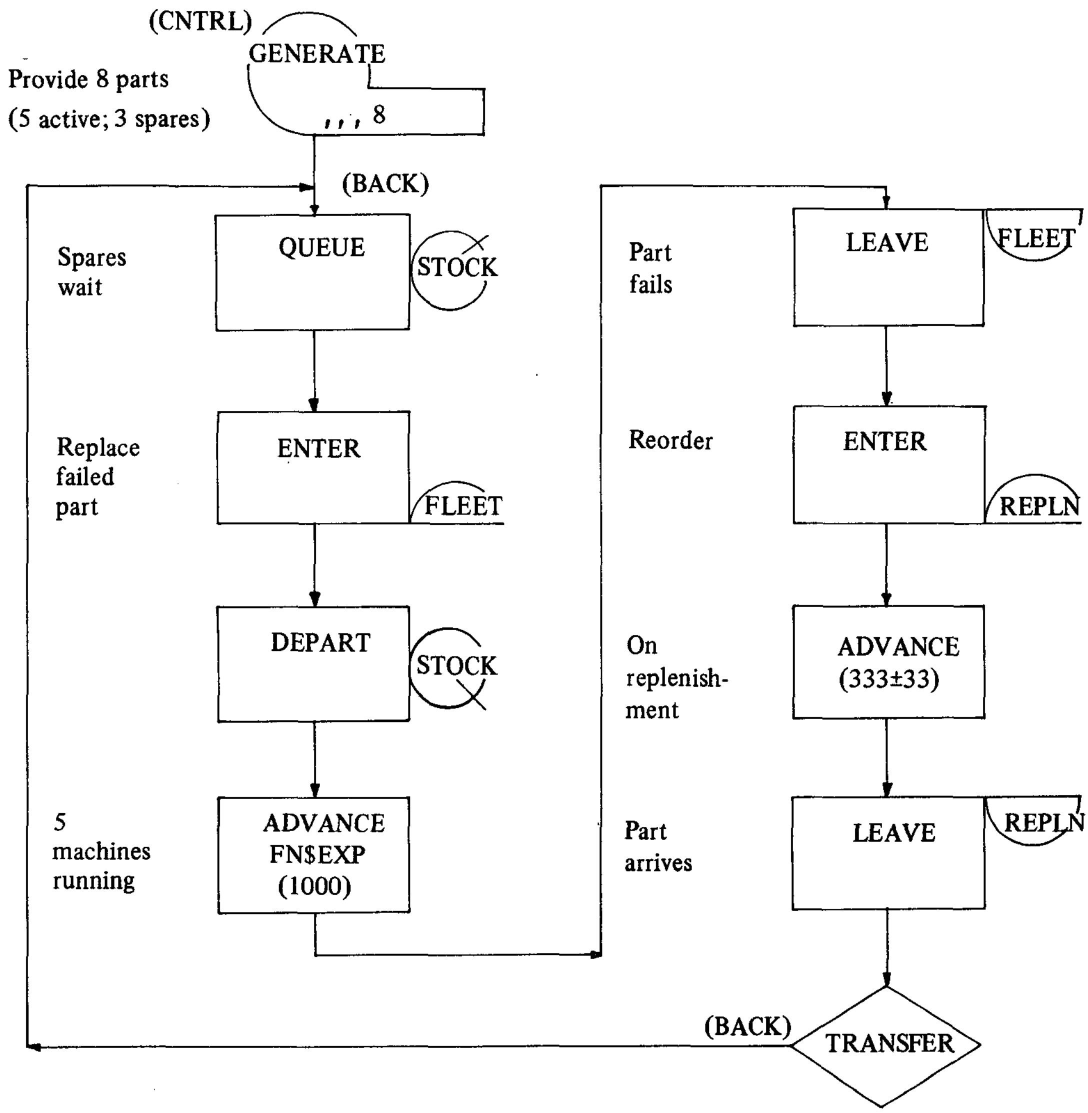

Fig. 2. GPSS Block Diagram

3. Results

Using exponential ($1/\mu$), uniform ($1/\mu \pm .1\mu$), and normal (with the same mean and standard deviation equal to .1 mean) replenishment time distributions, GPSS simulation results for a number of cases are obtained to examine the effect of the stock level S. Table 1 shows a portion of the simulation results. Note that as stock level increases, average contents of the queue STOCK and the storage FLEET increase. For each stock level, the average total inventory cost per unit time is

$$\bar{C}(\$_s/\$_h) = 1 \cdot \text{s–Exp[spares]} + \$_s/\$_h \cdot \text{s–Exp[backorders]}$$
$$= (\text{STOCK}) + \$_s/\$_h \cdot [N-(\text{FLEET})]$$

In table 1, minimum costs for $\$_s/\$_h$ = 10 and 100 are asterisked. The optimum stock level S* from the GPSS simulation is identical to the S* from the Park's algorithm as summarized in Table 2. Table 2 also includes simulation results for a number of other cases. The difference between the different distributions is quite small; giving the same S* values.

Numerical experiences show that the algorithm gives identical results compared to the GPSS simulation results under realistic ($N\lambda/\mu \lesssim 2$) situations. When the replenishment time is unrealistically long relative to the failure rate ($N\lambda/\mu \gtrsim 2$), the algorithm gives one unit larger S* values than the simulation.

Table 1. Simulation Results: Average Contents and Average Total Inventory Costs (for N=5, λ=.001, μ=.003)

S	replenishment time distribution											
	exponential $(1/\mu)$				uniform $(1/\mu \pm .1/\mu)$				normal $(1/\mu, .1/\mu)$			
	STOCK	FLEET	$\bar{C}(10)$	$\bar{C}(100)$	STOCK	FLEET	$\bar{C}(10)$	$\bar{C}(100)$	STOCK	FLEET	$\bar{C}(10)$	$\bar{C}(100)$
1	.195	4.305	7.145	69.695	.204	4.325	6.954	67.504	.212	4.327	6.940	67.512
2	.629	4.694	3.689	31.229	.716	4.716	3.556	29.116	.708	4.702	3.688	30.508
3	1.280	4.862	2.660*	15.080	1.549	4.901	2.539*	11.449	1.428	4.908	2.348*	10.628
4	2.418	4.972	2.698	5.218	2.338	4.969	2.648	5.438	2.336	4.964	2.696	5.936
5	3.438	4.994	3.498	4.038*	3.313	4.998	3.333	3.513*	3.337	4.993	3.407	4.037*
6	4.344	4.999	4.354	4.444	4.363	4.997	4.393	4.663	4.309	4.997	4.339	4.609
7	5.302	5.0	5.302	5.302	5.336	5.0	5.336	5.336	5.310	5.0	5.310	5.310

Table 2. S* values

N	λ/μ	$\$_s/\$_h$	algorithm	replenishment distribution in simulation		
				exponential	uniform	normal
2	1/2	10	2	2	2	2
5	1/3	10	3	3	3	3
5	1/3	100	5	5	5	5
5	1/5	10	2	2	2	2
5	1/5	100	4	4	4	4
5	1/10	10	1	1	1	1
5	1/10	100	3	3	3	3
20	1/10	100	6	6	6	6
20	1/20	100	4	4	4	4
20	1/40	100	3	3	3	3

ACKNOWLEDGEMENT

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2. T. Schriber, Simulation Using GPSS, John Wiley & Sons, New York, 1974.