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보증기간이 종료된 이후의 최적의 예방보전정책: 예방보전 비용이 예방보전 효과의 함수인 경우

2006. 5. 18.

정 기 문

정보통계학과

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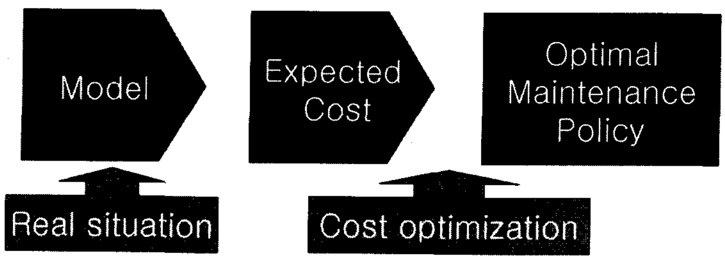
Optimal maintenance policy I



정보통계학과

Optimal maintenance policy II

- Without Warranty
  - Barlow and Hunter(1960)
  - Canfield(1986)
  - Nakagawa(1986)
  - Park, jung and Yum(2000)
  - Park and Jung(2002)
- Under Warranty
  - Sahin and Polatoglu(1996)
  - Jung and Park(2003)

→ *Optimal maintenance policy*

the expected cost rate per unit time

Model and assumptions I

- Manufacturer provides a certain type of *warranty*
- System is maintained preventively at *periodic* times and is *replaced* by a new system ay the Nth PM.
- If system fails between PMs, it undergoes only *minimal repair*
- PM slows the rate of system degradation
- *PM cost is an increasing function of the level of PM effect*

Model and assumptions II

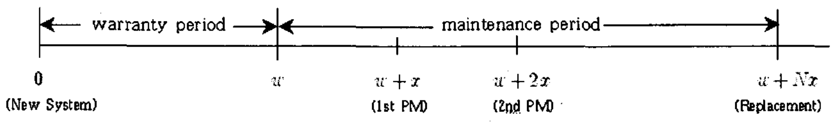
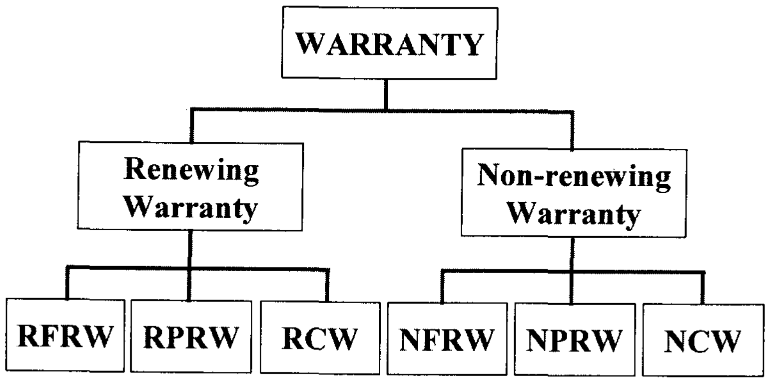


Figure 1. PM policy after warranty

Warranty Policy



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Expected cost rate per unit time I

(1) Renewing Warranty

$$C_R(x,N)=\frac{c_1+\overline{F}(w)\,(N-1)\boxed{C_{pm}(x,\tau)}+(c_m+c_{fm})\overline{F}(w)\,c_2}{I(w)+(w+Nx)\overline{F}(w)}$$

$$c_1=\begin{cases}\frac{c_r}{w}I(w)+c_r\overline{F}(w)+c_{fw}F(w), & \text{under } RPRW\\ c_r\overline{F}(w)+c_{fw}F(w), & \text{under } RFRW\end{cases}$$

$$c_2=\sum_{k=1}^{N-1}\sum_{i=1}^{k}\{h((i-1)(x-\tau)+(x+w))-h(i(x-\tau)+w)\}x+\sum_{k=1}^{N-1}\int_{kx+w}^{(k+1)x+w}h(t-k\tau)dt\,.$$

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Expected cost rate per unit time II

(2) Non-renewing Warranty

$$C_N(x,N)=\frac{c_3+(N-1)\boxed{C_{pm}(x,\tau)}+(c_m+c_{fm})c_4}{w+Nx}.$$

$$c_3=\begin{cases}c_r\frac{(w-y)}{w}+c_r+kc_{fw}, & \text{under } NPRW\\ c_r+kc_{fw}, & \text{under } NFRW\end{cases}$$

$$c_4=\sum_{k=1}^{N-1}\sum_{i=1}^{k}\{h((i-1)(x-\tau)+(x+y))-h(i(x-\tau)+y)\}x+\sum_{k=1}^{N-1}\int_{kx+y}^{(k+1)x+y}h(t-k\tau)dt\,.$$

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Optimal PM policy I

(1) Renewing Warranty

- <u>Step 1</u>

$$(I(w)+w\overline{F}(w))((N-1)C'_{pm}(x,\tau)+(c_m+c_{fm})(a_1+xa_2+a_3)$$
$$+N\overline{F}(w)((N-1)(xC'_{pm}(x,\tau)-C_{pm}(x,a))+(c_m+c_{fm})(x^2a_2+xa_3-a_4)=Nc_1$$

where

$$a_1=\sum_{k=1}^{N-1}\sum_{i=1}^{k}\{h((i-1)(x-\tau)+(x+w))-h(i(x-\tau)+w)\}$$

$$a_2=\sum_{k=1}^{N-1}\sum_{i=1}^{k}\{h'((i-1)(x-\tau)+(x+w))i-h'(i(x-\tau)+w)i\}$$

$$a_3=\sum_{k=0}^{N-1}\{(k+1)h((k+1)x+w-k\tau)-kh(kx+w-k\tau))\}$$

$$a_4=\sum_{k=0}^{N-1}\int_{kx+w}^{(k+1)x+w}h(t-k\tau)\ dt$$

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Optimal PM policy II

- <u>Step 2</u> $C_R(x_N,N)$

- <u>Step 3</u>

$$N^*=\min_N C(x_N,N),\quad N=1,2,3,\cdots.$$

(2) Non-renewing Warranty

정보통계학과

Numerical examples

- Weibull distribution
- $h(t)=\beta\lambda^{\beta}t^{\beta-1}$ for $\beta>1$ and $t\geq 0$
- $\beta=3$ and $\lambda=1$
- $C_{pm}(x, \tau)=c_0+c_1(x-\tau)^{-1}$
- $C_{pm}(x, \tau)=c_0+c_1\exp\{-(x-\tau)\}$

Table 1. Optimal PM policy: $C_{pm}(x, \tau)=c_0+c_1(x-\tau)^{-1}=c_0+c_1(x-\alpha x)^{-1}$
($\beta=3$, $\lambda=1$, $c_0=1$, $C_{mr}=1$, $C_{re}=30$, $w=0.5$, $y=0.3$, $l=1$)

Warranty Type	c_1	α	x^*	N^*	$C(x^*, N^*)$
RPRW.	0	0.1	1.8045308160	1	20.71236288
		0.3	1.8045308160	1	20.71236288
		0.5	0.9699940159	2	20.46671367
		0.7	0.7079218257	3	20.00742389
		0.9	0.4994735261	5	19.27667469
	0.2	0.1	1.8045308160	1	20.71236288
		0.3	1.8045308160	1	20.71236288
		0.5	0.9814147734	2	20.63063121
		0.7	1.0153048120	2	20.43087647
		0.9	1.0792839850	2	20.57370360
RFRW.	0	0.1	1.7321387270	1	19.43152886
		0.3	1.7321387270	1	19.43152886
		0.5	0.9320419488	2	19.25572750
		0.7	0.6807384641	3	18.87967420
		0.9	0.5724068304	4	18.27435506
	0.2	0.1	1.7321387270	1	19.43152886
		0.3	1.7321387270	1	19.43152886
		0.5	0.9446982377	2	19.43140935
		0.7	0.9781337259	2	19.26339771
		0.9	1.7321387270	1	19.43152886

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Table 1. Optimal PM policy: $C_{pm}(x, \tau)=c_0+c_1(x-\tau)^{-1}=c_0+c_1(x-\alpha x)^{-1}$

($\beta=3,\ \lambda=1,\ c_0=1,\ C_{mr}=1,\ C_{re}=30,\ w=0.5,\ y=0.3,\ l=1$)

Warranty Type	c_1	α	x^*	N^*	$C(x^*, N^*)$
NPRW.	0	0.1	2.1370400750	1	23.16274087
		0.3	2.1370400750	1	23.16274087
		0.5	0.8036595870	3	22.36546264
		0.7	0.5496431418	5	21.39174749
		0.9	0.4214412258	8	19.84292981
	0.2	0.1	2.1370400750	1	23.16274087
		0.3	1.1258884520	2	23.05772670
		0.5	1.1596878970	2	22.67593030
		0.7	0.8706459155	3	22.13623628
		0.9	0.9665035065	3	22.10246449
NFRW.	0	0.1	1.8706067040	1	18.37498050
		0.3	0.9839965492	2	18.36151415
		0.5	0.7081280049	3	18.03369622
		0.7	0.5864222829	4	17.44107862
		0.9	0.4670092284	6	16.47684262
	0.2	0.1	1.8706067040	1	18.37498050
		0.3	1.8706067040	1	18.37498050
		0.5	1.0228096920	2	18.20639057
		0.7	1.0607486600	2	17.96434157
		0.9	1.1294370780	2	18.03645453

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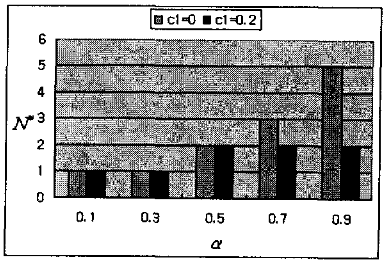
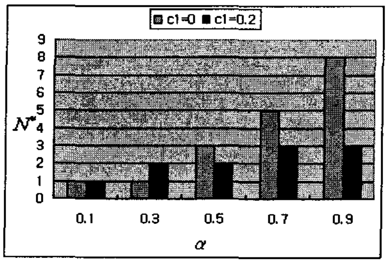
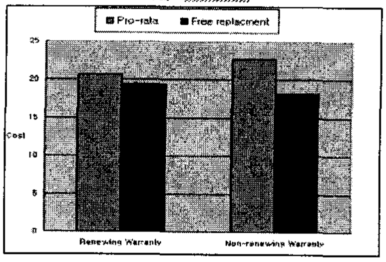


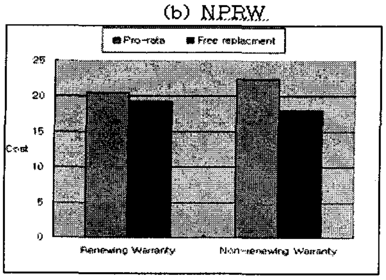
(a) RPRW.



(b) NPRW.



(a) $C_{pm}(x, \tau)=c_0+c_1(x-\alpha x)^{-1}$



(b) $C_{pm}(x, \tau)=c_0+c_1\exp\{-(x-\alpha x)\}$

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