Thailand Statistician
January 2021; 19(1): 154-161
http://statassoc.or.th
Contributed paper

Stochastic Modeling of a Non-Identical Redundant System with Priority in Repair Activities

Monika Saini, Kuntal Devi and Ashish Kumar*
Department of Mathematics and Statistics, Manipal University, Jaipur, Rajasthan, India.
*Corresponding author; e-mail: ashishbarak2020@gmail.com

Received: 12 February 2019
Revised: 5 October 2019
Accepted: 21 October 2019

Abstract

In the present study, an effort has been made to develop a stochastic model for a redundant system of non-identical units. One unit is treated as original and other is duplicate. Initially original unit is operative and duplicate unit is kept under cold standby mode. The concepts of preventive maintenance, maximum operation time and priority to repair of original unit over repair of duplicate unit are also incorporated in the development of the stochastic model. A single repair facility is available for performing all repair activities as and when required. All time dependent random variables are assumed to follow arbitrary distribution. The recurrence relations for various reliability measures have been developed by using regenerative point technique (RPT) and semi Markov process (SMP). To highlight the importance of the study numerical results has been drawn for a particular case.

Keywords: Reliability, availability, Weibull failure and repair laws, preventive maintenance, semi- Markov process, maximum operation time.

1. Introduction

In the current century computer science and information technology plays a key role in the life of human being. All most all sector like communication, education, medical, transportation, use the computing devices for their successful operation. With the increasing automation the complexity of these systems is also increasing rapidly. Due to the complexity, it becomes difficulty to operate these systems successfully. In this situation, it becomes the primary responsibility of system designers that these equipment perform satisfactorily. A lot of research work has been carried out by the researcher and scientists in the field of redundant systems by considering constant failure and repair rates and identical units. Gupta et al. (2013) carried out the cost-benefit analysis of a two duplicate-unit parallel system with repair/replacement and correlated lifetimes of the units. Kadian et al. (2012) carried out the cost analysis of a two-unit cold standby system subject to degradation, inspection and priority. Kumar and Malik (2014) proposed a reliability model for a computer system with priority to H/w repair over replacement of H/w and up-gradation of s/w subject to maximum operation time (MOT) and maximum repair time (MRT). Kumar et al. (2015) analyzed performance measures of a computer system with imperfect fault detection of hardware and preventive maintenance. Kishan and Jain (2012) studied a two non-identical unit standby system model with repair, inspection and post-repair under classical and Bayesian viewpoints. Kumar et al. (2015) suggested a stochastic behavior for a cold standby system with maximum repair time. Kumar et al. (2016) developed a stochastic modeling for a cold standby system of non-identical units. Recently, Kumar et al. (2016), Kumar et al. (2017), Kumar et al. (2018), Barak et al. (2018) and Barak et al. (2018) designed some stochastic model for redundant systems with priority, preventive maintenance, and Weibull failure and repair distributions. But, till now, no work has been carried out for non-identical unit systems using the concept of priority to repair of original unit over repair of duplicate unit.

By keeping the above facts in mine, here an effort has been made to develop a stochastic model for a redundant system of non-identical units. One unit is treated as original and other is duplicate. Initially original unit is operative and duplicate unit is kept under cold standby mode. The concepts of preventive maintenance, maximum operation time and priority to repair of original unit over repair of duplicate unit are also incorporated in the development of the stochastic model. A single repair facility is available for performing all repair activities as and when required. All time dependent random variables are assumed to follow arbitrary distribution. Printer and Xerox machines are most common used equipment's in most of the offices like academic institutions. Both can be utilized for the same purpose. Both are non-identical and it is a suitable example for our proposed model.

The probability density function (p.d.f.) of maximum operation time of original and duplicate unit is denoted by $g(t)=\alpha\eta t^{\eta-1}\exp(-\alpha t^{\eta})$. The p.d.f. of failure times of the original and duplicate unit are denoted by $f(t)=\beta\eta t^{\eta-1}\exp(-\beta t^{\eta})$ and $f_2(t)=h\eta t^{\eta-1}\exp(-ht^{\eta})$, respectively. The preventive maintenance rate of the original and duplicate units is denoted by the probability density function $g_1(t)=\gamma\eta t^{\eta-1}\exp(-\gamma t^{\eta})$. The random variables corresponding to repair rate of the original and duplicate units have the probability density function $f_1(t)=k\eta t^{\eta-1}\exp(-kt^{\eta})$ and $f_3(t)=l\eta t^{\eta-1}\exp(-lt^{\eta})$ respectively with $t\geq 0$ and $\theta,\eta,\alpha,\beta,h,k,l>0$. The recurrence relations for various reliability measures have been developed by using regenerative point technique (RPT) and semi Markov process (SMP). To highlight the importance of the study numerical results has been drawn for a particular case.

2. Model Description

In this section, a stochastic model has been developed for two non-identical unit system has been developed by using the notations and model described in Kumar et al. (2018). The concept of priority is also used in the development of model. Initially, one unit is operative and other is kept in cold standby. The system remain operative if at least one unit either original or duplicate is operative. The SMP and RPT have been used for formulation of recurrence relations. The system may be at any one of the following state:

$S_0(O,DCs)$ $S_1(Pm,Do)$ $S_2(Fur,Do)$ $S_3(O,DFur)$ $S_4(O,DPm)$
$S_5(Fwr,DPM)$ $S_6(FUR,DFwr)$ $S_7(FUR,DWPm)$ $S_8(WPm,DPM)$ $S_9(PM,DWPm)$
$S_{10}(PM,DFwr)$ $S_{11}(Fur,DFwr)$ $S_{12}(WPm,DFUR)$

In above mentioned states, S_0, S_1, S_2, S_3 and S_4 are operative and regenerative, S_{11} is only failed regenerative state and remaining states are failed non-regenerative state.

2.1. Transition probabilities

By using simple probabilistic arguments, the transition probability at each state S_i is as follows:

$$p_{01}=\frac{\alpha}{\alpha+\beta},\ p_{02}=\frac{\beta}{\alpha+\beta},\ p_{10}=\frac{\gamma}{\alpha+h+\gamma},\ p_{1.10}=\frac{h}{\alpha+\gamma+h}=p_{13.10},\ p_{19}=\frac{\alpha}{\alpha+\gamma+h}=p_{14.9},$$

$$p_{20}=\frac{k}{\alpha+k+h},\ p_{26}=\frac{h}{\alpha+h+k}=p_{23.6},\ p_{27}=\frac{\alpha}{\alpha+h+k}=p_{24.7},\ p_{30}=\frac{l}{l+\alpha+\beta},$$

$$p_{3.12}=\frac{\alpha}{\alpha+\beta+l}=p_{31.12},\ p_{3.11}=\frac{\beta}{\alpha+\beta+l},\ p_{40}=\frac{\gamma}{\alpha+\beta+\gamma},\ p_{45}=\frac{\beta}{\alpha+\beta+\gamma}=p_{42.5},$$

$$p_{48}=\frac{\alpha}{\alpha+\beta+\gamma}=p_{41.8}=p_{52}=p_{63}=p_{74}=p_{81}=p_{94}=p_{10.3}=p_{11.3}=p_{12.1}=1.$$

2.2. Mean sojourn times

The mean sojourn times (μ_i) is the state S_i are

$$\mu_0=\Gamma\left(\frac{1}{\eta}+1\right)\Big/(\alpha+\beta)^{1/\eta},\ \mu_1'=\Gamma\left(\frac{1}{\eta}+1\right)\left[\frac{1}{(\alpha+h+\gamma)^{\frac{1}{\eta}}}+\frac{1}{(\alpha+\gamma+h)(\gamma)^{\frac{1}{\eta}}}(\alpha+h)\right],$$

$$\mu_1=\Gamma\left(\frac{1}{\eta}+1\right)\Big/(\alpha+\gamma+h)^{1/\eta},$$

$$\mu_2'=\Gamma\left(\frac{1}{\eta}+1\right)\left[\frac{1}{(\alpha+h+k)^{1/\eta}}+\frac{1}{(\alpha+k+h)}\left(\frac{\alpha+h}{k^{1/\eta}}\right)\right],\ \mu_2=\Gamma\left(\frac{1}{\eta}+1\right)\Big/(\alpha+k+h)^{1/\eta},$$

$$\mu_3'=\Gamma\left(\frac{1}{\eta}+1\right)\left[\frac{1}{(\alpha+\beta+l)^{1/\eta}}+\frac{\alpha}{(\alpha+\beta+l)(l)^{1/\eta}}\right],\ \mu_3=\Gamma\left(\frac{1}{\eta}+1\right)\Big/(\alpha+\beta+l)^{1/\eta},$$

$$\mu_4'=\Gamma\left(\frac{1}{\eta}+1\right)\left[\frac{1}{(\alpha+\beta+\gamma)^{1/\eta}}+\frac{1}{(\alpha+\gamma+\beta)(\gamma)^{1/\eta}}(\alpha+\beta)\right],\ \mu_4=\Gamma\left(\frac{1}{\eta}+1\right)\Big/(\alpha+\beta+\gamma)^{1/\eta}.$$

2.3. Mean time to system failure

By considering simple probabilistic arguments and considering as the cumulative distribution function (c.d.f.) of first passage time from the regenerative state S_i to a failed state. The failed state is considered as an absorbing state. The recursive relations for $\phi_i(t)$ are as follows

$$\varphi_i(t)=\sum_j Q_{i,j}(t)®\varphi_j(t)+\sum_k Q_{i,k}(t). \tag{1}$$

In above expression, j represents an un-failed regenerative state to which the given regenerative state i can transit and k is a failed state to which the state i can transit directly. Taking Laplace-Stieltjes transformation of above Equation (1) and solving for $\tilde{\phi}_i(s),\ i=0.$ The mean time to system failure (MTSF) is given by

$$\text{MTSF}=\lim_{s\to 0}\frac{1-\tilde{\phi}_0(s)}{s}=\frac{N}{D}, \tag{2}$$

where $N=\mu_0+p_{01}\mu_1+p_{02}\mu_2$ and $D=1-p_{01}p_{10}-p_{02}p_{20}$. The numerical values of MTSF using Equation (2) for a particular case have been obtained and appdended in Table 1.

Table 1 MTSF ('000) and failure rate

β	$\alpha=2,\eta=0.5,$ $\gamma=5,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=0.5,$ $\gamma=7,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=1,$ $\gamma=5,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=1,$ $\gamma=7,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=2,$ $\gamma=5,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=2,$ $\gamma=7,h=0.009,$ $k=1.5,l=1.4$
0.01	4.9918	11.7910	5.9647	13.8080	8.9395	20.8745
0.02	4.7950	10.7622	5.7599	12.6725	8.6486	19.1946
0.03	4.6123	9.8940	5.5696	11.7138	8.3781	17.7760
0.04	4.4423	9.1515	5.3921	10.8934	8.1260	16.5621
0.05	4.2836	8.5094	5.2264	10.1835	7.8904	15.5116
0.06	4.1351	7.9487	5.0712	9.5632	7.6698	14.5936
0.07	3.9960	7.4548	4.9255	9.0165	7.4627	13.7844
0.08	3.8654	7.0165	4.7886	8.5310	7.2680	13.0659
0.09	3.7426	6.6251	4.6596	8.0970	7.0846	12.4235
0.10	3.6268	6.2733	4.5379	7.7067	6.9116	11.8458

2.4. Steady state availability

By considering simple probabilistic arguments and considering $A_i(t)$ be the probability that the system is in up-state at instant 't' given that the system entered regenerative state S_i at $t=0.$ The recursive relations for $A_i(t)$ are given as

$$A_i(t)=M_i(t)+\sum_j q_{i,j}^{(n)}(t)©A_j(t), \tag{3}$$

where j and i are any successive regenerative states which can transit through n transitions. $M_i(t)$ is the probability that system remains in upstate at S_i state.

$$M_0(t)=\exp(-(\alpha+\beta)t^\eta),\ \ M_1(t)=\exp(-(\alpha+h+\gamma)t^\eta),\ \ M_2(t)=\exp(-(\alpha+k+h)t^\eta),$$
$$M_3(t)=\exp(-(\alpha+\beta+l)t^\eta),\ \ M_4(t)=\exp(-(\alpha+\beta+\gamma)t^\eta). \tag{4}$$

Taking Laplace transformation of above relations (3) and (4) and solving for $A_i^*(s)$ for $i=0.$ The steady state availability is given by $A_0(\infty)=\lim_{s\to 0} sA_0^*(s)=\dfrac{N_2}{D_2},$ where

$$\begin{aligned}N_2=&(M_0(t)(((1-p_{41.8}p_{14.9})(1-p_{42.5}p_{24.7})(1-p_{3.11}p_{11.3}))+((p_{41.8}p_{24.7})(-p_{42.5}p_{14.9})(1-p_{3.11}p_{11.3}))\\&+((-p_{31.12})(p_{42.5}p_{14.9}p_{23.6}+p_{13.10}(1-p_{42.5}p_{24.7})))))-((M_1(t)+M_4(t)p_{14.9})((-p_{01})(1-p_{42.5}p_{24.7})\\&(1-p_{3.11}p_{11.3})+(p_{41.8}p_{24.7})(-p_{02})(1-p_{3.11}p_{11.3})-(p_{31.12}p_{02}p_{23.6})))+((M_2(t)+M_4(t)p_{24.7})((p_{01})\\&(p_{42.5}p_{14.9})(1-p_{3.11}p_{11.3})+(1-p_{41.8}p_{14.9})(p_{02})(1-p_{3.11}p_{11.3})-(p_{31.12}p_{02}p_{13.10})))-M_3(t)((-p_{01})\\&(p_{42.5}p_{14.9}p_{23.6}+p_{13.10}(1-p_{42.5}p_{24.7}))+(p_{02})((1-p_{41.8}p_{14.9}(-p_{23.6})-(p_{13.10}p_{41.8}p_{24.7})))),\\D_2=&(\mu_0(((1-p_{41.8}p_{14.9})(1-p_{42.5}p_{24.7})(1-p_{3.11}p_{11.3}))+((p_{41.8}p_{24.7})(-p_{42.5}p_{14.9})(1-p_{3.11}p_{11.3}))\\&+((-p_{31.12})(p_{42.5}p_{14.9}p_{23.6}+p_{13.10}(1-p_{42.5}p_{24.7})))))-((\mu_1'+\mu_4'p_{14.9})((-p_{01})(1-p_{42.5}p_{24.7})\\&(1-p_{3.11}p_{11.3})+(p_{41.8}p_{24.7})(-p_{02})(1-p_{3.11}p_{11.3})-(p_{31.12}p_{02}p_{23.6})))+((\mu_2'+\mu_4'p_{24.7})((p_{01})\\&(p_{42.5}p_{14.9})(1-p_{3.11}p_{11.3})+(1-p_{41.8}p_{14.9})(p_{02})(1-p_{3.11}p_{11.3})-(p_{31.12}p_{02}p_{13.10})))-(\mu_3'((-p_{01})\\&(p_{42.5}p_{14.9}p_{23.6}+p_{13.10}(1-p_{42.5}p_{24.7}))+(p_{02})((1-p_{41.8}p_{14.9}(-p_{23.6})-(p_{13.10}p_{41.8}p_{24.7}))))),\end{aligned} \tag{5}$$

The numerical values of system availability using expression (5) for a particular case have been obtained and appdended in Table 2.

Table 2 Availability and failure rate (β)

β	$\alpha=2,\eta=0.5,$ $\gamma=5,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=0.5,$ $\gamma=7,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=1,$ $\gamma=5,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=1,$ $\gamma=7,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=2,$ $\gamma=5,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=2,$ $\gamma=7,h=0.009,$ $k=1.5,l=1.4$
0.01	0.9394	0.9724	0.8941	0.9367	0.8715	0.9109
0.02	0.9347	0.9675	0.8917	0.9340	0.8701	0.9092
0.03	0.9300	0.9625	0.8893	0.9313	0.8687	0.9076
0.04	0.9253	0.9576	0.8869	0.9286	0.8673	0.9060
0.05	0.9206	0.9528	0.8845	0.9259	0.8659	0.9044
0.06	0.9159	0.9479	0.8822	0.9232	0.8646	0.9028
0.07	0.9113	0.9431	0.8799	0.9206	0.8632	0.9012
0.08	0.9066	0.9382	0.8776	0.9180	0.8619	0.8997
0.09	0.9020	0.9334	0.8753	0.9155	0.8606	0.8981
0.10	0.8974	0.9287	0.8731	0.9129	0.8593	0.8966

2.5. Busy period analysis for server

By considering simple probabilistic arguments and considering $B_i^R(t)$ and $B_i^{Pm}(t)$ the probability that the server is busy in repair and preventive maintenance activities of the unit at an instant 't' given that the system entered state S_i at $t=0$. The recursive relations for $B_i^R(t)$ and $B_i^{Pm}(t)$ are as follows:

$$B_i^R(t)=W_i(t)+\sum_j q_{i,j}^{(n)}(t)©B_j^R(t)\pi,$$
$$B_i^{pm}(t)=W_i(t)+\sum_j q_{i,j}^{(n)}(t)©B_j^{pm}(t), \tag{6}$$

where j and i are any successive regenerative states which can transit through n transitions. $W_i(t)$ be the probability that the server is busy in state S_i up to time t without making any transition to any other regenerative state or returning to the same via one or more non-regenerative states and so $W_2(t)=\exp(-(\alpha+k+h)t^\eta)$, $W_3(t)=\exp(-(\alpha+\beta+l)t^\eta)$, $W_{11}(t)=\exp(-(k)t^\eta)$, $W_1(t)=\exp(-(\alpha+h+\gamma)t^\eta)$, $W_4(t)=\exp(-(\alpha+\beta+\gamma)t^\eta)$.

By taking Laplace transformation of (6) and solving for $B_0^{*R}(s)$. The busy period of the server due to repair activities is given by $B_0^R=\lim_{s\to 0} sB_0^{*R}(s)=\dfrac{N_3^R}{D_2}$, $B_0^{Pm}=\lim_{s\to 0} sB_0^{*Pm}(s)=\dfrac{N_4^{Pm}}{D_2}$,

$$\begin{aligned}N_3^R&=((W_2(0))((p_{01})(p_{42.5}p_{14.9})(1-p_{3.11}p_{11.3})+(1-p_{41.8}p_{14.9})(p_{02})(1-p_{3.11}p_{11.3})-(p_{31.12}p_{02}p_{13.10})))\\&\quad-(W_3(0)+W_{11}(0)p_{3.11})((-p_{01})(p_{42.5}p_{14.9}p_{23.6}+p_{13.10}(1-p_{42.5}p_{24.7}))+(p_{02})((1-p_{41.8}p_{14.9}(-p_{23.6})\\&\quad-(p_{13.10}p_{41.8}p_{24.7})))),\end{aligned}$$

$$\begin{aligned}N_4^{Pm}&=((W_1(0)+W_4(0)p_{14.9})((p_{01})(1-p_{42.5}p_{24.7})(1-p_{3.11}p_{11.3})+(p_{41.8}p_{24.7})(p_{02})(1-p_{3.11}p_{11.3})\\&\quad+(p_{31.12}p_{02}p_{23.6})))+((W_4(0)p_{24.7})((p_{01})(p_{42.5}p_{14.9})(1-p_{3.11}p_{11.3})+(1-p_{41.8}p_{14.9})(p_{02})\\&\quad(1-p_{3.11}p_{11.3})-(p_{31.12}p_{02}p_{13.10}))),\end{aligned}$$

and D_2 is already mentioned in previous section.

2.6. Expected number of repair activities and server visits

By considering simple probabilistic arguments and considering $E_i^R(t)$, $E_i^{Pm}(t)$ and $N_i(t)$ be the expected number of repairs, preventive maintenance and visits by the server in $(0,t]$ given that the system entered the regenerative state S_i at $t=0$. The recursive relations for $E_i^R(t)$, $E_i^{Pm}(t)$ and $N_i(t)$ are given as

$$E_i^R(t)=\sum_j Q_{i,j}^{(n)}(t)® \left[\delta_j+E_j^R(t)\right],\ E_i^{Pm}(t)=\sum_j Q_{i,j}^{(n)}(t)® \left[\delta_j+E_j^{Pm}(t)\right],$$

$$N_i(t)=\sum_j Q_{i,j}^{(n)}(t)® \left[\delta_j+N_j(t)\right], \tag{7}$$

where j and i are any successive regenerative states which can transit through n transitions and $\delta_j=1,$ if j is the regenerative state where the server does job afresh, otherwise $\delta_j=0.$ Taking Laplace-Stieltjes transformation of relations (7) and solving for $\tilde{E}_0^R(s)$, $\tilde{E}_0^{Pm}(s)$ and $\tilde{N}_0(s)$. The expected numbers of repairs, preventive maintenances and visits per unit time are given by

$$E_0^R(\infty)=\lim_{s\to 0} s\tilde{E}_0^R(s)=\frac{N_5^R}{D_2},\ E_0^{Pm}(\infty)=\lim_{s\to 0} s\tilde{E}_0^{Pm}(s)=\frac{N_6^{Pm}}{D_2},\ N_0(\infty)=\lim_{s\to 0} s\tilde{N}_0(s)=\frac{N_7}{D_2},$$

$$\begin{aligned}N_5^R&=((p_{20}+p_{23.6}+p_{24.7})((p_{01})(p_{42.5}p_{14.9})(1-p_{3.11}p_{11.3})+(1-p_{41.8}p_{14.9})(p_{02})(1-p_{3.11}p_{11.3})\\&\quad-(p_{31.12}p_{02}p_{13.10})))-((p_{30}+p_{31.12}+p_{3.11})+p_{11.3}p_{3.11})((-p_{01})(p_{42.5}p_{14.9}p_{23.6}+p_{13.10}(1-p_{42.5}p_{24.7}))\\&\quad+(p_{02})((1-p_{41.8}p_{14.9}(-p_{23.6})-(p_{13.10}p_{41.8}p_{24.7})))),\end{aligned}$$

$$\begin{aligned}N_6^{Pm}&=(((p_{10}+p_{13.10}+p_{14.9})+(p_{40}+p_{41.8}+p_{42.5})p_{14.9})((p_{01})(1-p_{42.5}p_{24.7})(1-p_{3.11}p_{11.3})\\&\quad+(p_{41.8}p_{24.7})(p_{02})(1-p_{3.11}p_{11.3})+(p_{31.12}p_{02}p_{23.6})))+(((p_{40}+p_{41.8}+p_{42.5})p_{24.7})((p_{01})\\&\quad(p_{42.5}p_{14.9})(1-p_{3.11}p_{11.3})+(1-p_{41.8}p_{14.9})(p_{02})(1-p_{3.11}p_{11.3})-(p_{31.12}p_{02}p_{13.10}))),\end{aligned}$$

$$\begin{aligned}N_2&=(p_{01}+p_{02})(((1-p_{41.8}p_{14.9})(1-p_{42.5}p_{24.7})(1-p_{3.11}p_{11.3}))+((p_{41.8}p_{24.7})(-p_{42.5}p_{14.9})(1-p_{3.11}p_{11.3}))\\&\quad+((-p_{31.12})(p_{42.5}p_{14.9}p_{23.6}+p_{13.10}(1-p_{42.5}p_{24.7}))))),\end{aligned}$$

and D_2 is already mentioned in previous section.

2.7. Profit analysis

The profit incurred to the system model in steady state can be obtained as

$$P=K_0A_0-K_1B_0^{Pm}-K_2B_0^R-K_3E_0^{Pm}-K_4E_0^R-K_5N_0, \tag{8}$$

where K_0 is the revenue per unit up-time of the system and K_i $(i=1,2,3,4,5)$ is the associated expenditure per unit time for operation of system. The numerical values of system's profit using Equation (8) for a particular case have been derived and appdended in Table 3.

3. Conclusions

In the present study, an effort has been made to analyze the reliability measures of a cold standby system of non- identical units. For this purpose, numerical results for MTSF, availability and profit function have been obtained for a particular case in which all random variables are assumed Weibull distributed. The particular values are as follows $\alpha=2,\ \eta=0.5,\ \gamma=5,\ h=0.009,\ k=1.5,\ l=1.4,$ $K_0=5000,\ K_1=200,\ K_2=150,\ K_3=100,\ K_4=75,\ K_5=80.$ It is observed from Tables 1-3 that the MTSF, availability and profit of the system declines with the increase shape parameter (η) and failure rate of the unit while values of these parameters increase with increment of the preventive maintenance rate and repair rate. Finally, we conclude that by increasing the repair rate and preventive maintenance rate of the original and duplicate unit, the two non-identical units system can be made more profitable and available for use.

Table 3 Profit and failure rate (β)

β	$\alpha=2,\eta=0.5,$ $\gamma=5,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=0.5,$ $\gamma=7,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=1,$ $\gamma=5,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=1,$ $\gamma=7,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=2,$ $\gamma=5,h=0.009,$ $k=1.5,l=1.4$	$\alpha=2,\eta=2,$ $\gamma=7,h=0.009,$ $k=1.5,l=1.4$
0.01	4367.2	4526.9	4194.3	4393.8	4153.6	4342.5
0.02	4341.8	4500.4	4181.7	4379.5	4146.3	4334.0
0.03	4316.6	4474.0	4169.1	4365.3	4139.1	4325.6
0.04	4291.4	4447.7	4156.7	4351.2	4132.0	4317.2
0.05	4266.4	4421.6	4144.4	4337.3	4125.0	4309.0
0.06	4241.5	4395.6	4132.3	4323.5	4118.0	4300.9
0.07	4216.7	4369.7	4120.2	4309.9	4111.1	4292.8
0.08	4192.1	4343.9	4108.2	4296.4	4104.2	4284.9
0.09	4167.6	4318.3	4096.4	4283.0	4097.4	4277.0
0.10	4143.2	4292.7	4084.6	4269.8	4090.7	4269.2

Acknowledgements

The authors are thankful to the Editor and reviewers for useful comments and suggestions to improve the quality of the work.

References

Kishan R, Jain D. A two non-identical unit standby system model with repair, inspection and post-repair under classical and Bayesian viewpoints. J Reliab Stat Stud. 2012; 5(2): 85-103.

Kumar I, Kumar A, Saini M, Devi K. Probabilistic analysis of performance measures of redundant systems under Weibull failure and repair laws. Lecture Notes in Networks and Systems. 2017; 12: 11-18.

Kadian MS, Khatkar J. Malik SC. Cost analysis of a two-unit cold standby system subject to degradation, inspection and priority. Eksploatacja i Niezawodnosc. 2012; 14(4): 278-283.

Kumar A, Malik SC. Reliability modelling of a computer system with priority to H/W repair over replacement of H/W and up-gradation of S/W subject to MOT and MRT. Jordan J Mech Ind Eng. 2014; 8(4): 233-241.

Kumar A, Saini M, Devi K. Stochastic modeling of non-identical redundant systems with priority, preventive maintenance and Weibull failure and repair distributions. Life Cycle Reliab Saf Eng. 2018; 7(1): 61-70.

Gupta R, Kumar P. Cost benefit analysis of a two dissimilar unit cold standby system with Weibull failure and repair laws. Int J Syst Assur Eng Manag 2013; 4(4): 327-334.

Kumar A, Saini M, Malik SC. Performance Analysis of a Computer System with Imperfect Fault Detection of Hardware. Procedia Comp Sci. 2015; 45: 602-610.

Kumar A, Saini M, Devi K. Analysis of a redundant system with priority and Weibull distribution for failure and repair. Cogent Math. 2016; 3(1), DOI:10.1080/23311835.2015.1135721.

Barak MS, Neeraj, Barak SK. Profit analysis of a two-unit cold standby system model operating under different weather conditions. Life Cycle Reliab Saf Eng. 2018; 7: 173-183.

Barak MS, Yadav D, Barak SK. Stochastic analysis of two-unit redundant system with priority to inspection over repair. Life Cycle Reliab Saf Eng. 2018; 7: 71-79.

Kumar A, Baweja S, Barak MS. Stochastic behavior of a cold standby system with maximum repair time. Decis Sci Lett. 2015; 4: 569-578.

Kumar A, Saini M, Devi K. Performance analysis of a redundant system with Weibull failure and repair laws. Revista Investig Operacinal. 2016; 37(3): 247-257.