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Stochastic Behaviour of an 2-out-of-3 Cold Standby System Supported by an Automatic Repair Mechanism

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ABSTRACT

This paper examines a 2-out-of-3 redundant system consisting of identical units. At the initial stage, two units operate simultaneously, while the third unit remains in cold standby. An automatic repair mechanism is employed to restore failed units. Whenever one of the operating units fails, the standby unit is immediately activated. The model also takes into account the possibility of failure of the automatic repair mechanism itself. It is assumed that each repaired unit is restored to an as-good-as-new condition, and the switching time between units is considered negligible.

Keywords: Regenerative Point, MTSF, Availability, Busy Period.

1. INTRODUCTION

A significant body of research has been conducted in the field of reliability engineering, with particular emphasis on two-unit system models under a variety of operating environments. Researchers such as Kumar, Gupta, and Taneja [1996], along with Giri, Goyal, and Singh [2009], have contributed notable findings related to the analysis of two-unit systems. To address growing consumer needs, industries are increasingly adopting highly automated technologies. Incorporating standby or reserve units has been recognized as an effective approach to improving system reliability. These systems often rely on multiple parallel components to ensure continued operation. Here three units system is considered in which two units are sufficient to perform its work. Such a three unit redundant system is applied in real world to attain high reliability and performance. Considering this view a model is studied in this chapter consisting of three-units in which operation of two is necessary. In this model three units are considered out of which two works at a time and one is kept as a cold standby. Keeping in view more automation of the system an Automatic Repair Machine (ARM) is considered which detects a problem automatically and repair it whenever a unit is found faulty or failed. The standby unit will automatically starts working whenever an operative unit fails. In this model failure of ARM is considered, which is repaired by an expert repairman who is called whenever required. It is assumed that a unit after repair is as efficient as new and switch over time is negligible. Model is discussed by taking particular cases on the reliability parameters like as Availability, MTSF, Busy Period of Repair machine etc., and using mathematical tools like Markov Process, Markov chain and Regenerative Point Technique.

Assumptions and System Description:

- System is made-up of three identical units. Initially two units are operative and third are kept as cold standby.
- System is considered in up-state if two units are working, in partial up-state if only one unit is working and in down-state if no unit is working.
- A unit of the system has two forms failed or normal operative.
- Failure of a unit is self-detected.
- A failed unit is repaired by an Automatic Repair Machine (ARM) which is always with the system.
- In this model it is assumed that ARM will also fail.
- Failed ARM is repaired by an expert repairman.
- Failure rate of unit and ARM have an exponential distribution of time and repair rates are taken general distribution.
- The switching is perfect and instantaneous.
- Expert repairman is called whenever required.
- The random variables are considered as independent in nature.

NOTATIONS:

E :	Set of regenerative states
$\overline{E}$:	Set of non-regenerative states
λ :	Constant failure rate of a unit
α :	Constant failure rate of ARM
g (t), G (t):	probability density function and cumulative density function of repair time of a failed unit
h (t), H (t):	probability density function and cumulative density function of repair time of ARM
O:	Unit is in operative state
C_S:	Unit is in cold standby state
F_r:	Failed unit under repair
F_R:	Repair of failed unit continuous from previous state
F_{wr}, F_{WR}:	A failed unit waiting for repair, a failed unit waiting for repair from previous state
ARM_O:	Automatic Repair Machine in operative state
ARMr:	Automatic Repair Machine failed and under repair
Θ:	Symbol for Stieltjes Convolution
©:	Symbol for Convolution

MODEL

In this model failure of ARM is considered. Here it is assumed that whenever ARM fails an expert repairman is called who repairs the ARM only. There are total seven states (St0, St1, St2, St3, St4, St5, and St6) in which St0, St1 and St3 are in up-state, S2 and S4 are in partial up-state and S5 and S6 are in down-state. Here

: (St0, St1, St2, St3, St4, St5) regenerative states
: (St6) non- regenerative state

Transition Probabilities:

The transition probabilities from the state St_i to St_j are given by dQ_{ij} and in steady state p_{ij} denote the transition probability from state St_i to St_j are given as under

$dQ_{01} = \int_0^t \lambda e^{-\lambda t} dt$, $dQ_{10} = \int_0^t e^{-(\alpha+\lambda)t} g(t)dt$, $dQ_{12} = \int_0^t \lambda e^{-(\alpha+\lambda)t} \overline{G}(t)dt$,

$dQ_{13} = \int_0^t \alpha e^{-(\alpha+\lambda)t} \overline{G}(t)dt$, $dQ_{21} = \int_0^t e^{-(\alpha+\lambda)t} g(t)dt$, $dQ_{25} = \int_0^t \lambda e^{-(\alpha+\lambda)t} \overline{G}(t)dt$

$dQ_{24} = \int_0^t \alpha e^{-(\alpha+\lambda)t} \overline{G}(t)dt$, $dQ_{31} = \int_0^t e^{-\lambda t} h(t)dt$, $dQ_{34} = \int_0^t \lambda e^{-\lambda t} \overline{H}(t)dt$

$dQ_{42} = \int_0^t e^{-\lambda t} h(t)dt$, $dQ_{46} = \int_0^t \lambda e^{-\lambda t} \overline{H}(t)dt$, $dQ_{45}^{(6)} = \int_0^t (\lambda e^{-\lambda t} © 1) h(t)dt$

$dQ_5{}^{(6)}{}_5 \quad = \int_0^t (\alpha e^{-\alpha t}\bar{G}(t) © h(t))dt$

The non-zero p_{ij} are as follows

$p_{ij} = dQ_{ij}(\infty)$ or $p_{ij} = \lim_{t\to\infty} dQ_{ij}(t)$

$p_{01} = 1$, $p_{10} = g^*(\alpha+\lambda)$, $p_{12} = \frac{\lambda}{\alpha+\lambda}[1- g^*(\alpha+\lambda)]$, $p_{21} = g^*(\alpha+\lambda)$, $p_{34} = 1 - h^*(\lambda)$,

$p_{13} = p_{24} = \frac{\alpha}{\alpha+\lambda}[1-g^*(\alpha+\lambda)]$, $p_{25} = \frac{\lambda}{\alpha+\lambda}[1- g^*(\alpha+\lambda)]$, $p_{31} = h^*(\lambda)$, $p_{42} = h^*(\lambda)$,

$p_{46} = p\,4^{(6)}{}_5 = 1 - h^*(\lambda)$, $p\,5^{(6)}{}_5 = [1 - g^*(\lambda)]\,[h^*(\lambda)]$, $p_{52} = g^*(\alpha)$

We may easily verify the following relations

$p_{01} = 1$, $p_{10} = p_{21}$, $p_{12} = p_{25}$, $p_{13} = p_{24}$, $p_{31} = p_{42}$, $p_{34} = p\,4^{(6)}{}_5$, $p_{31} + p_{34} = 1$, $p_{10} + p_{12} + p_{13} = 1$

Mean Sojourn Times:

To calculate mean time of stay μ_i in state St_i, let T_i be this time. Then we have following relations

$\mu_0 = \frac{1}{\lambda}$, $\mu_1 = \frac{1}{\alpha+\lambda}[1- g^*(\alpha+\lambda)]$, $\mu_2 = \frac{1}{\alpha+\lambda}[1- g^*(\alpha+\lambda)]$, $\mu_3 = \frac{1}{\lambda}[1- h^*(\lambda)]$, $\mu_4 = \frac{1}{\lambda}[1- h^*(\lambda)]$, $\mu_5 = \frac{1}{\alpha}[1-g^*(\alpha)]$

$m_{01} = m_{21} = \frac{1}{\lambda}$, $m_{10} = -[g^*(\alpha+\lambda)]'$, $m_{12} = m_{25} = \frac{\lambda}{(\alpha+\lambda)^2} + \frac{\lambda}{(\alpha+\lambda)}[g^*(\alpha+\lambda)]' - \frac{\lambda}{(\alpha+\lambda)^2} g^*(\alpha+\lambda)$

$m_{13} = m_{24} = \frac{\alpha}{(\alpha+\lambda)^2} + \frac{\alpha}{(\alpha+\lambda)}[g^*(\alpha+\lambda)]' - \frac{\alpha}{(\alpha+\lambda)^2} g^*(\alpha+\lambda)$, $m_{31} = m_{42} = -[h^*(\lambda)]'$

$m_{34} = m_{46} = \frac{1}{\lambda}[1-h^*(\lambda)] + [h^*(\lambda)]'$, $m\,4^{(6)}{}_5 = -[h^*(0)]' - [h^*(\lambda)]'$, $m_{52} = -[g^*(\alpha)]'$

We may easily verify the following relations

$m_{31} + m_{34} = \frac{1}{\lambda}[1- h^*(\lambda)]$, $m_{10} + m_{12} + m_{13} = \mu_2$

MTSF:

The average time for system failure is given by

□0 (t) = dQ01 (t) Θ □1 (t)

□1 (t) = dQ10 (t) Θ □0 (t) + dQ12 (t) Θ □2 (t) + dQ13 (t) Θ □3 (t)

□2 (t) = dQ25 (t) + dQ21 (t) Θ □1 (t) + dQ24 (t) Θ □4 (t)

□3 (t) = dQ31 (t) Θ □1 (t) + dQ34 (t) Θ □4 (t)

□4 (t) = dQ46 (t) + dQ42 (t) Θ □2 (t)

Taking Laplacian Stieltjes Transforms for □0**(s), we get

$$□_0^{**}(s) = \frac{N(s)}{D(s)}$$

Here

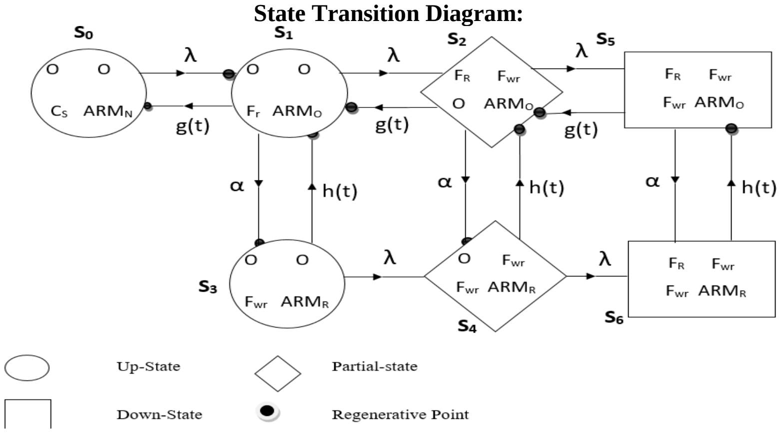
$N(s) = -q_{01}q_{12}q_{25} - q_{01}q_{12}q_{24}q_{46} - q_{01}q_{13}q_{34}q_{25}q_{42} - q_{01}q_{13}q_{34}q_{46}$

$D(s) = q_{24}q_{42} - q_{42}q_{13}q_{21}q_{34} - q_{42}q_{13}q_{31}q_{24} + q_{13}q_{31} - 1 - q_{12}q_{21} + q_{01}q_{10} - q_{01}q_{10}q_{24}q_{42}$

$$\text{MTSF} = □_0 = \lim_{s\to 0}\frac{1-\pi_0^{**}(s)}{s} = \frac{D'(0)-N'(0)}{D(0)}$$

$D'(0) - N'(0) = \mu_0[p_{10}p_{13}p_{31} - p_{10} - p^2_{12} - p_{12}p_{13}p_{34} - p_{12}p_{13}p_{34}p_{31} - p_{13}p^2_{34}] + m_{10}[p_{12} - p_{13}p^2_{31}] + m_{12}[p_{10} - 2p_{12} - p_{13}p_{34} - p_{13}p_{34}p_{31}] + m_{13}[p_{10}p_{13}p_{34} + 2p_{13}p^2_{31} + p_{10}p_{31} - p_{12}p_{13}p_{34} - p^2_{34} - p_{12}p_{34}] + m_{31}[p_{10}p_{13}p_{34} + 2p_{13}^2 p_{31} + p_{10}p_{31} - p_{12}p_{13}p_{34}] + m_{34}[p_{10}p_{13}p_{31} - p_{12}p_{13}p_{34} - 2p_{13}p_{34} - p_{12}p_{13}]$

State Transition Diagram:



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Availability of the System:

Let $Av_i(t)$ be the probability that a system is available at a point of time t after the unit entered the regenerative position at t = 0. The relations for $Av_i(t)$ are as follows:

$$Av_0(t) = M_0(t) + q_{01}(t) © Av_1(t)$$
$$Av_1(t) = M_1(t) + q_{10}(t) © Av_0(t) + q_{12}(t) © Av_2(t) + q_{13}(t) © Av_3(t)$$
$$Av_2(t) = M_2(t) + q_{21}(t) © Av_1(t) + q_{24}(t) © Av_4(t) + q_{25}(t) © Av_5(t)$$
$$Av_3(t) = M_3(t) + q_{31}(t) © Av_1(t) + q_{34}(t) © Av_4(t)$$
$$Av_4(t) = q_{42}(t) © Av_2(t) + q_{45}^{(6)}(t) © Av_5(t)$$
$$Av_5(t) = q_{52}(t) © Av_2(t) + q_{55}^{(6)}(t) © Av_5(t)$$

Here

$M_0(t) = \int_0^t e^{-\lambda t} d(t)$, $M_1(t) = \int_0^t e^{-(\alpha+\lambda)t}\bar{G}(t)d(t)$, $M_2(t) = \int_0^t e^{-(\alpha+\lambda)t}\bar{G}(t)d(t)$, $M_3(t) = \int_0^t e^{-\lambda t}\bar{H}(t)d(t)$

Now taking Laplacian Transforms for $Av_0^*(s)$, we get

$$Av_0^*(s) = \frac{N_1(s)}{D_1(s)}$$

Availability in the long run is as follows;

$$Av_0 = \lim_{s\to 0}(sAv_0^*(s)) = \frac{N_1(0)}{D_1'(0)}$$

Here

$N_1(0) = \mu_0 [(-p_{10}p_{13}p_{31}p_{34} + p_{10}p_{13}p_{34}p_{31}p_{55}^{(6)} - p_{10}p_{13}p_{34}^2p_{52}) + (p_{13}^2p_{31}^2 - p_{13}^2p_{31}^2p_{55}^{(6)}) + p_{13}^2p_{31}p_{34}p_{52} - p_{13}p_{31} + p_{13}p_{31}p_{55}^{(6)} + p_{13}p_{31}p_{52}p_{12}) + (-p_{13}p_{31} + p_{13}p_{31}p_{55}^{(6)} - p_{13}p_{52}p_{34} + 1 - p_{55}^{(6)} - p_{52}p_{12}) + (-p_{10}p_{12} + p_{10}p_{12}p_{55}^{(6)})] + \mu_1[(p_{13}p_{34}p_{31} + p_{13}p_{34}p_{31}p_{55}^{(6)} + p_{34}^2 p_{13}p_{52}) + (-p_{13}p_{31} + p_{13}p_{31}p_{55}^{(6)} - p_{13}p_{52}p_{34} + 1 - p_{55}^{(6)} - p_{52}p_{12}) + (p_{12} - p_{12}p_{55}^{(6)})] + \mu_3[- p_{13}^2p_{31} + p_{13}^2 p_{31}p_{55}^{(6)} - p_{13}^2p_{34}p_{52} + p_{13} - p_{13}p_{55}^{(6)} - p_{13}p_{52}p_{12}]$

$D_1'(0) = [(-p_{13} + p_{31}p_{55}^{(6)} - p_{34}p_{52})(m_{13}p_{10}p_{34} + m_{10}p_{13}p_{34} + m_{34}p_{13}p_{10}) + p_{10}p_{13}p_{34}(-m_{31} + m_{31}p_{55}^{(6)} + p_{31}m_{55}^{(6)} - m_{52}p_{34} - m_{45}^{(6)}p_{52})] - [m_{13}(2p_{31}^2 p_{13} - p_{31}^2 p_{13}p_{55}^{(6)} + p_{13}p_{31}^2p_{55}^{(6)} + 2p_{13}p_{31}p_{34}p_{52} + p_{31} - p_{31}p_{55}^{(6)} - p_{31}p_{52}p_{12}) + m_{31}(2p_{13}^2p_{31} + p_{13}^2p_{31}p_{55}^{(6)} + p_{13}p_{31}p_{34}p_{52} + p_{13} - p_{13}p_{55}^{(6)} - p_{13}p_{52}p_{12}) + m_{55}^{(6)}(p_{13}^2p_{31}^2 - p_{13}p_{31}) + m_{52}(p_{13}^2p_{31}p_{34} - p_{13}p_{31}p_{12}) + m_{34}(p_{13}^2p_{31}p_{52}) - m_{12}(p_{13}p_{31}p_{52})] + [m_{13}(-p_{31} + p_{31}p_{55}^{(6)} - p_{34}p_{52}) + m_{31}(-p_{13} + p_{13}p_{55}^{(6)}) + m_{55}^{(6)}(p_{13}p_{31} - 1) + m_{34}(- p_{13}p_{52}) + m_{52}(-p_{13}p_{34} - p_{12}) - m_{12}p_{52}] + [(m_{10}p_{12} + m_{12}p_{10})(m_{55}^{(6)} - 1) - p_{12}p_{10}m_{55}^{(6)}] + [m_{01}(-p_{10}p_{13}p_{31} + p_{10}p_{13}p_{31}p_{55}^{(6)} - p_{10}p_{13}p_{52}p_{34} + p_{10} - p_{10}p_{55}^{(6)} - p_{10}p_{52}p_{12}) + m_{10}(-p_{13}p_{31} + p_{13}p_{31}p_{55}^{(6)} - p_{13}p_{52}p_{34} + 1 - p_{55}^{(6)} - p_{52}p_{12}) + m_{10}(-p_{10}p_{31} + p_{10}p_{31}p_{55}^{(6)} + p_{10}p_{52}p_{34}) + m_{31}(-p_{10}p_{13} + p_{10}p_{13}p_{55}^{(6)}) + m_{55}^{(6)}(p_{10}p_{13}p_{31} - p_{10}) - m_{52}(p_{10}p_{13}p_{34} + p_{10}p_{12}) + m_{34}(p_{10}p_{13}p_{52}) + m_{12}(p_{10}p_{52})]$

Busy Period Analysis of ARM:

Let $Bp_i(t)$ is the busy period of an Automatic Repair Machine starting at a point at t=0 is as follows;

$$Bp_0(t) = q_{01}(t) © Bp_1(t)$$
$$Bp_1(t) = U_1(t) + q_{10}(t) © Bp_0(t) + q_{12}(t) © Bp_2(t) + q_{13}(t) © Bp_3(t)$$
$$Bp_2(t) = U_2(t) + q_{21}(t) © Bp_1(t) + q_{24}(t) © Bp_4(t) + q_{25}(t) © Bp_5(t)$$
$$Bp_3(t) = q_{31}(t) © Bp_1(t) + q_{34}(t) © Bp_4(t)$$
$$Bp_4(t) = q_{42}(t) © Bp_2(t) + q_{45}^{(6)}(t) © Bp_5(t)$$
$$Bp_5(t) = U_5(t) + q_{52}(t) © Bp_2(t) + q_{55}^{(6)}(t) © Bp_5(t)$$

Here

$U_1(t) = \int_0^t e^{-(\alpha+\lambda)t}\bar{G}(t)d(t)$, $U_2(t) = \int_0^t e^{-(\alpha+\lambda)t}\bar{G}(t)d(t)$, $U_5(t) = \int_0^t e^{-\alpha t}\bar{G}(t)d(t)$

Taking Laplacian Transforms for $Bp_0^*(s)$, we have

$$Bp_0^*(s) = \frac{N_2(s)}{D_1(s)}$$

In the steady state

$$Bp_0 = \lim_{s\to 0} sBp^*(s) = \lim_{s\to 0}\frac{sN_2(s)}{D_1(s)} = \frac{N_2(0)}{D_1'(0)}$$

Here

$N_2(0) = \mu_1[(p_{13}p_{34}p_{31} + p_{13}p_{34}p_{31}p_{55}^{(6)} + p_{34}^2p_{13}p_{52}) + (-p_{13}p_{31} + p_{13}p_{31}p_{55}^{(6)} - p_{13}p_{52}p_{34} + 1 - p_{55}^{(6)} - p_{52}p_{12}) + (p_{12} - p_{12}p_{55}^{(6)})] + \mu_5[(p_{34}^2p_{13} + p_{13}p_{34}p_{31}p_{12}) + (p_{12}p_{13}p_{34} + p_{12}^2)]$

$D_1'(0)$ is already defined.

Busy Period Analysis of Repairman:

Let $Bp'_i(t)$ is the busy period of repairman starting at a point at t=0 is as follows;

$$Bp'_0(t) = q_{01}(t) © Bp'_1(t)$$
$$Bp'_1(t) = q_{10}(t) © Bp'_0(t) + q_{12}(t) © Bp'_2(t) + q_{13}(t) © Bp'_3(t)$$
$$Bp'_2(t) = q_{21}(t) © Bp'_1(t) + q_{24}(t) © Bp'_4(t) + q_{25}(t) © Bp'_5(t)$$
$$Bp'_3(t) = V_3(t) + q_{31}(t) © Bp'_1(t) + q_{34}(t) © Bp'_4(t)$$
$$Bp'_4(t) = V_4(t) + q_{42}(t) © Bp'_2(t) + q_{45}^{(6)}(t) © Bp'_5(t)$$
$$Bp'_5(t) = q_{52}(t) © Bp'_2(t) + q_{55}^{(6)}(t) © Bp'_5(t)$$

Here

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$V_3(t) = \int_0^t e^{-\lambda t}\bar{H}(t)d(t)$, $V_4(t) = \int_0^t e^{-\lambda t}\bar{H}(t)d(t)$

Taking Laplacian Transforms for $Bp'^{*}_0(s)$, we have

$$Bp'^{*}_0(s) = \frac{N_3(s)}{D_1(s)}$$

In the steady state

$$Bp'_0 = \lim_{s\to 0} sBp'^{*}_0(s) = \lim_{s\to 0}\frac{sN_3(s)}{D_1(s)} = \frac{N_3(0)}{D_1'(0)}$$

Here

$N_3(0) = \mu_3[(p_{12}p_{13} - p_{12}p_{13}p_5{}^{(6)}{}_5) + (-p_{13}p_{31} + p_{13}p_{31}p_5{}^{(6)}{}_5 - p_{13}p_{52}p_{34} + p_{13} - p_{13}p_5{}^{(6)}{}_5 - p_{13}p_{52}p_{12})$
$+ (p_{13}p_{34} - p_{13}p_{34}p_5{}^{(6)}{}_5 - p_{13}p_{52}p_{12}p_{34})]$

$D_1'(0)$ is already defined.

Profit Function:

If P is profit function, then in long run it is given by

$P = r_1 * Av_0 - C_1 * Bp_0$

Where

C_1 = operating cost per unit time of ARM

Particular cases:

If we take repair rate and inspection time as negative binomial distribution as $g(t) = \gamma e^{-\gamma t}$, $h(t) = h e^{-ht}$

Then we get

$p_{01} = 1$, $p_{10} = \frac{\gamma}{\alpha+\lambda+\gamma} = p_{21}$, $p_{12} = \frac{\lambda}{\alpha+\lambda+\gamma} = p_{25}$, $p_{13} = \frac{\alpha}{\alpha+\lambda+\gamma} = p_{24}$

$p_{31} = \frac{h}{h+\lambda} = p_{42}$, $p_{34} = \frac{\lambda}{h+\lambda} = p_{46}$, $p_{52} = \frac{\gamma}{\alpha+\lambda}$, $p_4{}^{(6)}{}_5 = \frac{\lambda}{h+\lambda}$, $p_5{}^{(6)}{}_5 = \frac{\alpha}{\alpha+\gamma}$, $p_2{}^{(5)}{}_2 = \frac{\lambda}{\lambda+i}$

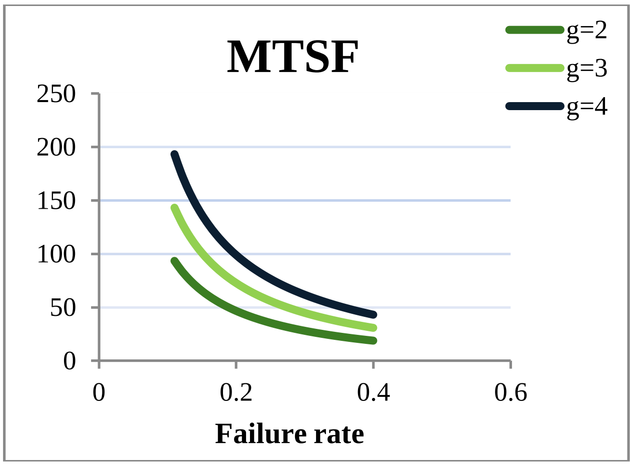
Mean Sojourn Time:

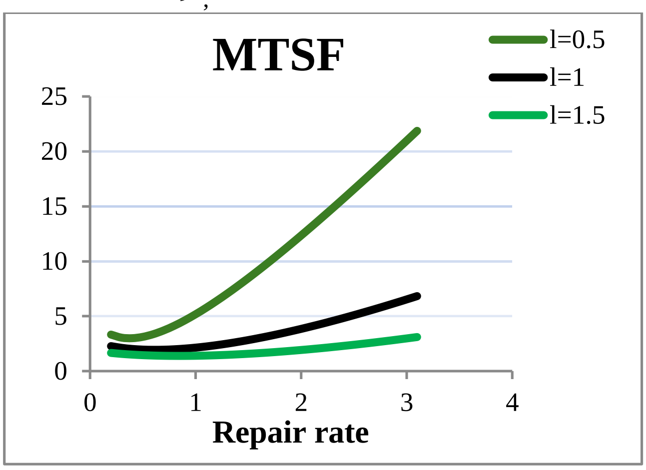
$\mu_0 = \frac{1}{\lambda}$, $\mu_1 = \frac{1}{\alpha+\lambda+\gamma}$, $\mu_2 = \frac{1}{\alpha+\lambda+\gamma}$, $\mu_3 = \frac{1}{h+\lambda}$, $\mu_4 = \frac{1}{h+\lambda}$, $\mu_5 = \frac{1}{\alpha+\gamma}$

Unconditional Mean Time:

$m_{01} = \frac{1}{\lambda}$, $m_{10} = \frac{\gamma}{(\alpha+\lambda+\gamma)^2} = m_{21}$, $m_{12} = \frac{\lambda}{(\alpha+\lambda+\gamma)^2} = m_{25}$, $m_{13} = \frac{\alpha}{(\alpha+\lambda+\gamma)^2} = m_{24}$, $m_{31} = \frac{h}{(h+\lambda)^2} = m_{42}$

$m_{34} = \frac{\lambda}{(h+\lambda)^2} = m_{46}$, $m_{52} = \frac{\gamma}{(\alpha+\lambda)^2}$, $m_4{}^{(6)}{}_5 = h\left\{\frac{1}{h^2} - \frac{1}{(h+\lambda)^2}\right\}$, $m_5{}^{(6)}{}_5 = \frac{\alpha h}{(\alpha+\gamma-h)}\left\{\frac{1}{h^2} - \frac{1}{(\alpha+\gamma)^2}\right\}$





CONCLUSION

In this paper, it is observed with the help of Graphs and Tables, the Failure Rate (λ) increases, MTSF and Availability of the System are decrease, which should be. In this study, **m-out-of-n Units Cold Standby System with no Perfect ARM**, no perfect ARM i.e. Automatic Repair Machine may also fail and this is repaired by a repairman also we used RPT to solve the various parameters of System. In future, Researchers can evaluated the parameters, when repair rate and failure rate are time-dependent and also discuss the cost and profit benefit analysis. Further results can also be apply to find the Waiting Time of Units and Number of Server's visits. Generally, the Management has fixed resources and by fixing the target Availability, we can provide the repair rate for optimum solution.

REFERENCES

[1] *Rani, J. (2020): Behaviour Analysis of Industrial Systems using RPT and RPGT; Ph.D. Thesis, OPJS, Churu, Rajasthan.*

[2] *Kumar, R. (2014): Mathematical Analysis of Multi-Unit Systems; Ph.D. Thesis, JJT University Jhunjhunu, Rajasthan.*

[3] *Sharma, A., Kumar, R. (June 2013): A 3 Out of 4 Units Systems with Maintenance and Replacement, JMASS Vol. 9, No. 1, pp 55-64.*

[4] *Singh, J. (2011), 'Reliability Technology in Daily Life'; JMASS, Vol.7, No.1, pp 54-58.*

[5] *Gupta, V.K., Kumar,K., Singh,J.& Goel,P.(2009), ' Profit Analysis of a Single Unit Operating System with a Capacity factor & undergoing Degradation'; Proc. Of National Conference; JMASS, Vol.5, No.2. pp 129-142.*

[6] *Giri, S., Goyal, Y.K. & Singh, J. (2009), 'Analysis of Agriculture Based Industry (Liquid Milk Plant) - A shortcut Approach'; JMASS, Vol.5, No.2, pp 95-109.*

[7] *Malik, S.C., Chand, P.,& Singh, J(2008)., Reliability And Profit Evaluation of an Operating System with Different Repair Strategy Subject to Degradation; JMASS, Vol.4, No. 1, June, 2008, 127-140.*

[8] *Gupta, V.K. & Singh, J. (2008), 'Availability and Profit Analysis of an Ash Handling Plant'; JMASS, Vol.4, No.1, pp 90-112.*

[9] *Gupta, V.K. & Singh, J. (2007), 'A New Approach for Availability Analysis'; IEEE Transactions on Reliability, TR 2007-107 Communicated.*

[10] *Goyal, R.& Kumar,A.(2006), 'Profit Evaluation of a reliability Model with Instruction, Replacement and Two of the Three Types of Repair Policy'; JMASS, Vol.4, No.1, pp 90-112.*

[11] *Chander, S., and Bansal, R.K.(2005), 'Profit analysis of a single-unit Reliability models with repair at different failure modes; Proc. Of International Conference on Reliability and SafetyEngineering'; Dec,2005, pp 577-588.*

[12] *Kumar, A., Gupta, S.K. and Taneja, G. (1996), 'Comparative study of the profit of a two server system including patience time and instruction time'. Micro electron Reliab, Vol.36, No.10, pp 1595-1601.*

[13] *Taneja, G. (1992), 'Stochastic and Profit Analysis of Some Reliability Models With Different Types of Failure and Repair'; Ph.D. Thesis, MDU, Rohtak (India).*