*Journal of Advances and Scholarly Researches in Allied Education*
*Vol. 16, Issue No. 4, March-2019, ISSN 2230-7540*

# Sensitivity Analysis of a Cold Standby System with Priority for Preventive Maintenance

**Arun Kumar[1]* Dr. Deepika Garg[2] Dr. Pardeep Goel[3]**

[1] Research Scholar, G. D. Goenka University, Gurugram, Haryana

[2] Assistant Professor, G. D. Goenka University, Gurugram, Haryana

[3] Associate Professor M. M. (P.G.) College, Fatehabad -125050, Haryana

***Abstract – The paper analyzes sensitivity analysis of a cold standby system with priority for preventive maintenance consist two identical units with server failure using Regenerative Point Graphical Technique (RPGT). In this present paper there are two units one of which is online while other is kept in cold standby mode. Online & cold standby unit are indistinguishable in nature and have just two modes one is full limit and second is totally finished failure. There is single repair facility which is available. Taking Repair rates and Failure rates are constant. A state chart of the framework delineating the transition rates is drawn. Sensitive analysis of framework is done which might be helpful to management in keeping up the different units of system Tables & figures are set up to look at and draw the conclusion.***

***Keywords: System Parameters, MTSF, RPGT etc.***

---------------------------------X---------------------------------

## INTRODUCTION

In this present paper there are two units one of which is online while other is kept in cold standby mode. Online & cold standby unit are indistinguishable in nature and have just two modes one is full limit and second is totally finished failure. There is single repairman as talked about to upkeep the units in all situations. Online unit just may experience preventive maintenance before failure. A unit is repaired just on its total disappointment need is appointed for preventive maintenance over the repair of a unit preventive upkeep office helps in declines the crumbling rates of online units in various working state. The irregular different related with failure & repair of units, server & preventive support and treatment time of server are measurably free and furthermore have distinct distributions probability.

The system is displayed utilizing semi-Markov procedure and RPGT different system reliability parameters. Sensitivity analysis tables & figures for framework parameters are set up for expanding failure and repair rates. Corresponding chart are drawn and analysis of parameters is composed from these tables and graphs in this manner acquired.

Gupta, R. [1] the paper discussed about a one unit framework alongside two sorts of repairman & repeat repair policies on failure of unit, this is attempted by any common repairman alongside the way that it may not ready to do a portion of complex repairs. Likewise, there might be a plausibility of harming the units amid repair by him, which can result it to go into increasingly more debased state. Kumar J. & Malik S. C. [2], Choudhary, A., Neeraj & Kumar, K. [3], Bhardwaj, R. K., Kour, K. & Malik S. C.[4] and Liu., R. [5] have also discussed preventive maintenance, reliability modeling analysis of a single unit and its applications. Kumar, R., Poonia, M. & Goel, P.[6] have also studied on stochastic and availability analysis of two units with increasing failure/ repair rates. Chaudhary Nidhi, Goel P. [7], Gupta, R., Sharma, S. & Bhardwaj [8] and Tuteja, R. K. & Taneja, G. [9] has studied availability and behavior analysis of two or more units system using RPGT technique. Ms. Rachita and Garg D. [10] and Kumar A., Goel P., Garg D., and Sahu A. [11]have also discussed reliability analysis using different technique.

### Assumptions and notations:-

1. A single repair man is accessible 24*7.
2. Repaired framework is as great/good.
3. Failure rate & landing rates are statistically independent.

○ : Good Working State

□ : Fizzled State

⬭ : Reduced state

$\alpha_i$:- Constant failure rate.

g(t)/f(t) :- repair / preventive maintenance time of unit.

w(t):- arrival/leading time of server.

AUr : Unit is fizzled & under fix.

AWr: Unit is fizzled & waiting for fix.

HUt: Server is fizzled & under treatment from past state.

HUT: Server is fizzled & continuously under treatment from past state.

AUR : Unit is fizzled & under repair from past state.

AWR: Unit is fizzled & waiting for repair continuously from past state.

**Model Description:-**

Taking into consideration above assumptions & notations, Transition Diagram of system is given Figure 1.

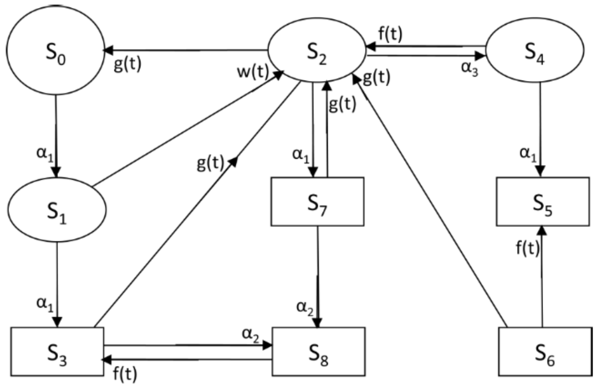


**Figure 1 Transition Diagram of system**

$S_0$ =CS, $S_1$ =AWr, $S_2$ = AUr, $S_3$ = AWr or AUR,

$S_4$ = AWr or Hut, $S_5$ = AWr, AWR, HUT, $S_6$ = AUr, AWR,

$S_7$ =AWr or AUR $S_8$ =AWr or AWR or HUt

**Transition Probability:**

qi,j(t): Probability compactness function regenerative state 'i 'and 'j'

pi,j: State transition probability of a regenerative state 'i' to a regenerative state 'j', pi,j = q_(i,j)^* (0);

**Table 1 Transition Probabilities**

| $q_{i,j}(t)$ | $P_{ij} = q^*_{i,j}(0)$ |
|---|---|
| $q_{0,1}(t) = \alpha_1 e^{-\alpha_1 t}$ | $p_{0,1} = 1$ |
| $q_{1,2}(t) = w(t)e^{-(\alpha_1)t}$<br>$q_{1,3}(t) = \alpha_1 e^{-(\alpha_1)t}\overline{w}(t)$ | $p_{1,2} = w^*(\alpha_1)$<br>$p_{1,3} = [1-w^*(\alpha_1)]$ |
| $q_{2,0}(t) = g(t)e^{-(\alpha_1+\alpha_2)t}$<br>$q_{2,4}(t) = \alpha_2 e^{-(\alpha_1+\alpha_2)t}\bar{G}t$<br>$q_{2,7}(t) = \alpha_1 e^{-(\alpha_1+\alpha_2)t}Gt$ | $p_{2,0} = g^*(\alpha_1+\alpha_2)$<br>$p_{2,4} = [\alpha_2/(\alpha_2+\alpha_1)][1-g^*(\alpha_2+\alpha_1)]$<br>$p_{2,7} = [\alpha_1/(\alpha_2+\alpha_1)][1-g^*(\alpha_2+\alpha_1)]$ |
| $q_{3,2}(t) = g(t)e^{-(\alpha_2)t}$<br>$q_{3,8}(t) = \alpha_2 e^{-(\alpha_2)t}\bar{G}t$ | $p_{3,2} = g^*(\alpha_2)$<br>$p_{3,8} = [1-G^*(\alpha_2)]$ |
| $q_{4,2}(t) = f(t)e^{-(\alpha_1)t}$<br>$q_{4,5}(t) = \alpha_1 e^{-(\alpha_1)t}\bar{F}t$ | $p_{4,2} = f^*(\alpha_1)$<br>$p_{4,5} = [1-f^*(\alpha_1)]$ |
| $q_{5,6}(t) = f(t)$ | $p_{5,6} = f^*(0)$ |
| $q_{6,2}(t) = g(t)e^{-(\alpha_2)t}$<br>$q_{6,8}(t) = \alpha_2 e^{-(\alpha_2)t}\bar{G}t$ | $p_{6,2} = g^*(\alpha_2)$<br>$p_{6,8} = [1-g^*(\alpha_2)]$ |
| $q_{7,2}(t) = g(t)e^{-(\alpha_2)t}$<br>$q_{7,8}(t) = \alpha_2 e^{-(\alpha_2)t}\bar{G}t$ | $p_{7,2} = g^*(\alpha_2)$<br>$p_{7,8} = [1-g^*(\alpha_2)]$ |
| $q_{8,3}(t) = f(t)$ | $p_{8,3} = f^*(0)$ |

It can be easily verified that

$p_{1,3}+p_{1,2} = 1$, $p_{2,0}+p_{2,4}+p_{2,7} = 1$, $p_{3,2}+p_{3,8} = 1$, $p_{4,2}+p_{4,5} = 1$

$p_{6,2}+p_{6,8} = 1$, $p_{7,2}+p_{7,8} = 1$, $p_{5,6} = 1$, $p_{8,3} = 1$

**Mean Sojourn Times**

$R_i(t)$ : Reliability of system at time t, $\mu_i$ : Mean sojourn time spent in state i,

**Table 2 Mean Sojourn Times**

| $R_i(t)$ | $\mu_i = R_i^*(0)$ |
|---|---|
| $R_0(t) = e^{-(\alpha_1)t}$ | $\mu_0 = 1/\alpha_1$ |
| $R_1(t) = e^{-(\alpha_1)t}\overline{w}t$ | $\mu_1 = [1-w^*(\alpha_1)]/\alpha_1$ |
| $R_2(t) = e^{-(\alpha_1+\alpha_2)t}\bar{G}t$ | $\mu_2 = [1-g^*(\alpha_1+\alpha_2)]/(\alpha_1+\alpha_2)$ |
| $R_3(t) = e^{-(\alpha_2)t}\bar{G}t$ | $\mu_3 = [1-g^*(\alpha_2)]/\alpha_2$ |
| $R_4(t) = e^{-(\alpha_1)t}\bar{F}t$ | $\mu_4 = [1-g^*(\alpha_1)]/\alpha_1$ |
| $R_5(t) = \bar{F}t$ | $\mu_3 = -f^*0$ |
| $R_6(t) = e^{-(\alpha_2)t}\bar{G}t$ | $\mu_6 = [1-g^*(\alpha_2)]/\alpha_2$ |
| $R_7(t) = e^{-(\alpha_2)t}\bar{G}t$ | $\mu_7 = [1-g^*(\alpha_2)]/\alpha_2$ |
| $R_8(t) = \bar{F}t$ | $\mu_8 = -f^*0$ |

**Let us take**

$g(t) = \beta_1 e^{-\beta_1(t)}$, $w(t) = \beta_2 e^{-\beta_2(t)}$, $f(t) = \beta_3 e^{-\beta_3(t)}$

$p_{0,1} = 1$, $p_{1,3} = \alpha_1/(\alpha_1+\beta_2)$, $p_{1,2} = \beta_2/(\beta_2+\alpha_1)$

$p_{2,0} = \beta_1/(\beta_1+\alpha_1+\alpha_2)$, $p_{2,4} = \alpha_2/(\beta_1+\alpha_1+\alpha_2)$, $p_{2,7} = \alpha_1/(\beta_1+\alpha_1+\alpha_2)$

$p_{3,2} = \beta_1/(\beta_1+\alpha_2)$, $p_{3,8} = \alpha_2/(\beta_1+\alpha_2)$, $p_{4,2} = \beta_3/(\beta_3+\alpha_1)$

$p_{4,5} = \alpha_1/(\alpha_1+\beta_3)$, $p_{5,6} = 1$, $p_{6,2} = \beta_1/(\beta_1+\alpha_2)$

$p_{6,8} = \alpha_2/(\alpha_2+\beta_1)$, $p_{7,2} = \beta_1/(\alpha_2+\beta_1)$, $p_{7,8} = \alpha_2/(\alpha_2+\beta_1)$

$p_{8,3} = 1$, $\mu_0 = 1/\alpha_1$, $\mu_2 = 1/(\alpha_1+\beta_2)$

$\mu_2 = 1/(\alpha_1+\alpha_2+\beta_1)$, $\mu_3 = 1/(\alpha_2+\beta_1)$, $\mu_4 = 1/(\alpha_1+\beta_1)$

$\mu_5 = 1/\beta_3$, $\mu_6 = 1/(\alpha_2+\beta_1)$, $\mu_7 = 1/(\alpha_2+\beta_1)$

$\mu_8 = 1/\beta_3$

**Path Probability**:

$V_{0,0} = 1$

$V_{0,1} = (0,1)$

$V_{0,2} = (0,1,2)/(1\text{-}Z_1)(1\text{-}Z_2)(1\text{-}Z_3)[(1\text{-}Z_4)/(1\text{-}Z_5)(1\text{-}Z_6)]+(0,1,3,2)/(1\text{-}Z_1)(1\text{-}Z_2)(1\text{-}Z_3)$
$[(1\text{-}Z_4)/(1\text{-}Z_5)(1\text{-}Z_6)](1\text{-}Z_6)[(1\text{-}Z_7)/(1\text{-}Z_1)(1\text{-}Z_2)(1\text{-}Z_3)][(1\text{-}Z_8)/(1\text{-}Z_2)][(1\text{-}Z_9)$
$/(1\text{-}Z_2)]\{[(1\text{-}Z_{10})/(1\text{-}Z_1)(1\text{-}Z_2)][(1\text{-}Z_8)/(1\text{-}Z_2)]\}\{[(1\text{-}Z_{11})/(1\text{-}Z_1)(1\text{-}Z_2)][(1\text{-}Z_8)$
$/(1\text{-}Z_2)]\}$ …………………. continued

**MTSF ($T_0$): ):** The regenerative un-failed states to which the system can transit(initial state '0'), before entering any failed state are: 'i' = 0,1,2,4 taking 'ξ' = '0'.

$$\text{MTSF}(T_0) = \left[\Sigma_{i,sr}\left\{\frac{\left\{pr\left(\xi \xrightarrow{sr(sff)} i\right)\right\}\mu i}{\Pi_{m_1 \neq \xi}\{1\text{-}V_{\overline{m_1 m_1}}\}}\right\}\right] \div \left[1\text{-}\Sigma_{sr}\left\{\frac{\left\{pr\left(\xi \xrightarrow{sr(sff)} \xi\right)\right\}}{\Pi_{m_2 \neq \xi}\{1\text{-}V_{\overline{m_2 m_2}}\}}\right\}\right]$$

$T_0 = (V_{0,0}\mu_0+V_{0,1}\mu_1+V_{0,2}\mu_2+V_{0,4}\mu_4)/(1\text{-}p_{2,7}p_{7,2}\text{-}p_{2,4}p_{4,2}\text{-}p_{2,4}p_{4,5}p_{5,6}p_{6,2}\text{-}p_{4,2}p_{2,4}\text{-}p_{4,5}p_{5,6}$
$p_{6,2}p_{2,4})$

**Availability of the System ($A_0$)**: The regenerative states at which the system is available are 'j' = 0 to 4 and the regenerative states are 'i' = 0 to 8 taking 'ξ' = '0' the total fraction of time for which the system is available is given by

$$A_0 = \left[\Sigma_{j,sr}\left\{\frac{\{pr(\xi^{sr\to}j)\}fj,\mu j}{\Pi_{m_1 \neq \xi}\{1\text{-}V_{\overline{m_1 m_1}}\}}\right\}\right] \div \left[\Sigma_{i,s_r}\left\{\frac{\{pr(\xi^{sr\to}i)\}\mu_i^1}{\Pi_{m_2 \neq \xi}\{1\text{-}V_{\overline{m_2 m_2}}\}}\right\}\right]$$

$$A_0 = \left[\Sigma_j V_{\xi,j}, f_j, \mu_j\right] \div \left[\Sigma_i V_{\xi,i}, f_j, \mu_i^1\right]$$

$$= (V_{2,0}\mu_0+V_{2,1}\mu_1+V_{2,2}\mu_2+V_{2,4}\mu_4)/D$$

Where $D = (V_{2,0}\mu_0+V_{2,1}\mu_1+V_{2,2}\mu_2+V_{2,3}\mu_3+V_{2,4}\mu_4+V_{2,5}\mu_5+V_{2,6}\mu_6+V_{2,7}\mu_7+V_{2,8}\mu_8)$

**Busy Period of the Server:** The regenerative states where server j = 1 to 8 & regenerative states are 'i' = 0 to 8, taking ξ = '0', the total fraction of time for which the server remains busy is

$$B_0 = \left[\Sigma_{j,sr}\left\{\frac{\{pr(\xi^{sr\to}j)\},nj}{\Pi_{m_1 \neq \xi}\{1\text{-}V_{\overline{m_1 m_1}}\}}\right\}\right] \div \left[\Sigma_{i,sr}\left\{\frac{\{pr(\xi^{sr\to}i)\}\mu_i^1}{\Pi_{m_2 \neq \xi}\{1\text{-}V_{\overline{m_2 m_2}}\}}\right\}\right]$$

$$B_0 = \left[\Sigma_j V_{\xi,j}, n_j\right] \div \left[\Sigma_i V_{\xi,i}, \mu_i^1\right]$$

$$B_0 = (V_{2,1}\mu_1+V_{2,2}\mu_2+V_{2,3}\mu_3+V_{2,4}\mu_4+V_{2,5}\mu_5+V_{2,6}\mu_6+V_{2,7}\mu_7+V_{2,8}\mu_8)/D$$

**Expected Fractional Number of Inspections by the repair man:** The regenerative states where the repair man do this job j = 3,5,6,7,8 the regenerative states are i = 0 to 8, Taking 'ξ' = '0', the number of visit by the repair man is given by

$$V_0 = \left[\Sigma_{j,sr}\left\{\frac{\{pr(\xi^{sr\to}j)\}}{\Pi_{k_1 \neq \xi}\{1\text{-}V_{\overline{k_1 k_1}}\}}\right\}\right] \div \left[\Sigma_{i,s_r}\left\{\frac{\{pr(\xi^{sr\to}i)\}\mu_i^1}{\Pi_{k_2 \neq \xi}\{1\text{-}V_{\overline{k_2 k_2}}\}}\right\}\right]$$

$$V_0 = \left[\Sigma_j V_{\xi,j}\right] \div \left[\Sigma_i V_{\xi,i}, \mu_i^1\right]$$

$$V_0 = (V_{2,3}+V_{2,5}+V_{2,6}+V_{2,7}+V_{2,8})/D$$

## SENSITIVITY ANALYSIS OF SYSTEM

**Scenario1:** Sensitivity Analysis w. r. t. change in repair rates**.** Taking $\alpha_i$ = 0.10 ($1 \le i \le 2$) and varying $\beta_1$, $\beta_2$, $\beta_3$, one by one respectively at 0.80, 0.90, 1.00

**MTSF ($T_0$):-**

**MTSF ($T_0$) Table**

| $\beta_i$ | $\beta_1$ | $\beta_2$ | $\beta_3$ |
|---|---|---|---|
| 0.80 | 15.6 | 15.6 | 15.6 |
| 0.90 | 15.6 | 15.6 | 15.6 |
| 1.00 | 15.6 | 15.6 | 15.6 |

**Table 3**

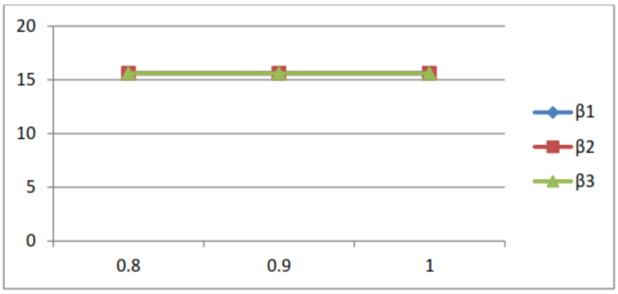


**Figure 2**

**Availability of the System ($A_0$) Table**

| $\beta_i$ | $\beta_1$ | $\beta_2$ | $\beta_3$ |
|---|---|---|---|
| 0.80 | 0.97598 | 0.97500 | 0.97478 |
| 0.90 | 0.97823 | 0.97598 | 0.97537 |
| 1.00 | 0.97987 | 0.97671 | 0.97598 |

**Table 4**

**Availability of the System Graph**

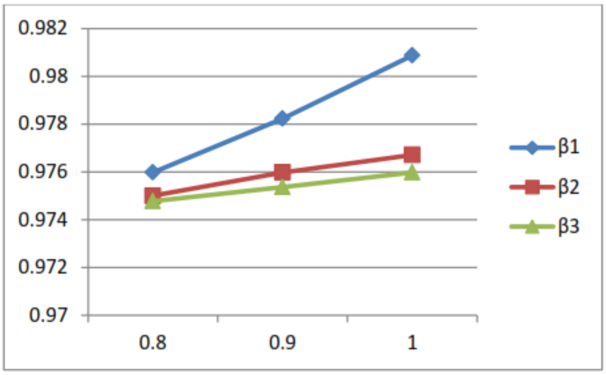


**Figure 3**

**Busy Period of the Server ($B_0$) Table**

| $\beta_i$ | $\beta_1$ | $\beta_2$ | $\beta_3$ |
|---|---|---|---|
| 0.80 | 0.21221 | 0.21999 | 0.21317 |
| 0.90 | 0.20384 | 0.21221 | 0.21273 |
| 1.00 | 0.17057 | 0.18459 | 0.21221 |

**Table 5**

**Busy Period of the Server Graph**

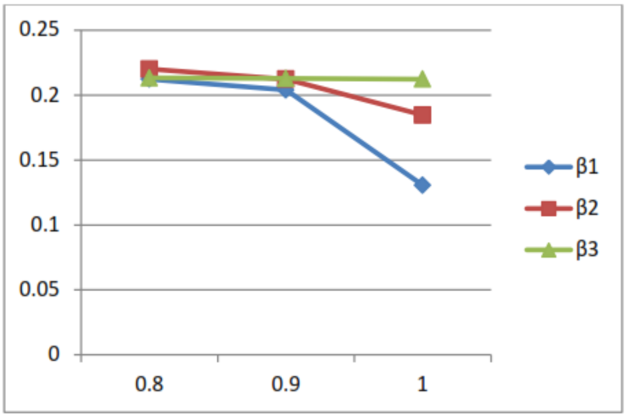


**Figure 4**

**Expected Fractional Number of Inspection by Repairman ($V_0$) Table**

| $\beta_i$ | $\beta_1$ | $\beta_2$ | $\beta_3$ |
|---|---|---|---|
| 0.80 | 0.02182 | 0.02272 | 0.02238 |
| 0.90 | 0.02147 | 0.02182 | 0.02189 |
| 1.00 | 0.02086 | 0.02124 | 0.02182 |

**Table 6**

**Expected Fractional Number of Inspection by the Repairman Graph**

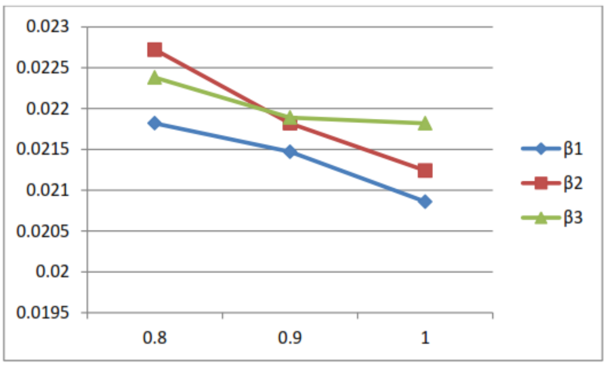


**Figure 5**

**Scenario2**: Now we consider Sensitivity Analysis scenario 2 with respect to change in failure rates: taking $\beta_i = 0.80$ ($1 \le i \le 3$) and varying $\alpha_1$, $\alpha_2$ one by one respectively at 0.10, 0.20, 0.30.

**Mean Time to System Failure ($T_0$):-**

**MTSF ($T_0$) Table**

| $\alpha_i$ | $\alpha_1$ | $\alpha_2$ |
|---|---|---|
| 0.10 | 22.87576 | 20.49264 |
| 0.20 | 22.89434 | 22.87576 |
| 0.30 | 23.61538 | 24.38438 |

**Table 7**

**Mean Time to System Failure Graph**

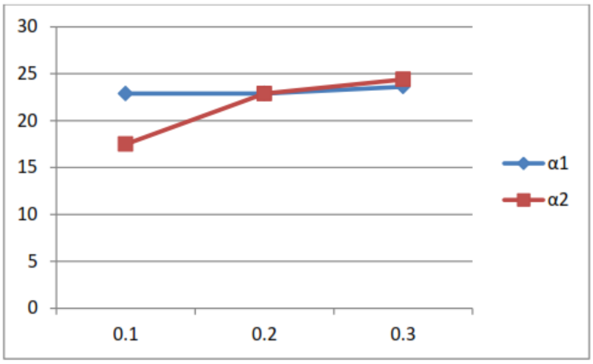


**Figure 6**

**Availability of the System ($A_0$) Table**

| $\alpha_i$ | $\alpha_1$ | $\alpha_2$ |
|---|---|---|
| 0.10 | 0.96812 | 0.98214 |
| 0.20 | 0.91640 | 0.96812 |
| 0.30 | 0.84752 | 0.89530 |

**Table 8**

**Availability of the System Graph**

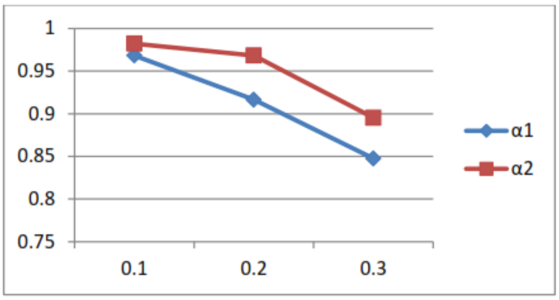


**Figure 7**

**Busy Period of the Server ($B_0$) Table**

| $\alpha_i$ | $\alpha_1$ | $\alpha_2$ |
|---|---|---|
| 0.10 | 0.23400 | 0.21428 |
| 0.20 | 0.38872 | 0.23400 |
| 0.30 | 0.50607 | 0.34996 |

**Table 9**

**Busy Period of the Server Graph**

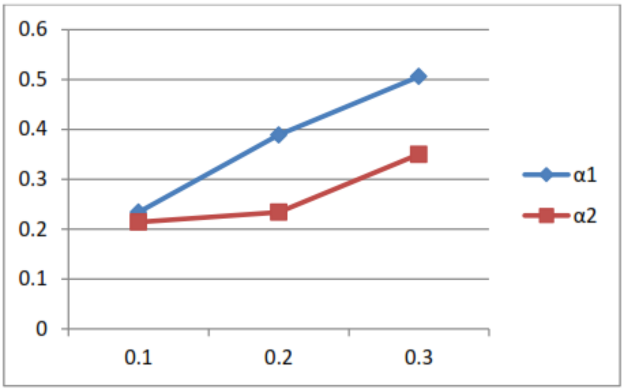


**Figure 8**

**Expected Fractional Number of Inspection by Repairman ($V_0$) Table**

| $\alpha_i$ | $\alpha_1$ | $\alpha_2$ |
|---|---|---|
| 0.10 | 0.02805 | 0.02736 |
| 0.20 | 0.02884 | 0.02805 |
| 0.30 | 0.02940 | 0.02913 |

**Table 10**

**Expected Fractional Number of Inspection by the Repairman Graph**

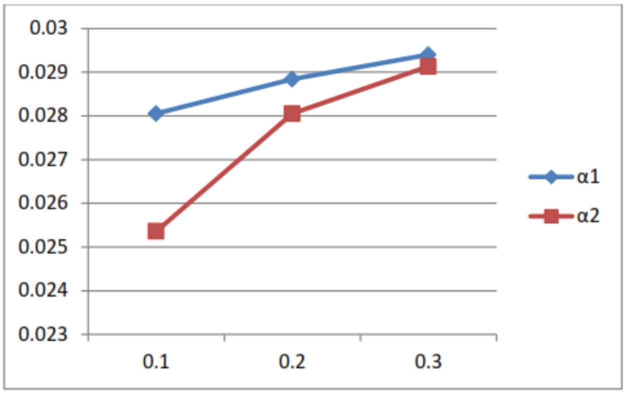


**Figure 9**

## CONCLUSION:-

From the above table 3 & figure 2, it is concluded that $T_0$ is constant for corresponding repair rates. From the above table 4 we see that $A_0$ increase more quickly with the expansion in repair rates of units. However, the rate of increase in greatest when β rate of server increase on contrasting the impact of β rates it is quicker with the expansion in repair rate of units. From table 5, we see that $B_0$ increase in repair rates, yet its rate of diminishing increasingly over the other repair rates if there should arise an occurrence of online units repair rates. From the table 6 it is seen that estimation of $V_0$ is same for same estimation of repair rates of units. Be that as it may, it is least when repair rate of units is highest. From the above table 7 & figure 6, we see that $T_0$ increment with the expansion in failure rates of units & server as we produced using top to bottom, while contrasting the tabular qualities in columns, we see that $T_0$ increment quick with the expansion in failure rate of online unit. From table 8 & figure 7, we see that $A_o$ decrease all the more quickly with the expansion, in restoration rate of preventive support, subsequently to keep estimation of $A_o$. From table 7 & figure 8 that it is concluded that value of $B_0$ Increases in all columns as failure rates increment. Be that as it may, it increment at quicker rate with increment in failure rate of online units. From table 10, we see that value of $V_0$ increment with the expansion in failure rates which is practical too.

## REFERENCES: -

1. Gupta, R. (2017). “Stochastic Analysis of a Repairable Model for One Unit System with Three Types of Repair Policy”, International Journal of Statistics and Applied Mathematics, Vol. 2 (6), ISSN 2456-1452, pp. 126-130.

2. Kumar J., Kadyan M. S., Malik S. C. & Jindal C. (2014). “Reliability Measures of a Single-Unit System Under Preventive Maintenance and Degradation With Arbitrary Distributions of Random Variables”, Journals of Reliability and Statistical Studies:, ISSN 0974-8024, Vol. 7, pp. 77–88.

3. Choudhary, A., Neeraj & Kumar, K. (2010). “Profit Analysis of a Complex System with Correlation in Time to Preventive Maintenance and Time Taken in Preventive Maintenance”, Journal of Reliability and Statistical Studies, Vol. 3 (1), ISSN 0974-8024, pp. 95-103.

4. Bhardwaj, R. K., Kour, K. & Malik S. C. (2015). “Stochastic Modeling of a System with Maintenance and Replacement of Standby Subject to Inspection”, Americal Journal of Theoretical and Applied Statistics, Vol. 4 (5), ISSN 2326-9006, pp. 339-346.

5. Liu. R. and Liu, Z. (2011). “Reliability Analysis of a One-Unit System with Finite Vacations”, Management Science Industrial Engineering (MSIE) International Conference, pp. 248-252.

6. Kumar, R., Poonia, M. & Goel, P. (2016). “Availability Analysis of Two Unit System with Warm Standby having Imperfect Switch over System using RPGT”,

International Journal of Applied Research, ISSN 2394-5869, Vol. 2 (6), pp. 280-288.

7. Chaudhary Nidhi, Goel P., Kumar Surender (2013). “Developing the reliability model for availability and behavior analysis of a distillery using Regenerative Point Graphical Technique”, IJIFR, ISSN: 2347-1697, Vol. 1 (4) pp. 26-40.

8. Gupta, R., Sharma, S. & Bhardwaj, P. (2016). Cost Benefit Analysis of a Urea Fertilizer Manufacturing System Model, Journal of Statistics an Application & Probability Letters An International Journal, Vol. 3, pp. 119-132.

9. Tuteja, R. K. & Taneja, G. (1993). Profit Analysis of a One Server One Unit System with Partial Failure Subject to Random Inspection, Micro Electronic Reliability, Vol. 33 (3), ISBN 0026-2714 (93)-90019-U, pp. 319-322.

10. Ms. Rachita and Garg, D. (2016). “Transient analysis of markovian queue model with multi stage service”, Redset, pp. 264-272.

11. Kumar A., Goel P., Garg D. and Sahu A. (2017). “System Behavior Analysis in the urea fertilizer industry”, Book: Data and Analysis, Redset 2017.

---

**Corresponding Author**

**Arun Kumar***

Research Scholar, G. D. Goenka University, Gurugram, Haryana

**rnkumar535@gmail.com**