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SENSITIVITY ANALYSIS OF A POLYTUBE INDUSTRY USING RPGT TECHNIQUE

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ABSTRACT

This work uses the Regenerative Point Graphical Technique (RPGT) to calculate the reliability parameters of a polytube plant with four units. The four subsystems that make up a Polytube plant are the Mixture (A), Extruder (B), Die (C), and Cutter (D). The plant's successful operation depends on the configuration of these subsystems in sequence. Subunits are placed in parallel in units C and D, but in series in units A and B. The system fails if one of the units fails, and it operates in reduced capacity if one of the C or D units is in a decreased state. The generated conclusions are checked using numerical examples. System sensitivity is analyzed, which could help management maintain the system's many components Tables and graphs are prepared to compare and draw the conclusion.

Keywords: Polytube, RPGT

1. Introduction

Reliability analysis occupies more important issues increasingly day by day in the manufacturing plant, oil industry, engineering system, soap cakes systems. The study of the repair/failure framework is a significant component in sensitivity analysis of process industry. For the last years, several researchers have studied the system parameters of different industrial systems using various methods, and a several research papers have been published in this direction. Sensitivity analysis of polytube industries has been evaluated in this paperusing RPGT technique.The behavior of a bread plant was examined by Kumar et al. in

[2018]. In order to do a sensitivity analysis on a cold standby framework made up of two identical units with server failure and prioritized for preventative maintenance, Kumar et al. [2019] used RPGT. Two halves make up the current paper, one of which is in use and the other of which is in cold standby mode. The good and fully failed modes are the only differences between online and cold standby equipment. A case study of an EAEP manufacturing facility was examined by Rajbala et al. [2019] in their work on system modeling and analysis in 2019. A study of the urea fertilizer industry's behavior was conducted by Kumar et al. [2017]. The mathematical formulation and profit function of an edible oil refinery facility were investigated by Kumar et al. in 2017. In a paper mill washing unit, Kumar et al. [2019] investigated mathematical formulation and behavior study. Using RPGT, Agrawal et al. [2021] looked at the Reverse Osmosis Water Treatment Plant. In their study, Kumar et al. [2018] investigated a 3:4:: outstanding system plant's sensitivity analysis. PSO was used by Kumari et al. [2021] to research limited situations. Using a heuristic approach, Rajbala et al. [2022] investigated the redundancy allocation problem in the cylinder manufacturing plant.A Polytube industry consists of four subunits Mixture (A), Extruder (B), Die (C), and Cutter (D) all of which have sub-segment in the series arrangement initially, when all units are in full working state then system working full capacity, whereas unit C work in reduced state there by, the system works in reduced capacity so if anyone of units of a subsystem comes up fails from failure of that system, subsequently the failure of the entire system. Mixture (A) mixes raw material such as rising, calcium carbonate, PVC wax, and chemicals in the appropriate proportion for manufacturing pipe. Extruder (B) is consists of a heater to heat raw material at a different temperature. Die (C) is used to make different sizes of pipes. Subunit C can work in reduced State. Cutter (D) is used to cut different size of pipe. Taking failure /repair rates independent, constant and considering different probabilities, is drawn in Figure 4.1 to find Secondary, Primary, and Tertiary circuits. The problem/issues are solving using RPGT to decide framework parameters. System behavior, sensitivity analysis and cost benefit is discussed with the assistance of tables and figures.

2. Assumptions and Notations

- Repaired framework that is as good.
- The subunit may work on reduced capacity also.

A, B, C, D : Denote the subsystem is working in good condition.

C^{-}, D^{-} : Indicate reduced state of the subsystem 'C' and 'D'.

a, b, c, d : Denote the failed state.

$(0 \leq i \leq 3)$ α_i: Failure rate of subsystem A, C, B, and D respectively.

$(0 \leq i \leq 3)$ β_i: Repair rate of subsystem A, C, B, and D respectively.

3. Transition Diagram

Considering the above notations and assumptions transition diagram is presented in Fig. 1.

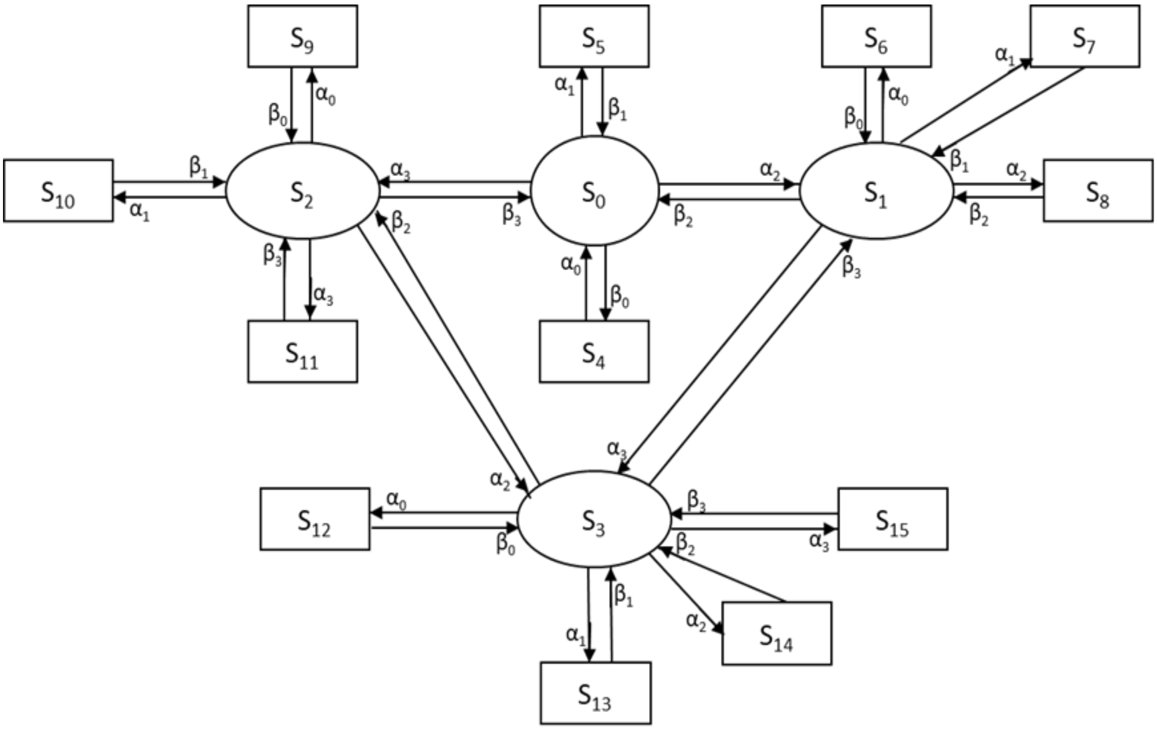

Fig. 1: Transition Diagram of System

$S_0 = ABCD$, $S_1 = AB\bar{C}D$, $S_2 = ABC\bar{D}$,

$S_3 = AB\overline{CD}$ $S_4 = aBCD$, $S_5 = AbcD$,

$S_6 = aB\bar{C}D$, $S_7 = Ab\bar{C}D$ $S_8 = ABcD$,

$S_9 = aBC\bar{D}$, $S_{10} = Abc\bar{D}$, $S_{11} = ABCd$

$S_{12} = aB\overline{CD}$, $S_{13}= Ab\overline{CD}$, $S_{14}= ABc\bar{D}$,

$S_{15} = AB\bar{c}d$

4. Transition Probabilities and Mean Sojourn Time.

p_f: Transition probabilities factor of transition. $p_{i,j}$: $p_{i,j}= q_{i,j}(t)$^* (0); where * indicates Laplace transformation. $p_{i,j.k}$: $p_{i,j.k} = q_{i,j.k}(t)$^* (0).

Table 1: Transition Probabilities

$q_{i,j}(t)$	$P_{ij} = q^*_{i,j}(0)$
$q_{0,1}(t) = \alpha_2 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3)t}$ $q_{0,2}(t) = \alpha_3 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3)t}$ $q_{0,4}(t) = \alpha_0 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3)t}$ $q_{0,5}(t) = \alpha_1 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3)t}$	$p_{0,1}= \alpha_0/(\alpha_3+\alpha_0+\alpha_1+\alpha_2)$ $p_{0,2}= \alpha_3/(\alpha_1+\alpha_3+\alpha_0+\alpha_2)$ $p_{0,4}= \alpha_0/(\alpha_0+\alpha_1+\alpha_3+\alpha_2)$ $p_{0,5}= \alpha_1/(\alpha_2+\alpha_0+\alpha_1+\alpha_3)$
$q_{1,0}(t) = \beta_2 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2)t}$ $q_{1,3}(t) = \alpha_3 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2)t}$ $q_{1,6}(t) = \alpha_0 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2)t}$ $q_{1,7}(t) = \alpha_1 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2)t}$ $q_{1,8}(t) = \alpha_2 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2)t}$	$p_{1,0}= \beta_2/(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2)$ $p_{1,3}= \alpha_3/(\alpha_3+\alpha_0+\alpha_2+\alpha_1+\beta_2)$ $p_{1,6}= \alpha_0/(\alpha_0+\alpha_2+\alpha_1+\alpha_3+\beta_2)$ $p_{1,7}= \alpha_1/(\alpha_0+\alpha_2+\alpha_1+\alpha_3+\beta_2)$ $p_{1,8}= \alpha_2/(\alpha_2+\alpha_1+\alpha_0+\alpha_3+\beta_2)$
$q_{2,0}(t) = \beta_3 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_3)t}$ $q_{2,3}(t) = \alpha_2 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_3)t}$ $q_{2,9}(t) = \alpha_0 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_3)t}$ $q_{2,10}(t)= \alpha_1 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_3)t}$	$p_{2,0}= \beta_3/(\alpha_0+\alpha_2+\alpha_1+\alpha_3+\beta_3)$ $p_{2,3}= \alpha_2/(\alpha_3+\alpha_2+\alpha_1+\alpha_0+\beta_3)$ $p_{2,9}= \alpha_0/(\alpha_3+\alpha_1+\alpha_0+\alpha_2+\beta_3)$ $p_{2,10}= \alpha_1/(\alpha_2+\alpha_1+\alpha_0+\alpha_3+\beta_3)$ $p_{2,11}= \alpha_3/(\alpha_0+\alpha_3+\alpha_2+\alpha_1+\beta_3)$

$q_{2,11}(t)= \alpha_3 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_3)t}$	
$q_{3,1}(t) = \beta_3 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2+\beta_3)t}$ $q_{3,2}(t) = \beta_2 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2+\beta_3)t}$ $q_{3,12}(t)= \alpha_0 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2+\beta_3)t}$ $q_{3,13}(t)= \alpha_1 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2+\beta_3)t}$ $q_{3,14}(t)= \alpha_2 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2+\beta_3)t}$ $q_{3,15}(t)= \alpha_3 e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2+\beta_3)t}$	$p_{3,1}= \beta_3/(\alpha_2+\alpha_1+\alpha_0+\alpha_3+\beta_3+\beta_2)$ $p_{3,2}= \beta_2/(\alpha_0+\alpha_3+\alpha_2+\alpha_1+\beta_3+\beta_2)$ $p_{3,12}= \alpha_0/(\alpha_0+\alpha_1+\alpha_3+\alpha_2+\beta_3+\beta_2)$ $p_{3,13}= \alpha_1/(\alpha_1+\alpha_1+\alpha_0+\alpha_3+\beta_3+\beta_2)$ $p_{3,14}= \alpha_2/(\alpha_0+\alpha_2+\alpha_1+\alpha_3+\beta_3+\beta_2)$ $p_{3,15}= \alpha_3/(\alpha_2+\alpha_1+\alpha_0+\alpha_3+\beta_3+\beta_2)$
$q_{4,0}(t)= \beta_0 e^{-\beta_0 t}$	$p_{4,0}= 1$
$q_{5,0}(t)= \beta_1 e^{-\beta_1 t}$	$p_{5,1}= 1$
$q_{6,1}(t)= \beta_0 e^{-\beta_0 t}$	$p_{6,1}= 1$
$q_{7,1}(t)= \beta_1 e^{-\beta_1 t}$	$p_{7,1}= 1$
$q_{8,1}(t)= \beta_2 e^{-\beta_2 t}$	$p_{8,1}= 1$
$q_{9,2}(t)= \beta_0 e^{-\beta_0 t}$	$p_{9,2}= 1$
$q_{10,2}(t)=\beta_1 e^{-\beta_1 t}$	$p_{10,2}= 1$
$q_{11,2}(t)=\beta_3 e^{-\beta_3 t}$	$p_{11,2}= 1$
$q_{12,3}(t)=\beta_0 e^{-\beta_0 t}$	$p_{12,3}= 1$
$q_{13,3}(t)=\beta_1 e^{-\beta_1 t}$	$p_{13,3}= 1$
$q_{14,3}(t)=\beta_2 e^{-\beta_2 t}$	$p_{14,3}= 1$
$q_{15,3}(t)=\beta_3 e^{-\beta_3 t}$	$p_{15,3}= 1$

Mean Sojourn Time

At various verses these are given in table 2

Table 2: Mean Sojourn Time

$R_i(t)$	$\mu_i = R_i^*(0)$
$R_0(t) = e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3)t}$	$\mu_0 = 1/(\alpha_0+\alpha_1+\alpha_2+\alpha_3)$
$R_1(t) = e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2)t}$	$\mu_1 = 1/(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2)$
$R_2(t) = e^{-(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_3)t}$	$\mu_2 = 1/(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_3)$
$R_3(t) = e^{-((\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2+\beta_3))t}$	$\mu_3 = 1/(\alpha_0+\alpha_1+\alpha_2+\alpha_3+\beta_2+\beta_3)$
$R_4(t) = e^{-\beta_0 t}$	$\mu_4 = 1/\beta_0$
$R_5(t) = e^{-\beta_1 t}$	$\mu_5 = 1/\beta_1$
$R_6(t) = e^{-\beta_0 t}$	$\mu_6 = 1/\beta_0$
$R_7(t) = e^{-\beta_1 t}$	$\mu_7 = 1/\beta_1$
$R_8(t) = e^{-\beta_2 t}$	$\mu_8 = 1/\beta_2$
$R_9(t) = e^{-\beta_0 t}$	$\mu_9 = 1/\beta_0$
$R_{10}(t) = e^{-\beta_1 t}$	$\mu_{10} = 1/\beta_1$
$R_{11}(t) = e^{-\beta_3 t}$	$\mu_{11} = 1/\beta_3$
$R_{12}(t) = e^{-\beta_0 t}$	$\mu_{12} = 1/\beta_0$
$R_{13}(t) = e^{-\beta_1 t}$	$\mu_{13} = 1/\beta_1$
$R_{14}(t) = e^{-\beta_2 t}$	$\mu_{14} = 1/\beta_2$
$R_{15}(t) = e^{-\beta_3 t}$	$\mu_{15} = 1/\beta_3$

5. Path probabilities

The various transition probabilities/likelihood factors of reachable states from base states are below.

$V_{0,0} = 1$

$V_{0,1} = (0, 1)/ (Z_2(Z_1)(Z_3)[(Z_4)/(Z_7)(Z_6)(Z_5)(Z_8)\{(Z_9)/(Z_{12})(Z_{11})(Z_{10})\}] + (0, 2, 3, 1)/$

$(Z_4)(Z_1)(Z_3)[(Z_2)/ (Z_5)(Z_7)(Z_6)(Z_8)\{(Z_9)/(Z_{10})(Z_{11})(Z_{12})\}](Z_{10})(Z_{11})(Z_{12})[(Z_{13})/$

$(Z_5)(Z_6)(Z_7)(Z_8)\{(Z_{14})/ (Z_1)(Z_2)(Z_3)\}](Z_5)(Z_6)(Z_7)(Z_8)\{(Z_9) [(Z_{14})/ (Z_1)(Z_2)(Z_3)]$

$[(Z_9)/ (Z_{10})(Z_{11})(Z_{12})]$

$V_{0,2}$ = ………Continuous

6. Results

MTSF (T_0): The regenerative un-fizzled states in which framework can transit from state '0', Preceding any fizzled state are: 'j' = 0 taking 'ξ' = 0.

$$\text{MTSF }(T_0) = \left[\sum_{i,sr}\left\{\frac{\left\{pr\left(\xi\xrightarrow{sr\,(sff)} i\right)\right\}\mu i}{\Pi_{m_{1\neq\xi}}\{1-V_{\overline{m_1 m_1}}\}}\right\}\right] \div \left[1-\sum_{sr}\left\{\frac{\left\{pr\left(\xi\xrightarrow{sr\,(sff)}\xi\right)\right\}}{\Pi_{m_{2\neq\xi}}\{1-V_{\overline{m_2 m_2}}\}}\right\}\right]$$

$T_0 = V_{0,0}\,\mu_0 = [1/ (\alpha_0 + \alpha_1 + \alpha_2 + \alpha_3)]$

Availability of the System (A_0): The states in which framework is accessible are 'j' = 0 ≤ j ≤ 3 and regenerative state are 'i' = 0 ≤ i ≤ 15 taking 'ξ' = 0 the all-out portion of time for which framework is accessible is given by

$$A_0 = \left[\sum_{j,sr}\left\{\frac{\{pr\,(\xi^{sr}\rightarrow j)\}fj,\mu j}{\Pi_{m_{1\neq\xi}}\{1-V_{\overline{m_1 m_1}}\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\{pr\,(\xi^{sr}\rightarrow i)\}\mu_i^1}{\Pi_{m_{2\neq\xi}}\{1-V_{\overline{m_2 m_2}}\}}\right\}\right]$$

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

$= (V_{0,j}\,\mu_j)/ D;\ (0 \le j \le 3)$

Where $D = (V_{0,0}\,\mu_0);\ (0 \le i \le 15)$

Server of the Busy Period (B_0): The states in which server is busy are 'j'= 1≤ j ≤ 15 and 'i' = 0 ≤ i ≤ 15 taking 'ξ' = 0, total fraction of time for server is busy

$$B_0 = \left[\sum_{j,sr}\left\{\frac{\{pr\,(\xi^{sr}\rightarrow j)\},nj}{\Pi_{m_{1\neq\xi}}\{1-V_{\overline{m_1 m_1}}\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\{pr\,(\xi^{sr}\rightarrow i)\}\mu_i^1}{\Pi_{m_{2\neq\xi}}\{1-V_{\overline{m_2 m_2}}\}}\right\}\right]$$

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

$B_0 = (V_{0,j}\,\mu_j)/ D;\ (1 \le j \le 15)$

Expected Fractional Number of Inspections by repairman (V_0): The states where repairman do this job 'j' = 4 ≤ j ≤ 15 and 'i' = 0 ≤ i ≤ 15; is given by

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$$V_0 = \left[\sum_{j,sr}\left\{\frac{\{pr\,(\xi^{sr}\rightarrow j)\}}{\Pi_{k_{1\neq\xi}}\left\{1-V_{\overline{k_1 k_1}}\right\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\{pr\,(\xi^{sr}\rightarrow i)\}\mu_i^1}{\Pi_{k_{2\neq\xi}}\left\{1-V_{\overline{k_2 k_2}}\right\}}\right\}\right]$$

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

$$V_0 = (V_{0,\,j})/\,D;\ (4 \leq j \leq 15)$$

7. Sensitivity Analysis

Furthermore, the above following paragraphs depict two sensitivity analysis scenarios and corresponding results in tabular and graphical forms analyzed.

Scenario1: Sensitivity analysis with respect to change in repair rates**.** Taking, $\alpha_i = 0.10$ $(0 \leq i \leq 3)$ and varying β_i one by one respectively at 0.85, 0.90, 0.95, 1.00

Mean Time to System Failure (T_0)

Table 3: Mean Time to System Failure (T_0)

β_i	β_0	β_1	β_2	β_3
0.85	2.50	2.50	2.50	2.50
0.90	2.50	2.50	2.50	2.50
0.95	2.50	2.50	2.50	2.50
1.00	2.50	2.50	2.50	2.50

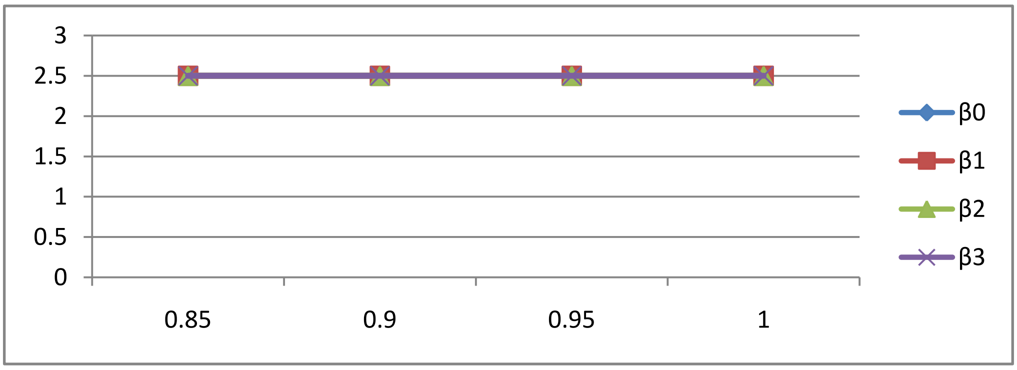

Fig. 2: Mean Time to System Failure

MTSF is fairly very large i.e., 2.50, and is independent of repair rates of units.

Availability of the System (A_0)

Table 4: Availability of the System (A_0)

β_i	β_0	β_1	β_2	β_3
0.85	0.79869	0.79484	0.77543	0.77001
0.90	0.80695	0.79869	0.78285	0.78905
0.95	0.80754	0.80215	0.79869	0.79345
1.00	0.81731	0.80530	0.80453	0.79869

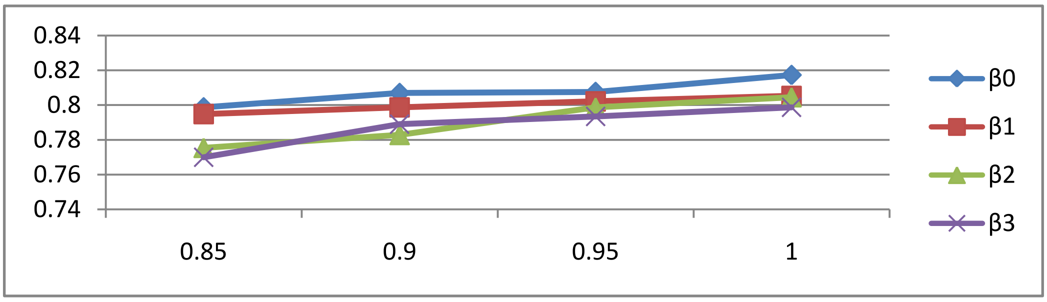

Fig. 3: Availability of the System

Table 4 and fig. 3, it concluded that availability is maximum when the repair rate of unit 'A' is maximum in comparison to the repair rate of other units.

Server of the Busy Period (B_0)

Table 5: Server of the Busy Period (B_0)

β_i	β_0	β_1	β_2	β_3
0.85	0.33950	0.34268	0.34818	0.35642
0.90	0.33267	0.33950	0.34402	0.34970
0.95	0.33218	0.33663	0.33950	0.34293
1.00	0.32102	0.33404	0.33344	0.33950

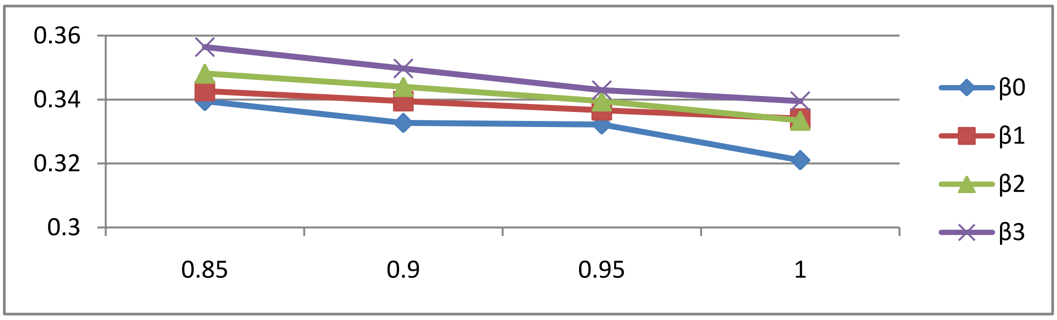

Fig. 4: Server of the Busy Period

Expected Fractional Number of Inspections by Repairman (V_0)

Table 6: Expected Fractional Numbers of Inspections by Repairman (V_0)

β_i	β_0	β_1	β_2	β_3
0.85	0.17718	0.17587	0.17612	0.17600
0.90	0.17801	0.17718	0.17678	0.17613
0.95	0.17868	0.17749	0.17718	0.17698
1.00	0.17970	0.17819	0.17773	0.17718

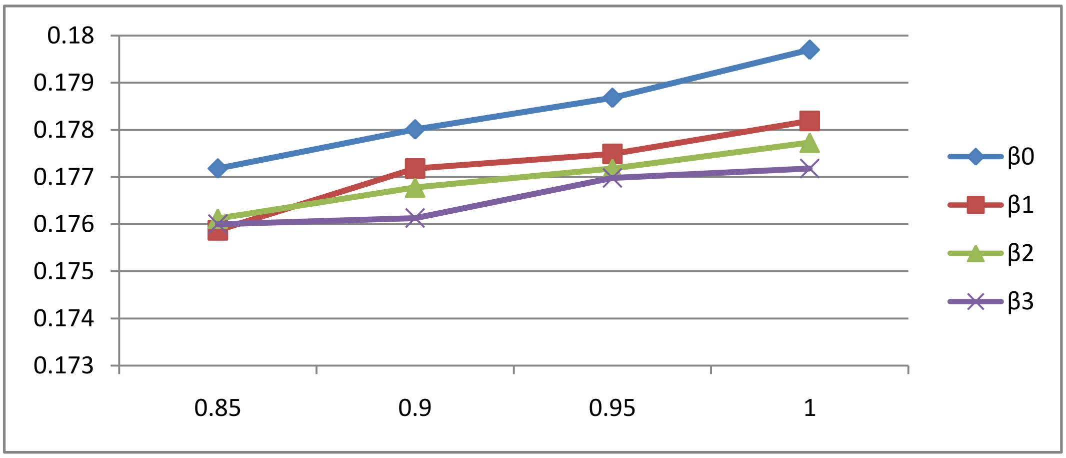

Fig. 5:Expected Fractional Number of Inspections by the Repairman

From table 6 and graph, 5 shows that the values in columns, while going from top to bottom, conclude that the proportional V_0 is minimal. When the repair rate of unit 'D' is minimal compared to repair rates of other units, more care should be taken for repairing unit D over the other units.

Scenario2: Now consider the sensitivity analysis scenario 2 with respect to change in failure rates: taking, $\beta_i = 0.80$ $(0 \le i \le 3)$ and varying α_0, α_1, α_2, α_3 one by one respectively at 0.10, 0.15, 0.20, 0.25.

Mean Time to System Failure (T_0)

Table 7: Mean Time to System Failure (T_0)

α_i	α_0	α_1	α_2	α_3
0.10	1.42857	1.53846	1.66666	1.81818
0.15	1.33333	1.42857	1.53846	1.66666
0.20	1.25000	1.33333	1.42857	1.53846
0.25	1.17647	1.25000	1.33333	1.42857

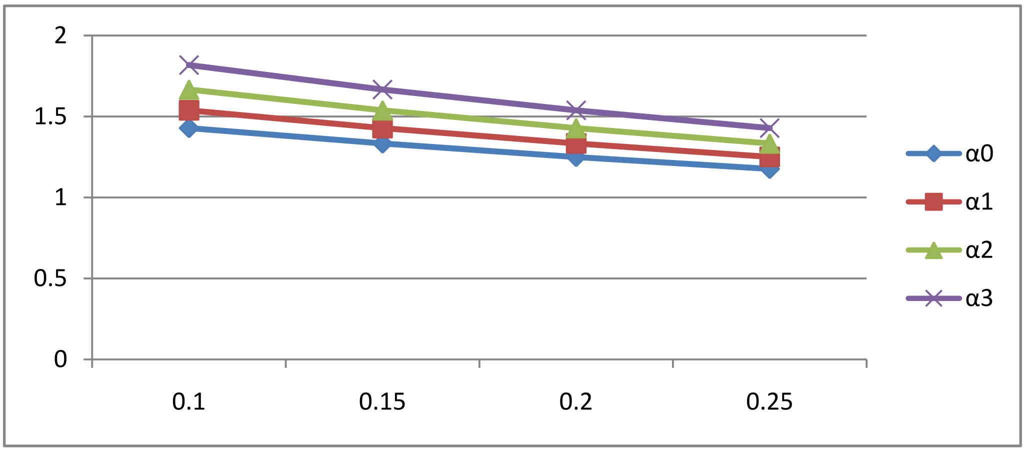

Fig. 6: Mean Time to System Failure

It concluded that MTSF is Maximum when failure rate unit 'D' is minimum, and MTSF is Minimum when the failure rate of Mixture unit 'A' is Maximum. Hence, having an optimum value of the MTSF failure rate of 'D' should be kept minimal compared to the failure rates of other units.

Availability of the System (A_0)

Table 8: Availability of the System (A_0)

α_i	α_0	α_1	α_2	α_3
0.10	0.67849	0.71033	0.69124	0.73970
0.15	0.65058	0.67846	0.68754	0.71706
0.20	0.61287	0.65818	0.67846	0.69430
0.25	0.58691	0.63252	0.66563	0.67846

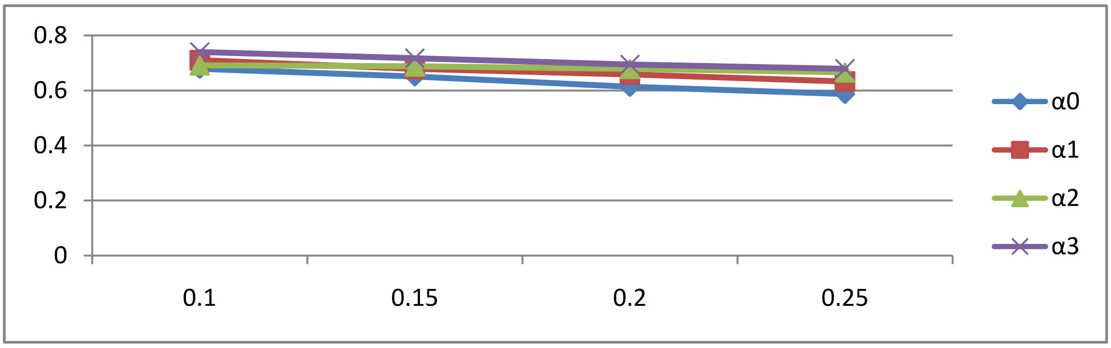

Fig. 7: Availability of the System

The above table and fig. 7, it is concluded that availability is Maximum when the failure rate of unit D is Minimum, and its value is 0.73970. Its minimum value is 0.59691, corresponding to the highest value of the failure rate of unit A.

Server of the Busy Period (B_0)

Table 9: Server of the Busy Period (B_0)

α_i	α_0	α_1	α_2	α_3
0.10	0.57149	0.55398	0.52679	0.49301
0.15	0.58675	0.57149	0.54418	0.51914
0.20	0.61057	0.58001	0.57149	0.54225
0.25	0.63041	0.59315	0.59706	0.57149

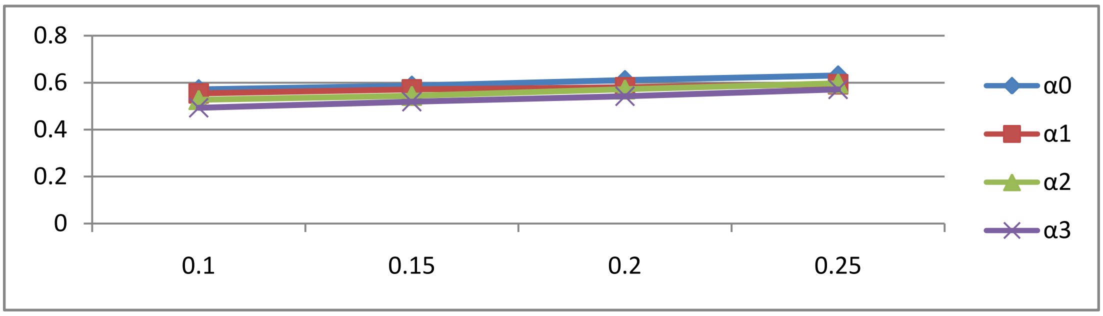

Fig. 8: Server of the Busy Period

Table 9, shows that the busy period decreases with the increase in failure rates of units and is Minimum hence the failure rate of unit D is Minimum in comparison to the failure rates of other units.

Expected Fractional Number of Inspections by Repairman (V_0)

Table 10: Expected Fractional Number of Inspections by Repairman (V_0)

α_i	α_0	α_1	α_2	α_3
0.10	0.25723	0.23174	0.21830	0.21217
0.15	0.27954	0.25723	0.23526	0.23709
0.20	0.30971	0.32914	0.25723	0.24456
0.25	0.34604	0.37324	0.26750	0.25723

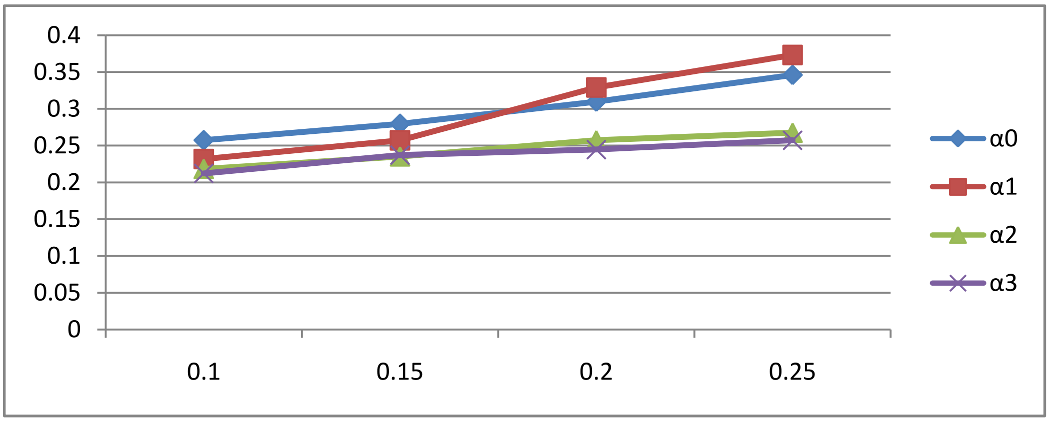

Fig. 9: Expected Fractional Number of Inspections by Repairman

8. Conclusion:

The practically busy period should be decreased with an increase in the units' repair rates, which is shown in table 5 and fig. 4. A server of busy period is Minimum when the repair rate of system 'A' is 1, and the minimum value is 0.32102. A server of busy period is Maximum when the Cutter unit repair rate in comparison to other units; hence repairman should be efficient in repairing the Cutter unit. If the repair rates are the lowest, the server will have to be busier to fix the problem. Hence the server will take more time to repair the units from the above table and graph. While observing from top to bottom in columns, one sees that the server of busy period decreases, which is practical trend in almost all simulations above the graph and verifies the similar results.There is no significant change in the value of V0 due to an increase in the values of the units' failure rates but is minimum when the failure rate or unit D is minimum compared to the failure rates of other units.

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