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Mathematical Modeling and Behavior Analysis of a Rice Plant Using RPGT

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Abstract: - In this paper we describe a Rice plant which comprises of four subsystems. The Rice Plant basically comprises of four subsystems specifically Cleaning, Husking, Separation, and Elevator. Cleaning has two sub-units. At first cleaning dries the crud material (paddy) and places it into the husker. Husking is utilized to strip off husk from the paddy. Separation isolates rice and husk. At that point polishing shines the rice for example it strip off bran from the rice. Elevator is utilized to review the rice for example to isolate the long grain and short grain. Then with the assistance of whitening black rice are isolated from evaluated rice. A single repairman who examines and repairs the units as and when need emerge. Availability of rice plant is determined with the assistance of RPGT and accessibility of the arrangement of rice plant for various values of repair and failure rates of subsystems is additionally determined. Profit optimization is also examined. System behavior is discussed with the help of graphs and tables.

Keywords:-Availability, Base-State, MTSF, Steady State.

1. Introduction:

Rice plant is the most established and the biggest agro handling industry. Rice is the fundamental food crop and being a tropical plant, flourishes easily in warm and sticky environment. India is one of the world's biggest makers of white rice, representing 20% of entire world creation and it is the staple nourishment for 65% of the population in India. Rice is India's transcendent yield, and is the staple food of individuals of the eastern and southern parts of country. India is the second biggest maker of rice on the planet close to China, and is likewise one of the main exporters of rice on the planet market. Indian Basmati rice has been a top pick among worldwide rice purchasers. Indian rice is getting exceptionally aggressive and has been distinguished as one of the significant items for send out. It is one of the central grains of India. That is the reason rice plants assume significant part for the individual. So reliability engineers, maker and government leaders should guarantee high profitability, stable activity of rice plants. Processing is a critical advance in after creation of rice. The fundamental goal of a rice processing framework is to eliminate the husk and the wheat layers, and produce palatable white rice that is adequately processed and liberated from pollutions. An exertion has been made in this section to do the performance analysis of a rice plant situated in Hisar, India. Kumar, A. and Garg, D.[2019] have discussed the reliability technology theory and its applications. Kumar, A., Goel, P. and Garg, D. [2018] have studied behaviour analysis of a bread making system. Kumar, A., et. al. [2019] analyzed sensitivity analysis of a cold standby framework with priority for preventive maintenance consist two identical units with server failure utilizing RPGT. Present paper consists two units one of which is online while other is kept is cold standby mode. Online & cold standby unit are indistinguishable in nature & have just two modes one is good and other is totally failed. Rajbala, et al. [2019] have studied the system modeling and analysis: a case study EAEP manufacturing plant.Kumar, A., Goel, P., Garg, D., and Sahu, A. [2017] have studied behavior analysis in the urea fertilizer industry. Kumar, A., Garg, D., and Goel, P. [2017] have examined the mathematical modeling & profit analysis of an edible oil refinery plant. Kumar, A., Garg, D., and Goel, P. [2019] studied mathematical modeling & behavioral analysis of a washing unit in paper mill. Kumar, A et. al. [2018] paper analyzed sensitivity analysis of 3:4:: good system plant.

This paper further presents the time dependent and consistent state accessibility when failure and repair rates are variable and steady individually. The mathematical problem along these lines created has additionally been solved systematically and numerically for few decisions of the failure/repair rates of subsystems. A solitary worker who inspects and repairs the units as and when need emerge. Fuzzy concept is utilized to decide disappointment conditions of a unit. Assuming the worker report, that unit isn't repairable; it is supplanted by another one. Taking failure rates dramatic, repair rates general and contemplating different probabilities, a transition diagram of system is created to decide Primary, Secondary & Tertiary circuits and Base state. Problem is defined and solved utilized RPGT. Repair/Failure is statistically independent. Expressions for system parameters for example MTSF, availability, number of server visits and server of busy period are assessed to consider the behavior of the framework for steady state. System behavior is discussed with the assistance of graphs and tables.

2. System Description

The rice plant consists of following four sub-systems.

Elevator (E): Elevator is upward vehicle equipment that productively moves individuals or goods b/w floors (levels, decks of a structure, vessel or different designs). Elevators are for the most part controlled by electric engines that either drive traction cables and stabilizer frameworks like a crane, or siphon water liquid to raise a cylindrical piston like a jack.

Cleaning (C): The capacity of cleaner is to eliminate all debasements and unfilled grains from paddy. These are two indistinguishable sub-units working in equal. This unit can work with one unit in diminished limit. They are

1. **Whitening (W):** The capacity of whitening unit is to eliminate all or some portion of the wheat layer and germ from earthy colored rice.
2. **Polishing (L):** This subsystem improves presence of processed rice by eliminating excess grain particles & by cleaning the outside of processed portion.

Husking (H): This subsystem eliminates husk from paddy. Disappointment of this subsystem causes the total disappointment of the framework.

Separation (S): This subsystem isolates the husked paddy from wheat rice. Disappointment of the subsystem causes the total disappointment of the framework.

3. Assumptions and Notations

1. Switching over is imperfect.
2. A single repairman is available 24*7.
3. The framework is argued under steady state condition's.

λ_1 : Constant failure rate of the unit 'E' from full capacity to complete failure.

λ_2: Constant failure rate of the standby 'C'; λ_3: Constant failure rate of the unit 'H'.

θ_1: Constant repair rate of main unit; θ_2: Constant repair rate of standby.

θ_3: Constant repair rate of unit 'H'; θ_4: Constant repair rate of the switch.

E/e: Unit 'A' in good / failed state.

C/ (C)//c: Redundant unit in operative/ standby / failed state.

H / h : Unit 'C' in operative / failed state

S/s: Switch in operative/ failed state.

4. Transition Diagram of the System:

S_1 = E(C)HS; S_2 = e(C)Hs; S_3 = e(C)HS; S_4 = E(C)hS; S_5 =E(C)Hs

S_6 = e(C)hS; S_7 = EcHs; S_8 = ecHS; S_9 = EcHS; S_{10} = EchS

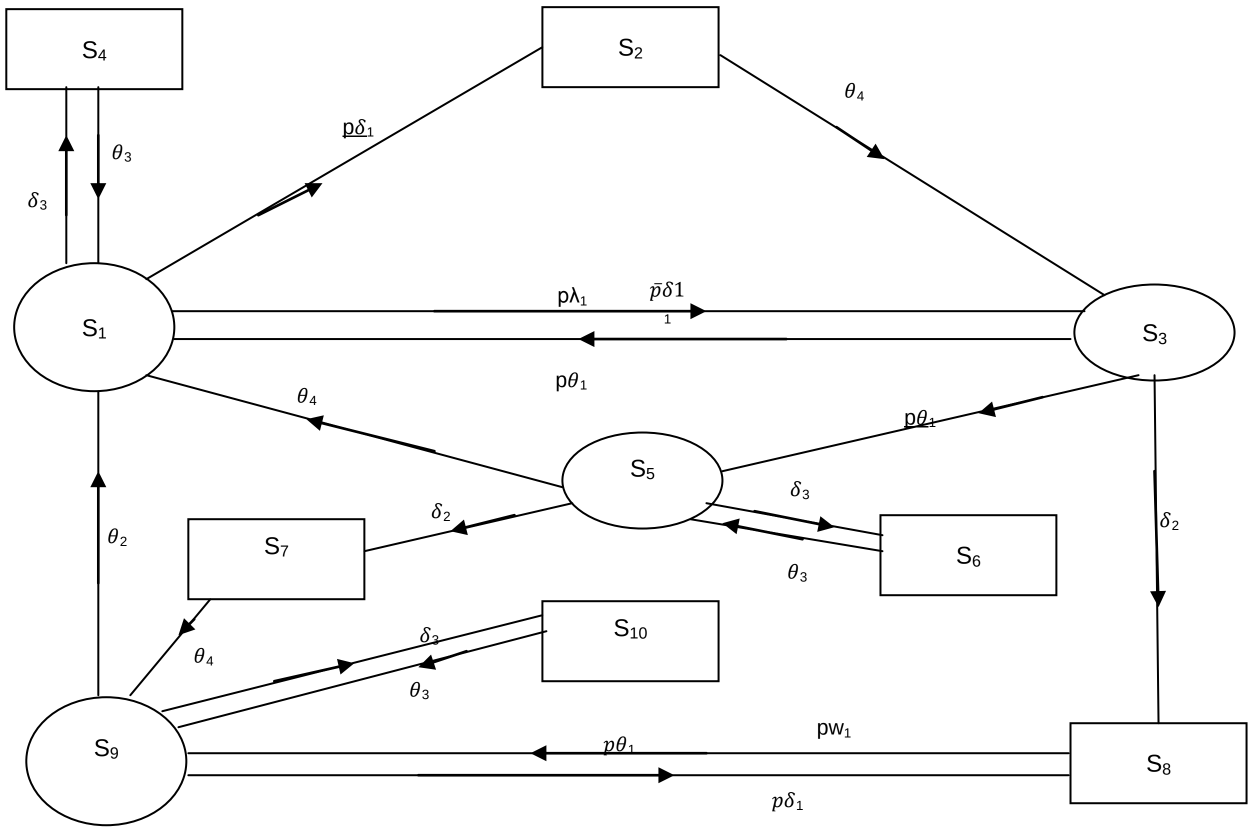

Figure 3.1 Transition Diagrams

State	Symbol
Up-state	○
Failed State	▭
Reduced State	⬭

Table 15. Transition Probabilities and Mean Sojourn Times:

Table: 2 Transition Probabilities

$q_{i,j}(t)$	$p_{i,j}=q_{i,j}^*(0)$
$q_{1,2}=p\delta_1 e^{-(p\delta_1+\bar{p}\delta_1+\delta_3)t}$ $q_{1,3}=\bar{p}\delta_1 e^{-(p\delta_1+\bar{p}\delta_1+\delta_3)t}$ $q_{1,4}=\delta_3 e^{-(p\delta_1+\bar{p}\delta_1+\delta_3)t}$	$p_{1,2}=p\delta_1/(p\delta_1+\bar{p}\delta_1+\delta_3)$ $p_{1,3}=\bar{p}\delta_1/(p\delta_1+\bar{p}\delta_1+\delta_3)$ $p_{1,4}=\delta_3/(p\delta_1+\bar{p}\delta_1+\delta_3)$
$q_{2,1}=\bar{p}\delta_1 e^{-(\bar{p}\delta_1+\theta_4)t}$ $q_{2,3}=\theta_4 e^{-(\bar{p}\delta_1+\theta_4)t}$	$p_{2,1}=\bar{p}\delta_1/(\bar{p}\delta_1+\theta_4)$ $p_{2,3}=\theta_4/(\bar{p}\delta_1+\theta_4)$
$q_{3,1}=p\theta_1 e^{-(p\theta_1+\bar{p}\theta_1+\delta_1)t}$ $q_{3,5}=\bar{p}\theta_1 e^{-(p\theta_1+\bar{p}\theta_1+\delta_1)t}$ $q_{3,8}=\delta_2 e^{-(p\theta_1+\bar{p}\theta_1+\delta_2)t}$	$p_{3,1}=p\theta_1/(p\theta_1+\bar{p}\theta_1+\delta_2)$ $p_{3,5}=\bar{p}\theta_1/(p\theta_1+\bar{p}\theta_1+\delta_2)$ $p_{3,8}=\delta_2/(p\theta_1+\bar{p}\theta_1+\delta_2)$

$q_{4,1} = \theta_3 e^{-(\theta_3)t}$	$p_{4,1} = 1$
$q_{5,1} = \theta_4 e^{-(\theta_4+\delta_3+\delta_2)t}$ $q_{5,6} = \delta_3 e^{-(\theta_4+\delta_3+\delta_2)t}$ $q_{5,7} = \delta_2 e^{-(\theta_4+\delta_3+\delta_2)t}$	$p_{5,1} = \theta_4/(\theta_4 + \delta_3 + \delta_2)$ $p_{5,6} = \delta_1/(\theta_4 + \delta_3 + \delta_2)$ $p_{5,7} = \delta_2/(\theta_4 + \delta_3 + \delta_2)$
$q_{6,5} = \theta_3 e^{-(\theta_3)t}$	$p_{6,5} = 1$
$q_{7,9} = \theta_4 e^{-(\theta_4)t}$	$p_{7,9} = 1$
$q_{8,9} = p\delta_3 e^{-(p\delta_3)t}$	$p_{8,9} = 1$
$q_{9,1} = \theta_2 e^{-(\theta_2+p\delta_1+\delta_3)t}$ $q_{9,8} = p\delta_1 e^{-(\theta_2+p\delta_1+\delta_3)t}$ $q_{9,10} = \delta_3 e^{-(\theta_2+p\delta_1+\delta_3)t}$	$p_{9,1} = \theta_2/(\theta_2 + p\delta_1 + \delta_3)$ $p_{9,8} = p\delta_1/(\theta_2 + p\delta_1 + \delta_3)$ $p_{9,10} = \delta_3/(\theta_2 + p\delta_1 + \delta_3)$
$q_{10,9} = \theta_3 e^{-(\theta_3)t}$	$p_{10,9} = 1$

Table: 3 Mean Sojourn Times

R_i(t)	μ_i=R_i*(0)
R_1(t) = $e^{-(p\delta_1+\bar{p}\delta_1+\delta_3)t}$	μ_1=1/($p\delta_1 + \bar{p}\delta_1 + \delta_3$)
R_2(t) = $e^{-(\bar{p}\delta_1+\theta_4)t}$	μ_2=1/($\bar{p}\delta_1 + \theta_4$)
R_3(t) = $e^{-(p\theta_1+\bar{p}\theta_1+\delta_2)t}$	μ_3=1/($p\theta_1 + \bar{p}\theta_1 + \delta_2$)
R_4(t) = $e^{-(\theta_3)t}$	μ_4=1/(θ_3)
R_5(t) = $e^{-(\theta_4+\delta_3+\delta_2)t}$	μ_5=1/($\theta_4 + \delta_3 + \delta_2$)
R_6(t) = $e^{-(\theta_3)t}$	μ_6=1/(θ_3)
R_7(t) = $e^{-(\theta_4)t}$	μ_7=1/(θ_4)
R_8(t) = $e^{-(p\delta_3)t}$	μ_8=1/($p\delta_3$)
R_9(t) = $e^{-(\theta_2+p\delta_1+\delta_3)t}$	μ_9=1/($\theta_2 + p\delta_1 + \delta_3$)
R_{10}(t) = $e^{-(\theta_3)t}$	μ_{10}=1/(θ_3)

6. Transition Probability Factors: - The mean time to system failure and all the key parameters of the system (under steady state conditions) are evaluated by using Regenerative Point Graphical Technique (RPGT) and using '0' as the base state of the system as under: -

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

$V_{1,2}$= (1, 2) = $p_{1,2}$

$V_{1,3}$= …… continued

7. Evaluation of Parameters: - The MTSF and all key parameters of the framework are estimated by applying RPGT taking '0' as base state.

(a) MTSF (T_0): The regenerative un-failed states to which the framework can transit (Initial state '1') before entering any failed state are: for 'ξ' = '1',

$$\text{MTSF }(T_0) = \left[\sum_{i,s_r}\left\{\frac{\left\{pr\left(\xi\xrightarrow{s_r(s_{ff})}i\right)\right\}\mu_i}{\prod_{m_1\neq\xi}\{1-V_{\overline{m_1,m_1}}\}}\right\}\right] \div \left[1-\sum_{s_r}\left\{\frac{\left\{pr\left(\xi\xrightarrow{s_r(s_{ff})}\xi\right)\right\}\mu_i^1}{\prod_{m_2\neq\xi}(1-V_{\overline{m_2,m_2}})}\right\}\right]$$

$= [(1, 1)\mu_1 + (1, 2)\mu_2 + (1, 2, 3)\mu_3 + (1, 3)\mu_4 + (1, 3,5)\mu_5 + (1, 2, 3,5)\mu_6]/$

[1 - (1, 3, 1) + (1, 2, 3, 1) + (1, 3, 5, 1) + (1, 2, 3, 5, 1)

$= [\mu_1 + p_{1,2}\mu_2 + p_{1,2}p_{2,3}\mu_3 + p_{1,3}\mu_4 + p_{1,3}p_{3,5}\mu_5 + p_{1,2}p_{2,3}p_{3,5}\mu_6]/$

$[1-(p_{1,3}p_{3,1}) + (p_{1,2}p_{2,3}p_{3,1}) + (p_{1,3}p_{3,5}p_{5,1}) + (p_{1,2}p_{2,3}p_{3,5}p_{5,1})]$

(b) Availability of the System (A_0): The regenerative states at which the framework is available are j=1, 3,5,9 and regenerative states are i= 1 to 10 for 'ξ'='1',

$$A_0 = \left[\sum_{j,s_r}\left\{\frac{\left\{pr\left(\xi\xrightarrow{s_r}j\right)\right\}f_j\mu_j}{\prod_{m_1\neq\xi}\{1-V_{m_1,m_1}\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\left\{pr\left(\xi\xrightarrow{s_r}i\right)\right\}}{\prod_{m_2\neq\xi}(1-V_{m_2,m_2})}\right\}\right]$$

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

$=[V_{1,1}f_1\mu_1 + V_{1,3}f_3\mu_3 + V_{1,5}f_5\mu_5 + V_{1,9}f_9\mu_9] \div [V_{1,3}\mu_3^1 + V_{1,1}\mu_1^1 + V_{1,2}\mu_2^1 + V_{1,4}\mu_4^1$

$+V_{1,5}\mu_5^1 + V_{1,6}\mu_6^1 + V_{1,7}\mu_7^1 + V_{1,8}\mu_8^1 + V_{1,9}\mu_9^1 + V_{1,10}\mu_{10}^1]$

$=[V_{1,1}\mu_1 + V_{1,3}\mu_3 + V_{1,5}\mu_5 + V_{1,9}\mu_9] \div D$

$D = [V_{1,1}\mu_1 + V_{1,2}\mu_2 + V_{1,3}\mu_3 + V_{1,4}\mu_4 + V_{1,5}\mu_5 + V_{1,6}\mu_6 + V_{1,7}\mu_7 + V_{1,8}\mu_8 + V_{1,9}\mu_9 + V_{0,10}\mu_{10}]$

(c) Busy Period of the Server (B_0): The regenerative states where the server is busy while doing repairs are j = 2 to 10

$$B_0 = \left[\sum_{j,s_r}\left\{\frac{\left\{pr\left(\xi\xrightarrow{s_r}j\right)\right\}n_j}{\prod_{m_1\neq\xi}\{1-V_{m_1,m_1}\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\left\{pr\left(\xi\xrightarrow{s_r}i\right)\right\}\mu_i^1}{\prod_{m_2\neq\xi}(1-V_{m_2,m_2})}\right\}\right]$$

$B_0 = (V_{1,2}n_2 + V_{1,3}n_3 + V_{1,4}n_4 + V_{1,5}n_5 + V_{1,6}n_6 + V_{1,7}n_7 + V_{1,8}n_8 + V_{1,9}n_9 + V_{1,10}n_{10})/D$

$D = [V_{1,1}\mu_1 + V_{1,2}\mu_2 + V_{1,3}\mu_3 + V_{1,4}\mu_4 + V_{1,5}\mu_5 + V_{1,6}\mu_6 + V_{1,7}\mu_7 + V_{1,8}\mu_8 + V_{1,9}\mu_9 + V_{0,10}\mu_{10}]$

(d) Expected number of server's visits (V_0): The regenerative state to which server visits a fresh are j=2, 3, 4 and the regenerative states are j=0 to 10.

$$V_0 = \left[\sum_{j,s_r}\left\{\frac{\left\{pr\left(\xi\xrightarrow{s_r}j\right)\right\}}{\prod_{k_1\neq\xi}\{1-V_{k_1,k_1}\}}\right\}\right] \div \left[\sum_{i,s_r}\left\{\frac{\left\{pr\left(\xi\xrightarrow{s_r}i\right)\right\}\mu_i^1}{\prod_{k_2\neq\xi}(1-V_{k_2,k_2})}\right\}\right]$$

$V_0 = (V_{1,2} + V_{1,3} + V_{1,4})/D$

$D = [V_{1,1}\mu_1 + V_{1,2}\mu_2 + V_{1,3}\mu_3 + V_{1,4}\mu_4 + V_{1,5}\mu_5 + V_{1,6}\mu_6 + V_{1,7}\mu_7 + V_{1,8}\mu_8 + V_{1,9}\mu_9 + V_{0,10}\mu_{10}]$

8. **Particular Cases**: -

For $\delta_i = \delta\,; 1 \le i \le 3; \theta_i = \theta_; 1 \le i \le 4;$ p = 1, p = 0,

9.Analytical Discussion:

Mean Time to System Failure (T_0):-

Table 4: MTSF

$\delta\theta$	0.50	0.60	0.70
0.10	2.43	2.30	2.34
0.20	2.23	2.17	2.12
0.30	2.04	1.92	1.81

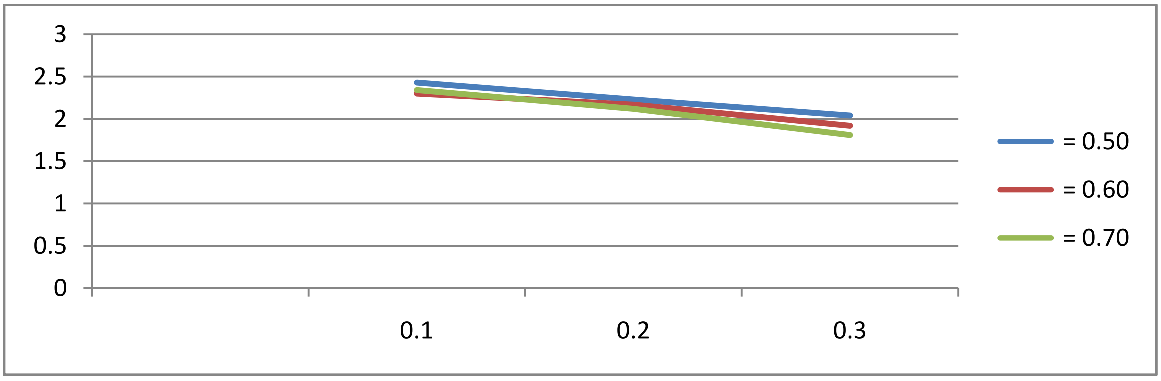

Figure 2: MTSF

Availability of the System (A_0):-

Table 5: Availability of System

$\delta\theta$	0.50	0.60	0.70
0.10	0.92	0.95	0.98
0.20	0.82	0.87	0.92
0.30	0.74	0.77	0.81

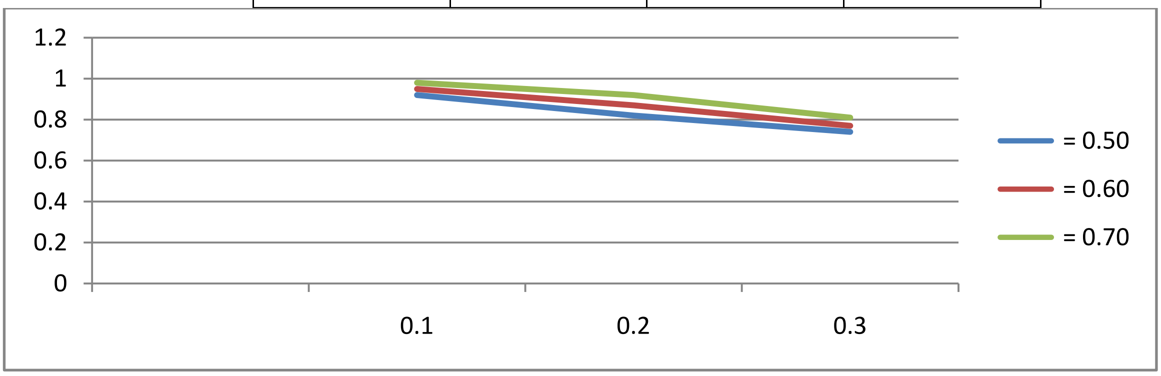

Figure 3: Availability of System

Server of busy period (B_0):-

Table 6: Server of busy period

$\delta\theta$	0.50	0.60	0.70
0.10	0.22	0.20	0.17
0.20	0.35	0.34	0.31
0.30	0.53	0.49	0.48

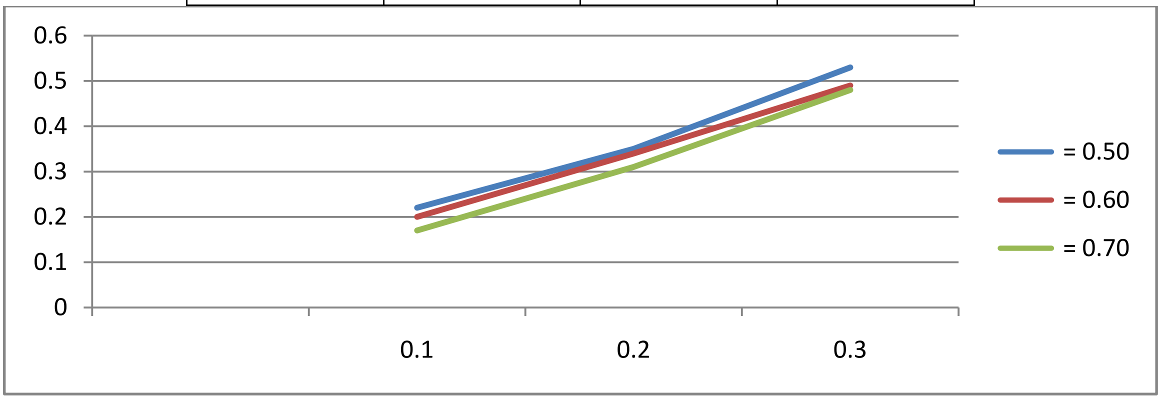

Figure 4: Server of the busy period

Expected Fractional No. of Inspection by Repairman (V_0) :-

Table 7: Expected Fractional No. of Inspection by Repairman

$\delta\theta$	0.50	0.60	0.70
0.10	0.21	0.22	0.23
0.20	0.28	0.30	0.31
0.30	0.42	0.46	0.51

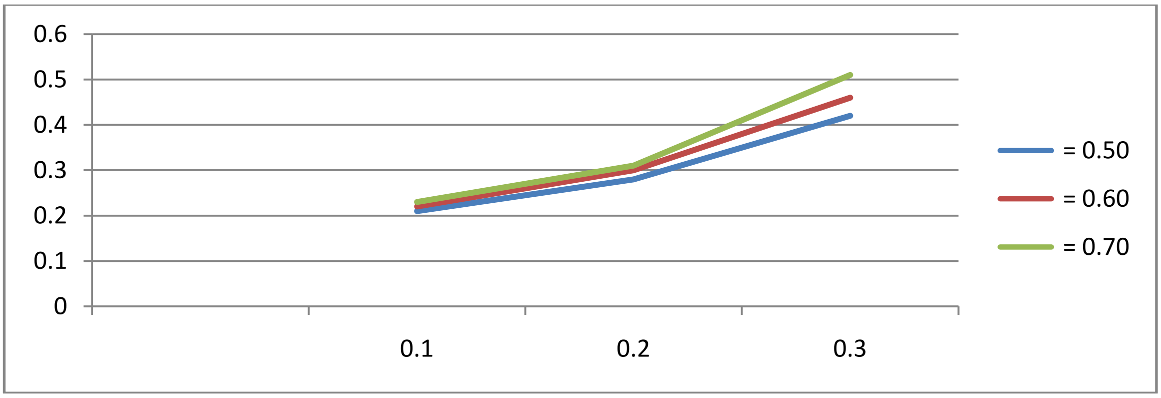

Figure 5: Expected Fractional No. of Inspection by Repairman

Conclusion: Increasing the repair rates of the unit, availability of should increase which is depicted by graphs 3 drawn, as it should be practically.From figure 4, that expending the failure rates the B_0 increases.

Failure rates considered as constant, for increasing the value of repair rate then the B_0decreases. It is shows that when failure rates increases V_0increase and repair rates increases thenV_0 increases.The table 4 and figure 2, it is shows that when failure rates increases the MTSF decrease and repair rates increases then the MTSF decreases.

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