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Mathematical modeling and Behaviour analysis of a case study of rice plant using RPGT technique

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Abstract

In this research paper, Behaviour analysis of a Rice Plant is carried out by using Regenerative Point Graphical Technique (RPGT) under specific conditions for system parameters. The Rice Plant basically comprises of five subsystems specifically Elevator (E), Cleaning (C), Whitening (W), Polishing (P), and Husking and Separation (H). At first cleaning dries the crud material and places it into the husker. Husking is utilized to strip off husk from the rice. 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. All the machines are arranged in series. The system is in a working state when all subsystems are in good condition. A repair facility is accessible for all subunits. Finally, numerical analysis is carried out for calculating the performance measures and their comparisons.

Keywords: Regenerative point graphical technique (RPGT), availability, rice plant

Introduction

In the planning, manufacture, and arrangement of mechanical segments, reliability is a major consideration. The consequences of segment dissatisfaction become more fundamental when the number of systems and mining equipment continue to grow. Compared to planned maintenance or repair, an unplanned failure may result in far greater repair expenses. Enhancing the segments' availability and dependability is one way to lessen the effect of failures. The collection and analysis of appropriate data is a first step in improving availability and reliability.

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. One of the most popular options for rice buyers worldwide is Indian Basmati rice. Indian rice has been identified as one of the important commodities to export and is becoming incredibly aggressive. It is among India's staple cereals. For this reason, rice plants play an important role in the lives of individuals. Therefore, government officials, manufacturers, and reliability engineers should ensure that rice plants operate steadily and profitably. After rice is created, processing is a crucial step. The main objective of a rice processing system is to remove the husk and the layers of wheat in order to create edible white rice that has been sufficiently processed and cleaned of impurities. An exertion is also made in section to do performance analysis of one of the rice plant located in Haryana, India. Present research discusses behavior and behaviour analysis of repairable Rice plant using RPGT, in contemplating Markov exhibiting for demonstrating system parameters situations. The impact of repair and failure of units is inspected to acknowledge the ideal dimension of execution of framework parameters.

Each framework and sub-framework should continue to operate for a long period at a low cost under the specified parameters in order to support the effective and efficient tasks of process plants. As a result, the complicated current structure's improvement in adequacy with regard to numerous cost-affected and dependability records has become essential from a late start. In the process sector, a variety of execution estimates are used to illustrate how a plant is operating, such as system parameters. Two or three of the criteria are helpful for planning the units at the start, while the most are related to the operating stage. It consists of a small number of sub-frameworks that operate in an evolving manner; additionally, each subsystem may be composed of distinct components related in different configurations. To determine a unit's functional or disappointing condition, a fuzzy concept is used. Secondary, primary, and tertiary circuits are identified by analysing a transition diagram of the framework, taking into account general and constant repair rates and exponential (constant) failure rates. RPGT is used to resolve the problems and determine the framework parameters. Figures are used to help discuss system behaviour and cost-benefit. Numerous scientists and field researchers have previously contributed to the topic of reliability study, and their findings are presently being examined for potential advancements. According to Kumar *et al.* (2018) ^[4], Devi *et al.* (2023) ^[7] investigated the current paper carries a thorough nonfiction review to categorise, assess, and record the standing studies related to the RAP Behaviour of a bread plant. Kumar *et al.* (2019) ^[6, 9] used RPGT to do a sensitivity analysis on a cold standby framework consisting of two similar units with server failure and prioritised for preventative maintenance. The paper is divided into two halves, one of which is in operation and the other in cold standby mode. Kuamar (2023) ^[1] conducted research on the 3:4:: G System With Preventive Upkeep's profit analysis. Devi and Garg (2022) ^[3] talked about the three algorithms specifically, the hybrid genetic algorithm and the heuristic algorithm (HA) that can be used to solve the Redundancy Allocation Problem (RAP) when combined with particle swarm optimisation. Rajbala *et al.* (2022) ^[2] looked into the redundancy allocation issue in the cylinder manufacturing factory using a HA technique. Kumari *et al.* (2021) ^[5] employed Particle Swarm Optimisation (PSO) to solve the constrained issue, while Kumar *et al.* (2019) ^[6, 9] examined the mathematical formulation and behaviour analysis of a paper mill washing unit.

Objectives of Study:

- To model the system parameters of Rice Plant using RPGT.
- To find the values of failure/repair rates of subsystems this will optimize the system parameters.
- To find out Mathematical Modeling And Behaviour Analysis of A Case Study of Rice Plant Using RPGT Technique

Assumptions and Notations

- There is one repairman whose availability is 24x7 and another server is called on need basis.
- The distributions of repair and failure times are constant.
- Failures/repairs be present statistically independent.
- Repair system is a perfect.
- The system is discussed for steady-state conditions.
- The units' failures and repair distributions are distinct.

$m_i (1 \leq i \leq 5)$: Constant failure rate of units.

$n_i (1 \leq i \leq 5)$: Constant repair rate of units.

○ : Working Stat

□ : Failed State

E, C, W, P, H : Unit in full capacity working.

e, c, w, p, h : Failed unit.

$\bar{E}, \bar{C}, \bar{W}, \bar{P}, \bar{H}$: Unit A denote the unit is under repair

Transition Diagram

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

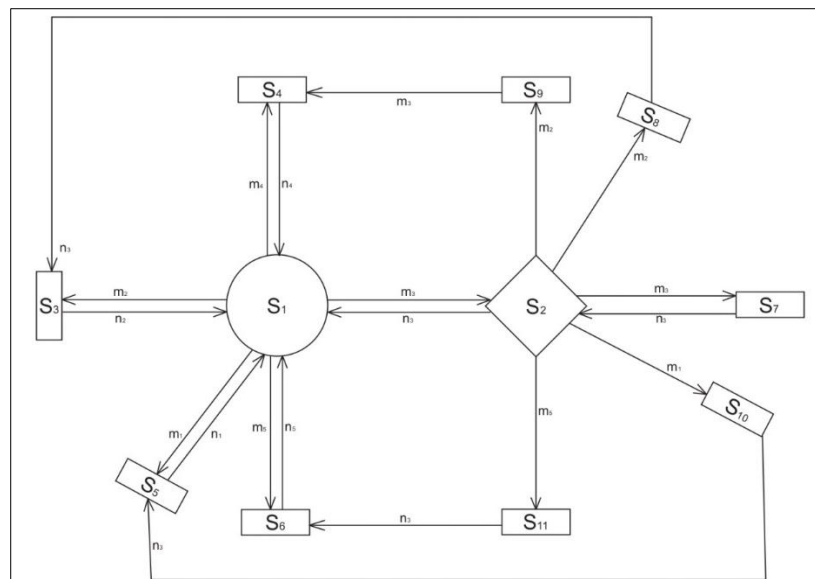


Fig 1: Transition Diagram of System

$S_1 = ECWPH, S_2 = EC\bar{W}PH, S_3 = E\bar{C}WPH,$
 $S_4 = EC\bar{W}\bar{P}H, S_5 = \bar{E}CWPH, S_6 = ECW\bar{P}H,$
 $S_7 = ECwPH, S_8 = EcWPH, S_9 = EcWPH,$
 $S_{10} = eCWPH, S_{11} = ECWPh$

Methodology:

The formulae for four system parameters using RPGT are as beneath

MTSF:

$$MTSF = \left[\sum_{x,s_r} \left\{ \frac{\{pr(0 \xrightarrow{s_r} x)\}_{\mu_x}}{\prod_{m_1 \neq 0} \{1 - V_{m_1, m_1}\}} \right\} \right] \div \left[1 - \sum_{s_r} \left\{ \frac{\{pr(0 \xrightarrow{s_r} 0)\}}{\prod_{m_2 \neq 0} \{1 - V_{m_2, m_2}\}} \right\} \right] \quad (1)$$

Availability of the System:

$$A_0 = \left[\sum_{y,s_r} \left\{ \frac{\{pr(0 \xrightarrow{s_r} y)\}_{f_y, \mu_y}}{\prod_{m_1 \neq 0} \{1 - V_{m_1, m_1}\}} \right\} \right] \div \left[\sum_{x,s_r} \left\{ \frac{\{pr(0 \xrightarrow{s_r} x)\}_{\mu_x^1}}{\prod_{m_2 \neq 0} \{1 - V_{m_2, m_2}\}} \right\} \right] \quad (2)$$

Server of the Busy Period:

$$B_0 = \left[\sum_{j,s_r} \left\{ \frac{\{pr(\xi \xrightarrow{s_r} j)\}_{\eta_j}}{\prod_{k_1 \neq \xi} \{1 - V_{k_1, k_1}\}} \right\} \right] \div \left[\sum_{i,s_r} \left\{ \frac{\{pr(\xi \xrightarrow{s_r} i)\}_{\mu_i^1}}{\prod_{k_2 \neq \xi} \{1 - V_{k_2, k_2}\}} \right\} \right] \quad (3)$$

Expected Fractional Number of Inspections by repairman:

$$V_0 = \left[\sum_{j,s_r} \left\{ \frac{\{pr(\xi \xrightarrow{s_r} j)\}}{\prod_{k_1 \neq \xi} \{1 - V_{k_1, k_1}\}} \right\} \right] \div \left[\sum_{i,s_r} \left\{ \frac{\{pr(\xi \xrightarrow{s_r} i)\}_{\mu_i^1}}{\prod_{k_2 \neq \xi} \{1 - V_{k_2, k_2}\}} \right\} \right] \quad (4)$$

Where,

i : a reformative un-failed state to which the organization can transit up to that time incoming any failed state while arriving the initial 0-state at period $t = 0$.

m_1 : a reformative state lengthways the path $(0 \xrightarrow{s_r(sff)} x)$, at which a $m_1 - \text{cycle}$ is designed through reformative un-failed states.

m_2 : a reformative state lengthways the path at which a is molded through regenerative un-failed states.

Transition Probabilities and Mean Sojourn Time

$q_{ij}(t)$: p. d. f. of the main passage period as of a reformative state 'i' to a reformative state 'j' or to a unsuccessful state 'j' without staying any supplementary reformative state in $(0, t]$

p_{ij} : Steady state transition likelihood since a reformative state 'i' to a reformative state 'j' shorn of go to one extra reformative state $p_{i,j} = q_{i,j}^*(0)$ Transition Probabilities and Mean Sojourn Times using RPGT are given below in tables 1 and 2.

Table 1: Transition Probabilities

$q_{ij}(t)$	$P_{ij} = q_{ij}^*(0)$
$q_{1,2}(t) = m_3 e^{-(m_3+m_4+m_2+m_1+m_5)t}$	$p_{1,2} = m_3/(m_3 + m_4 + m_2 + m_1 + m_5)$
$q_{1,3}(t) = m_2 e^{-(m_3+m_4+m_2+m_1+m_5)t}$	$p_{1,3} = m_2/(m_3 + m_4 + m_2 + m_1 + m_5)$
$q_{1,4}(t) = m_4 e^{-(m_3+m_4+m_2+m_1+m_5)t}$	$p_{1,4} = m_4/(m_3 + m_4 + m_2 + m_1 + m_5)$
$q_{1,5}(t) = m_1 e^{-(m_3+m_4+m_2+m_1+m_5)t}$	$p_{1,5} = m_1/(m_3 + m_4 + m_2 + m_1 + m_5)$
$q_{1,6}(t) = m_5 e^{-(m_3+m_4+m_2+m_1+m_5)t}$	$p_{1,6} = m_5/(m_3 + m_4 + m_2 + m_1 + m_5)$
$q_{3,2}(t) = n_3 e^{-(n_3+2m_2+m_3+m_1+m_5)t}$	$p_{3,2} = n_3/(n_3 + 2m_2 + m_3 + m_1 + m_5)$
$q_{3,8}(t) = m_3 e^{-(n_3+2m_2+m_3+m_1+m_5)t}$	$p_{3,8} = \alpha_3/(n_3 + 2m_2 + m_3 + m_1 + m_5)$
$q_{3,9}(t) = m_2 e^{-(n_3+2m_2+m_3+m_1+m_5)t}$	$p_{3,9} = \alpha_2/(n_3 + 2m_2 + m_3 + m_1 + m_5)$
$q_{3,10}(t) = m_2 e^{-(n_3+2m_2+m_3+m_1+m_5)t}$	$p_{3,10} = \alpha_2/(n_3 + 2m_2 + m_3 + m_1 + m_5)$
$q_{3,11}(t) = m_1 e^{-(n_3+2m_2+m_3+m_1+m_5)t}$	$p_{3,11} = \alpha_1/(n_3 + 2m_2 + m_3 + m_1 + m_5)$
$q_{3,12}(t) = m_5 e^{-(n_3+2m_2+m_3+m_1+m_5)t}$	$p_{3,12} = \alpha_5/(n_3 + 2m_2 + m_3 + m_1 + m_5)$
$q_{3,1}(t) = n_2 e^{-n_2 t}$	$p_{3,1} = 1$
$q_{4,1}(t) = n_4 e^{-n_4 t}$	$p_{4,1} = 1$
$q_{5,1}(t) = m_1 e^{-m_1 t}$	$p_{5,1} = 1$
$q_{6,1}(t) = n_5 e^{-n_5 t}$	$p_{6,1} = 1$
$q_{7,2}(t) = n_3 e^{-n_3 t}$	$p_{7,2} = 1$
$q_{8,3}(t) = n_3 e^{-n_3 t}$	$p_{8,3} = 1$
$q_{9,4}(t) = m_3 e^{-m_3 t}$	$p_{9,4} = 1$
$q_{10,5}(t) = n_3 e^{-n_3 t}$	$p_{10,5} = 1$

$q_{11,6}(t) = n_3 e^{-n_3 t}$	$p_{11,6} = 1$
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Table 2: Mean Sojourn Time

$R_i(t)$	$\mu_i = R_i'(0)$
$R_1(t) = e^{-(m_3+m_4+m_2+m_1+m_5)t}$	$\mu_1 = 1/(m_3 + m_4 + m_2 + m_1 + m_5)$
$R_2(t) = e^{-(m_3+m_4+m_2+m_1+m_5)t}$	$\mu_2 = 1/(m_3 + m_4 + m_2 + m_1 + m_5)$
$R_3(t) = e^{-n_2 t}$	$\mu_3 = 1/n_2$
$R_4(t) = e^{-n_4 t}$	$\mu_4 = 1/n_4$
$R_5(t) = e^{-m_1 t}$	$\mu_5 = 1/m_1$
$R_6(t) = e^{-n_5 t}$	$\mu_6 = 1/n_5$
$R_7(t) = e^{-n_3 t}$	$\mu_7 = 1/n_3$
$R_8(t) = e^{-n_3 t}$	$\mu_8 = 1/n_3$
$R_9(t) = e^{-\alpha_4 t}$	$\mu_9 = 1/\alpha_4$
$R_{10}(t) = e^{-n_3 t}$	$\mu_{10} = 1/n_3$
$R_{11}(t) = e^{-n_3 t}$	$\mu_{11} = 1/n_3$

Path probabilities

The path probabilities from base state (the state having maximum number of main circuits and least number of subordinate and third levels of circuits) is given by,

$$V_{1,1} = 1$$

$$V_{1,2} = [m_3(n_3 + 3m_2 + m_5 + m_1 + m_3)] / [(m_3 + m_4 + m_1 + m_2 + m_5)(n_3 + 3m_2 + m_1 + m_5)]$$

$$V_{1,3} = (m_2 n_3 + 3m_2^3 + m_2 m_1 + m_2 m_5 + m_3 m_2) / (m_3 + m_4 + m_2 + m_1 + m_5)(n_3 + 3m_2 + m_1 + m_5)$$

$$V_{1,4} = \dots \dots \dots \text{Continuous}$$

System Parameters Modelling

MTSF (T_0): The regenerative un-fizzled states in which framework can transit from initial state '0', Preceding any fizzled state are: 'i' = 1, 2 taking ' ξ ' = '1'.

$$T_0 = (V_{1,i} \mu_i) / (1 - p_{1,2} p_{2,1}); (1 \leq i \leq 2) \quad (5)$$

Availability of the System (A_0): The states in which framework is accessible are 'j' = 1, 2 and regenerative states are 'i' = 1 $\leq$ i $\leq$ 11 taking ' ξ ' = '1' the all-out portion of time for which framework is accessible is given by

$$A_0 = [\sum_j V_{\xi,j}, f_j, \mu_j] \div [\sum_i V_{\xi,i}, f_i, \mu_i^1] \\ = (V_{1,2} \mu_i) / D; (1 \leq i \leq 2) \quad (6)$$

$$\text{Where } D = (V_{1,j} \mu_j); (1 \leq j \leq 11)$$

Server of the Busy Period (B_0): The states in which server is busy are 'j' = 2 $\leq$ j $\leq$ 11 and states are 'i' = 1 $\leq$ i $\leq$ 11, from base state ξ = '1', total fraction of time for which server is busy

$$B_0 = [\sum_j V_{\xi,j}, n_j] \div [\sum_i V_{\xi,i}, \mu_i^1] \\ B_0 = (V_{1,j} \mu_j) / D; (2 \leq j \leq 11) \quad (7)$$

Expected Fractional Number of Inspections by repairman (V_0): The states where repairmen do this job 'j' = 2, states are 'i' = 1 $\leq$ i $\leq$ 11, Taking ' ξ ' = 1, number of visits by repairman is given by

$$V_0 = [\sum_j V_{\xi,j}] \div [\sum_i V_{\xi,i}, \mu_i^1] = (V_{1,2} \mu_2) / D \quad (8)$$

Simulation

To analyze the system in a better way and for ease of calculations, assuming equal values of failure and repair rates for all units, as m, n in equations (5) to (8), and keeping all unit's failure rates small and repair rates higher, then the equations for various parameters of the system are as under,

Mean Time to System Failure (T_0): $m_i = m; n_i = n; (1 \leq i \leq 5)$

Table 3: Mean Time to System Failure (T_0)

	n = 0.80	n = 0.85	n = 0.90	n = 0.95
m = 0.10	0.388	0.305	0.245	0.202
m = 0.15	0.387	0.304	0.244	0.201
m = 0.20	0.386	0.303	0.243	0.200
m = 0.25	0.385	0.302	0.242	0.199

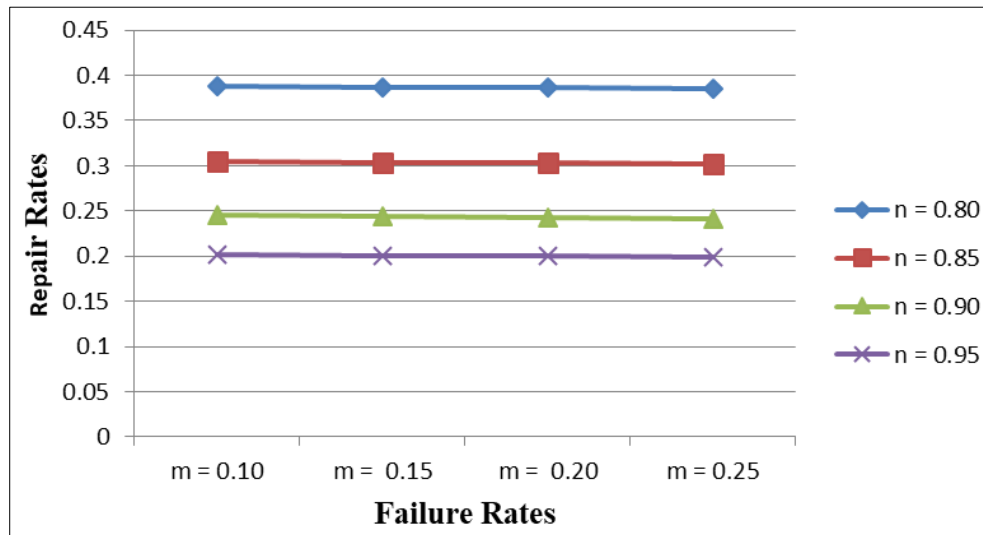


Fig 2: Mean Time to System Failure

Figure 2 and table 3, show the behavior analysis of system mean time to system failure versus failure rate (m) of unit of the system for various values of repair rate (n). It is concluded that T_0 decrease with increase in the values of failure rate (n).

Availability of the System (A_0)

Table 4: Availability of the System (A_0)

	n = 0.80	n = 0.85	n = 0.90	n = 0.95
m = 0.10	0.642	0.660	0.681	0.698
m = 0.15	0.602	0.619	0.637	0.655
m = 0.20	0.556	0.572	0.592	0.609
m = 0.25	0.521	0.540	0.556	0.572

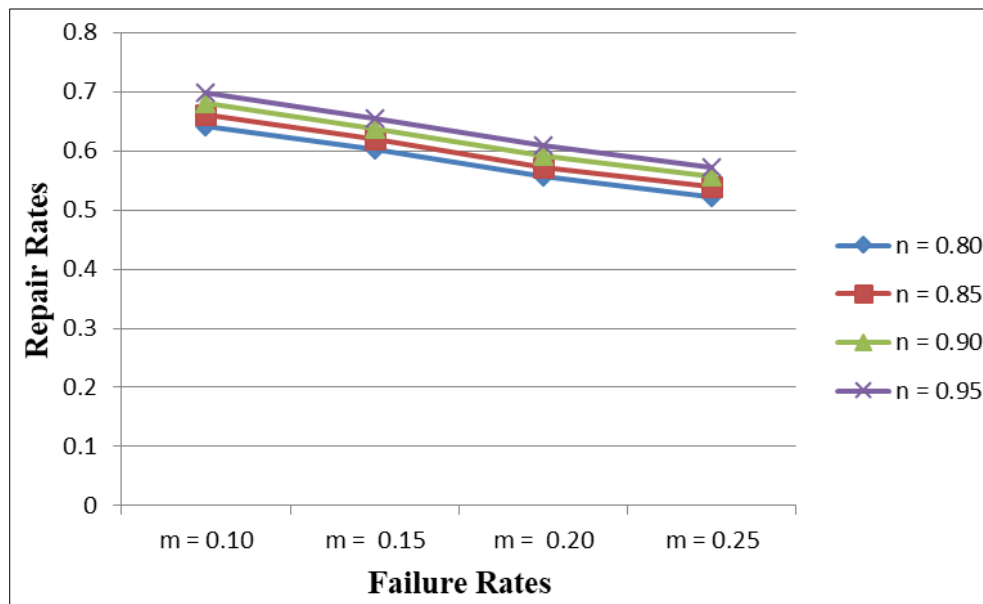


Fig 3: Availability of the System

From above figure 3 and table 4, it concluded that the Availability as opposed to repair rate (n) of the unit of system for various values of failure rate (m).

Server of the Busy Period (B_0)

Table 5: Server of the Busy Period (B_0)

	n = 0.80	n = 0.85	n = 0.90	n = 0.95
m = 0.10	0.562	0.542	0.516	0.486
m = 0.15	0.648	0.620	0.587	0.545
m = 0.20	0.754	0.732	0.662	0.567
m = 0.25	0.878	0.820	0.738	0.659

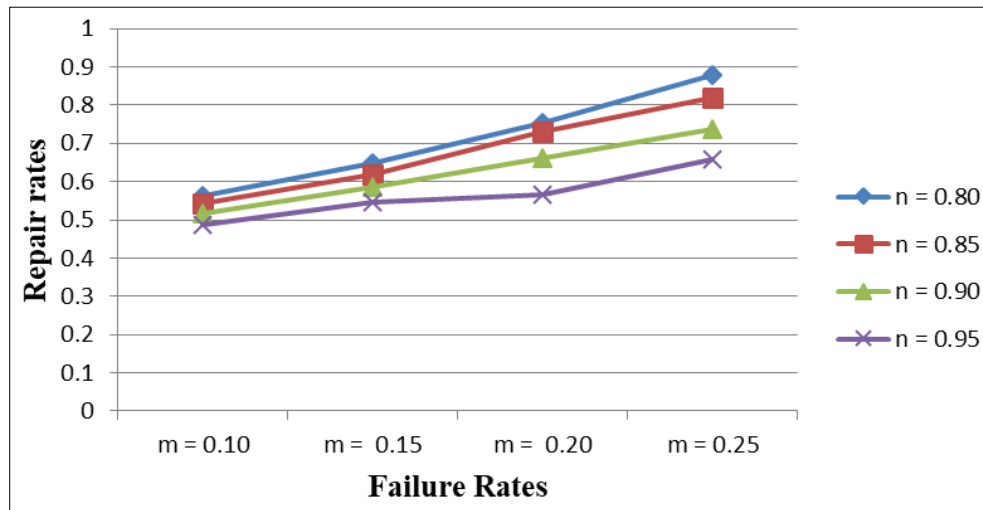


Fig 4: Server of the Busy Period

Figure 4 and Table 5, it is concluded that the value of the busy period decrease when the repair rate is increase and decreases with increase in failure rate.

Expected Fractional Number of Inspections by Repairman (V_0)

Table 6: Expected Fractional Numbers of Inspections by Repairman

	n = 0.80	n = 0.85	n = 0.90	n = 0.95
m = 0.10	0.117	0.114	0.111	0.108
m = 0.15	0.186	0.183	0.180	0.177
m = 0.20	0.248	0.245	0.242	0.239
m = 0.25	0.314	0.311	0.308	0.305

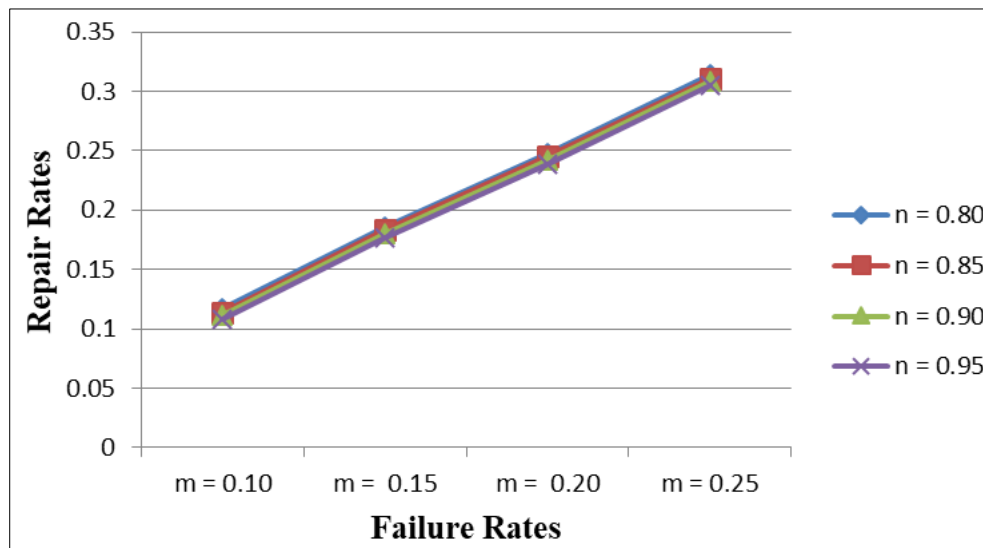


Fig 5: Expected Number of Server's Visits

Figure 5 and table 6 demonstrate that the V_0 is decreased when the repair rate is increase and increase with the expansion in failure rate, which ought to be really.

Conclusions

Here studying all the system parameters of the system, it is seen that minor rise in repair rate of units will increase the availability and MTSF, which in turn will increase the availability. Industrial managers value the many indicators of system efficacy that RPGT may produce, such as anticipated profit, busy period, MTSF, steady-state accessibility, and dependability. The current study will assist the companies in determining how many redundant components they can buy for a specific amount of money. A comparative study of the suggested methods also gave the management an idea of which approach would yield the best outcomes.

Conflict of Authors

There is no conflict of authors.

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