Journal of Namibian Studies, 35 (2023) : 373-383 ISSN: 2197-5523 (online)

Special Issue Of Engineering Technology And Science

Availability And Profit Analysis Of Nidec Manufacturing Plant Using Rpgt Techniques

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Abstract:

This paper presents a novel research study of the profit analysis regarding failure/repair rates of subunits of a Nippon Densan Corporation (NIDEC) Manufacturing Plant comprising of a various of subunits of varying manufacturing nature. In this paper behaviour and profit analysis of Nidec manufacturing plant are evaluated. The Nidec manufacturing plant contains six subsystems named as CNC machine (C), VMC machine (V), CNC hobbing machine (H), Induction hording machine (I), Grinding machine (G), and Polishing machine (P) so Nidec plant is a very complex system. All the subsystems are connected in series. A state transition diagram is developed using Markov process. The investigation of the system is completed by accepting that repair rates and failure rates are considered to be constant. The mathematical modeling is done by regenerative point graphical technique. The results are presented in the form of tables and graphs.

Keywords: - MTSF, Profit Analysis, RPGT, Availability, Steady-State.

1. Introduction:

Reliability is a substantial apprehension in the planning, design and manufacturing procedure of mechanical components. As the number of organizations and scope of the mining equipment retain on increase, the implication of component failure develops always critical. This paper discusses the Availability and Maintenance Analysis of NIDEC Manufacturing Plant Using RPGT Technique. Reliability and availability are significant characteristics of a repairable system. Nippon Densan Corporation (NIDEC) Manufacturing produces and sells various motors and Chip/smartcard for computers, smartphones, and other devices. The Smartcard/Chip is a memory device that can be used to back-up parameter sets and PLC programs, and copy them from one drive to another and its consists of six sub-systems associated in series system i.e. CNC machine, VMC machine, CNC Hobbing machine, Induction Hording machine, Grinding machine, and Polishing machine. The working of every sub-system is important for the effective optimization of the system. In this chapter behaviour and profit analysis of Nidec manufacturing plant are evaluated. The Nidec manufacturing plant contains six subsystems named as CNC machine (C), VMC machine (V), CNC hobbing machine (H), Induction hording machine (I), Grinding machine (G), and Polishing machine (P) so Nidec plant is a very complex system. All the subsystems are connected in series. Unit 'C' is more sensitive than that of different subunits thus 'H' is the standby subunit. A solitary server is available for 24 x 7 hours to repair the entire failures of the subunits. All units have instantly recognizable failure and repair rates in all states. Server while serving or keeping the units C', 'V', 'H', 'I', 'G', and 'P' additionally fall down accordingly needs a service treatment (refreshment) which is given a need premise in the order server. (Devi and Garg 2022) discussed the three algorithms specifically HA, COGA and HGAPSO are applied to solve RAP. Present paper carriages a comprehensive literature review to classify, evaluate and intercept the standing studies related to the RAP (Devi et al. 2023) behavior of a bread plant was examined by (Kumar et al. 2018). 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 paper, one of which is in use and the other of which is in cold standby mode. PSO was used by (Kumari et al. 2021) to research limited situations. (Kumar et al. 2019) investigated mathematical formulation and behavior study of a paper mill washing unit, 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 state transition diagram is developed using Markov process. The investigation of the system is completed by accepting that repair rates and failure rates are considered to be constant. The mathematical modeling is done by regenerative point graphical technique. The results are presented in the form of tables and graphs. In this study the profit analysis is dependent upon the steady state availability, busy period of server and expected number of repairman.

2. Assumptions and Notations

- Repairs and repair rates are considered to be constant.
- A single maintenance specialist is available for 24 x 7 hours to repair the all types of failures of the subunits.
- Capital letters C, V, H, I, G, and P are used for good working state.
- Small letters c, v, h, i, g, and p indicate the failed state.
- $\overline{\mathrm{H}}$ Is used for reduced state.
- $\mathrm{m_i} (2 \leq \mathrm{i} \leq 8)$: Denote the failure rates of the subsystem.
- $\mathrm{n_i}$ $(2 \leq \mathrm{i} \leq 8)$: Denote the repair rates of the subsystems.

3. Transition Diagram

By taking into consideration all the above notations and assumptions, the Transition Diagram of the system is given in Figure 1.

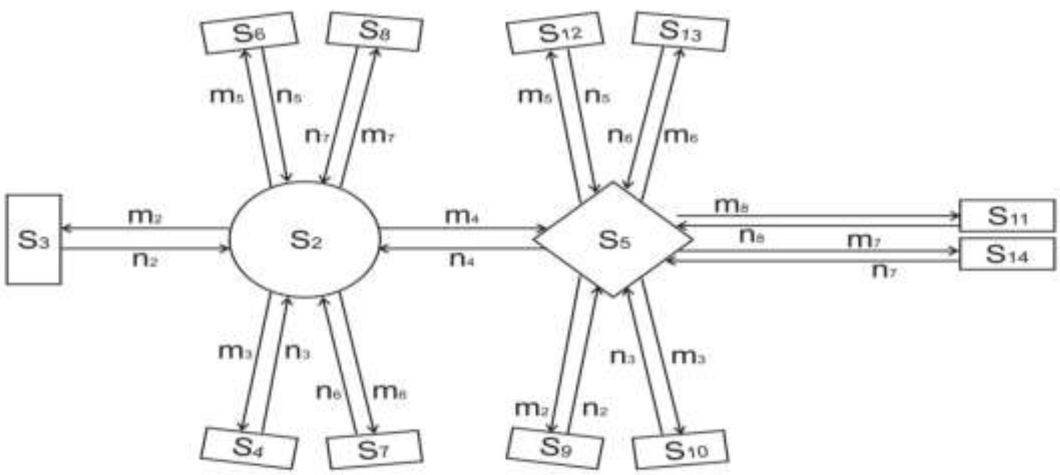

Figure 1: State transition diagram of the Nidec manufacturing plant.

S_2 = [CVHIGP], S_3 = [cVHIGP], S_4 = [CvHIGP], S_5 = [CV$\overline{\text{H}}$IGP], S_6 = [CVHiGP], S_7 = [CVHIgP], S_8 = [CVHIGp], S_9 = [cV$\overline{\text{H}}$IGP], S_{10} = [Cv$\overline{\text{H}}$IGP], S_{11} = [CVhIGP], S_{12} = [CV$\overline{\text{H}}$iGP], S_{13} = [CV$\overline{\text{H}}$IgP], S_{14} = [CV$\overline{\text{H}}$IGp],

4. Transition Probability and the Mean sojourn times.

Table 1: Transition Probabilities

$q_{i,j}(t)$	$p_{ij} = q^*_{i,j}(t)$
$q_{2,3}(t) = m_2 e^{-(m_2+m_4+m_6+m_3+m_5+m_7)t}$	$p_{2,3} = \frac{m_2}{(m_2+m_4+m_6+m_3+m_5+m_7)}$
$q_{2,4}(t) = m_3 e^{-(m_2+m_4+m_6+m_3+m_5+m_7)t}$	$p_{2,4} = \frac{m_3}{(m_2+m_4+m_6+m_3+m_5+m_7)}$
$q_{2,5}(t) = m_4 e^{-(m_2+m_4+m_6+m_3+m_5+m_7)t}$	$p_{2,5} = \frac{m_4}{(m_2+m_4+m_6+m_3+m_5+m_7)}$
$q_{2,6}(t) = m_5 e^{-(m_2+m_4+m_6+m_3+m_5+m_7)t}$	$p_{2,6} = \frac{m_5}{(m_2+m_4+m_6+m_3+m_5+m_7)}$
$q_{2,7}(t) = m_6 e^{-(m_2+m_4+m_6+m_3+m_5+m_7)t}$	$p_{2,7} = \frac{m_6}{(m_2+m_4+m_6+m_3+m_5+m_7)}$
$q_{2,8}(t) = m_7 e^{-(m_2+m_4+m_6+m_3+m_5+m_7)t}$	$p_{2,8} = \frac{m_7}{(m_2+m_4+m_6+m_3+m_5+m_7)}$
$q_{3,2}(t) = n_2 e^{-(n_2)t}$	$p_{3,2}=1$
$q_{4,2}(t) = n_3 e^{-(n_3)t}$	$p_{4,2}=1$
$q_{5,2}(t) = n_4 e^{-(m_2+n_4+m_6+m_3+m_8+m_5+m_7)t}$	$p_{5,2} = \frac{n_4}{(m_2+n_4+m_6+m_3+m_8+m_5+m_7)}$
$q_{5,9}(t) = m_2 e^{-(m_2+n_4+m_6+m_3+m_8+m_5+m_7)t}$	$p_{5,9} = \frac{m_2}{(m_2+n_4+m_6+m_3+m_8+m_5+m_7)}$
$q_{5,10}(t) = m_3 e^{-(m_2+n_4+m_6+m_3+m_8+m_5+m_7)t}$	$p_{5,10} = \frac{m_3}{(m_2+n_4+m_6+m_3+m_8+m_5+m_7)}$
$q_{5,11}(t) = m_8 e^{-(m_2+n_4+m_6+m_3+m_8+m_5+m_7)t}$	$p_{5,11} = \frac{m_8}{(m_2+n_4+m_6+m_3+m_8+m_5+m_7)}$
$q_{5,12}(t) = m_5 e^{-(m_2+n_4+m_6+m_3+m_8+m_5+m_7)t}$	$p_{5,12} = \frac{m_5}{(m_2+n_4+m_6+m_3+m_8+m_5+m_7)}$

$q_{5,13}(t) = m_6 e^{-(m_2+n_4+m_6+m_3+m_8+m_5+m_7)t}$	$p_{5,13}=\frac{m_6}{(m_2+n_4+m_6+m_3+m_8+m_5+m_7)}$
$q_{5,14}(t) = m_7 e^{-(m_2+n_4+m_6+m_3+m_8+m_5+m_7)t}$	$p_{5,14}=\frac{m_7}{(m_2+n_4+m_6+m_3+m_8+m_5+m_7)}$
$q_{6,2}(t) = n_5 e^{-(n_5)t}$	$p_{6,2}=1$
$q_{7,2}(t) = n_6 e^{-(n_6)t}$	$p_{7,2}=1$
$q_{8,2}(t) = n_7 e^{-(n_7)t}$	$p_{8,2}=1$
$q_{9,5}(t) = n_2 e^{-(n_2)t}$	$p_{9,5}=1$
$q_{10,5}(t) = n_3 e^{-(n_3)t}$	$p_{10,5}=1$
$q_{11,5}(t) = n_8 e^{-(n_8)t}$	$p_{11,5}=1$
$q_{12,5}(t) = n_5 e^{-(n_5)t}$	$p_{12,5}=1$
$q_{13,5}(t) = n_6 e^{-(n_6)t}$	$p_{13,5}=1$
$q_{14,5}(t) = n_7 e^{-(n_7)t}$	$p_{14,5}=1$

Table 2: Mean Sojourn Time

$R_i(t)$	$\mu_i=R_i^*(2)$
$R_2(t) = e^{-(m_2+m_4+m_6+m_3+m_5+m_7)t}$	$\mu_2 = \frac{m_2}{(m_2+m_4+m_6+m_3+m_5+m_7)}$
$R_3(t) = e^{-(n_2)t}$	$\mu_3 = \frac{1}{n_2}$
$R_4(t) = e^{-(n_3)t}$	$\mu_4 = \frac{1}{n_3}$
$R_5(t) = e^{-(m_2+n_4+m_6+m_3+m_8+m_5+m_7)t}$	$\mu_5 = \frac{1}{(m_2+n_4+m_6+m_3+m_8+m_5+m_7)}$
$R_6(t) = e^{-(n_5)t}$	$\mu_6 = \frac{1}{n_5}$
$R_7(t) = e^{-(n_6)t}$	$\mu_7 = \frac{1}{n_6}$
$R_8(t) = e^{-(n_7)t}$	$\mu_8 = \frac{1}{n_7}$
$R_9(t) = e^{-(n_2)t}$	$\mu_9 = \frac{1}{n_2}$
$R_{10}(t) = e^{-(n_3)t}$	$\mu_{10} = \frac{1}{n_3}$
$R_{11}(t) = e^{-(n_8)t}$	$\mu_{11} = \frac{1}{n_8}$

$R_{12}(t) = e^{-(n_5)t}$	$\mu_{12} = \frac{1}{n_5}$
$R_{13}(t) = e^{-(n_6)t}$	$\mu_{13} = \frac{1}{n_6}$
$R_{14}(t) = e^{-(n_7)t}$	$\mu_{14} = \frac{1}{n_7}$

5. **Assessment of parameter:**

The Mean time to system failure and all the key parameters of the framework under determined state conditions are assessed, applying RPGT and utilizing '2' as the base-condition of the framework as under: The transition probability variables of all the reachable states from the base state '2' is:

$V_{2,2} = 1$
$V_{2,3} = (2, 3) = P_{2,3} = \frac{m_2}{(m_2+m_4+m_6+m_3+m_5+m_7)}$
$V_{2,4} = (2, 4) = P_{2,4} = \frac{m_3}{(m_2+m_4+m_6+m_3+m_5+m_7)}$
$V_{2,5}$ = ……..Continuous

6. **EVALUATION OF PARAMETERS OF THE SYSTEM:**

Mean time to System Failure (MTSF) (T_0): The states to which the system moves from initial state '2', before going to any failed state are: 'i' = 2, 5 taking base state 'ξ' = '2'.
i = 1,2,3,4 taking 'ε' =1
MTSF = ($V_{2,2}\,\mu_2 + V_{2,5}\,\mu_5$) / [1- (2, 5, 2)]
Availability of The System (A_0): The states in which the system works in reduced or full are 'j' = 2, 5, and i = 2, 3… 14 taking base state 'ξ' = '2' the total fraction of time for which the system is available is given by
$A_0 = (V_{2,2}\,\mu_2 + V_{2,5}\,\mu_5) / D$
Where $D = V_{2,2}\,\mu_2 + V_{2,3}\,\mu_3 + V_{2,4}\,\mu_4 + V_{2,5}\,\mu_5 + V_{2,6}\,\mu_6 + V_{2,7}\,\mu_7 + V_{2,8}\,\mu_8 + V_{2,9}\,\mu_9 + V_{2,10}\,\mu_{10} + V_{2,11}\,\mu_{11} + V_{2,12}\,\mu_{12} + V_{2,13}\,\mu_{13} + V_{2,14}\,\mu_{14}$
Busy Period of the Server: The regenerative states where server 'j' = 3 to 14 and regenerative states are 'i' = 2 to 14, taking base state 'ξ' = '2', the total fraction of time for which the server remains busy is
$B_0 = [V_{2,3}\,\mu_3 + V_{2,4}\,\mu_4 + V_{2,5}\,\mu_5 + V_{2,6}\,\mu_6 + V_{2,7}\,\mu_7 + V_{2,8}\,\mu_8 + V_{2,9}\,\mu_9 + V_{2,10}\,\mu_{10} + V_{2,11}\,\mu_{11} + V_{2,12}\,\mu_{12} + V_{2,13}\,\mu_{13} + V_{2,14}\,\mu_{14}]/D$
Where $D = V_{2,2}\,\mu_2 + V_{2,3}\,\mu_3 + V_{2,4}\,\mu_4 + V_{2,5}\,\mu_5 + V_{2,6}\,\mu_6 + V_{2,7}\,\mu_7 + V_{2,8}\,\mu_8 + V_{2,9}\,\mu_9 + V_{2,10}\,\mu_{10} + V_{2,11}\,\mu_{11} + V_{2,12}\,\mu_{12} + V_{2,13}\,\mu_{13} + V_{2,14}\,\mu_{14}$

Journal of Namibian Studies, 35 (2023) : 373-383 ISSN: 2197-5523 (online)

Special Issue Of Engineering Technology And Science

Expected Fractional Number of Inspections by the repair man: The regenerative states where the repair man does this job j = 2, 3 Taking base state 'ξ' = '2', the number of visit by the repair man is given by

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

$A_0 = (V_{2,2} + V_{2,5}) / D$

Where $D = V_{2,2}\,\mu_2 + V_{2,3}\,\mu_3 + V_{2,4}\,\mu_4 + V_{2,5}\,\mu_5 + V_{2,6}\,\mu_6 + V_{2,7}\,\mu_7 + V_{2,8}\,\mu_8 + V_{2,9}\,\mu_9 + V_{2,10}\,\mu_{10} + V_{2,11}\,\mu_{11} + V_{2,12}\,\mu_{12} + V_{2,13}\,\mu_{13} + V_{2,14}\,\mu_{14}$

7. Particular Cases: -

Specific Cases:- $m_i\,(2 \le i \le 8) = m$; $n_i\,(2 \le i \le 8) = n$

Table 3: Mean time to system failure

T_0	n = 0.50	n = 0.55	n = 0.60	n = 0.65	n = 0.70
m = 0.10	4.71	4.69	4.67	4.65	4.63
m = 0.15	3.49	3.47	3.45	3.43	3.41
m = 0.20	2.69	2.67	2.65	2.63	2.61
m = 0.25	1.79	1.77	1.75	1.73	1.71
m = 0.30	0.81	0.79	0.77	0.75	0.73

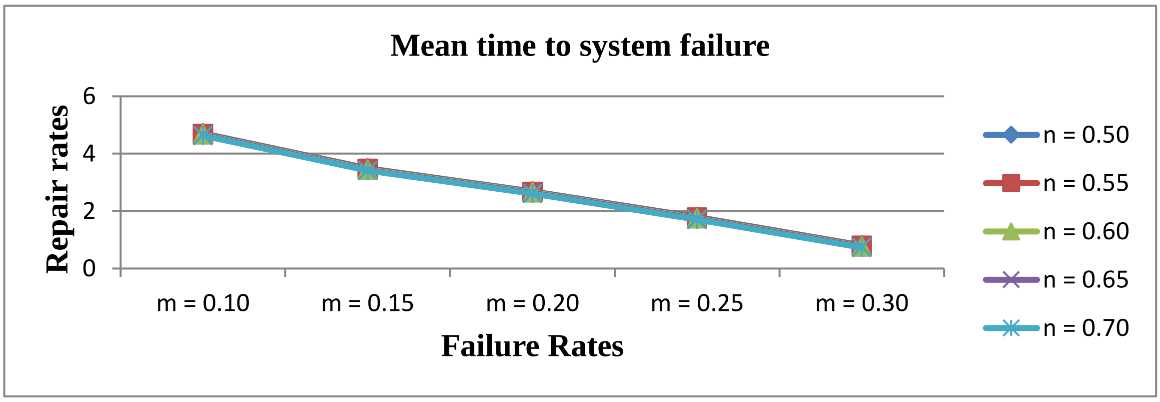

Figure 2: Mean time to system failure

Table 4: Availability of System (A_0)

A_0	n = 0.50	n = 0.55	n = 0.60	n = 0.65	n = 0.70
m = 0.10	3.81	3.85	3.89	3.93	3.97
m = 0.15	3.69	3.73	3.77	3.81	3.85
m = 0.20	3.57	3.61	3.65	3.69	3.73

m = 0.25	3.44	3.48	3.52	3.56	3.60
m = 0.30	3.33	3.37	3.41	3.45	3.49

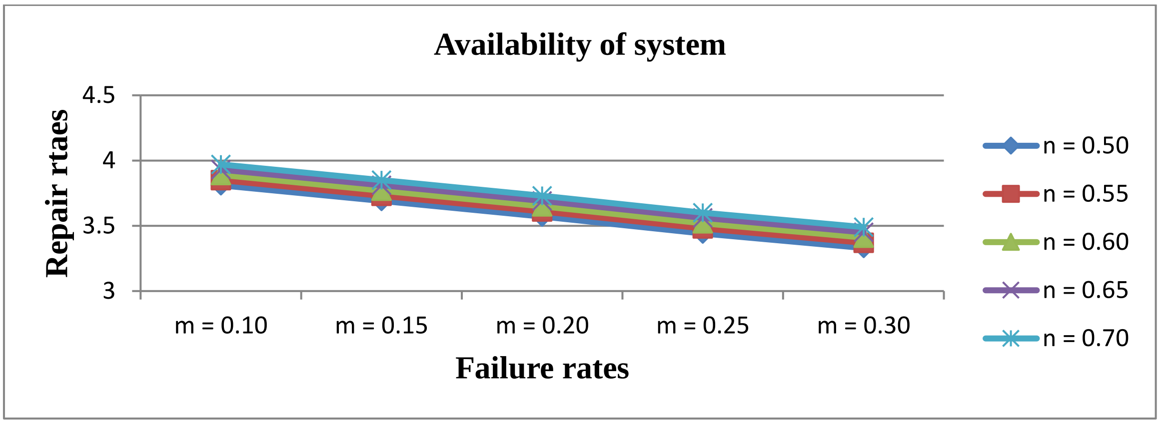

Figure 3: Availability of System (A_0)

Table 5: Busy period of the server (B_0)

B_0	n = 0.50	n = 0.55	n = 0.60	n = 0.65	n = 0.70
m = 0.10	3.56	3.54	3.52	3.50	3.48
m = 0.15	3.59	3.57	3.55	3.53	3.51
m = 0.20	3.62	3.60	3.58	3.56	3.54
m = 0.25	3.65	3.63	3.61	3.59	3.57
m = 0.30	3.68	3.66	3.64	3.62	3.60

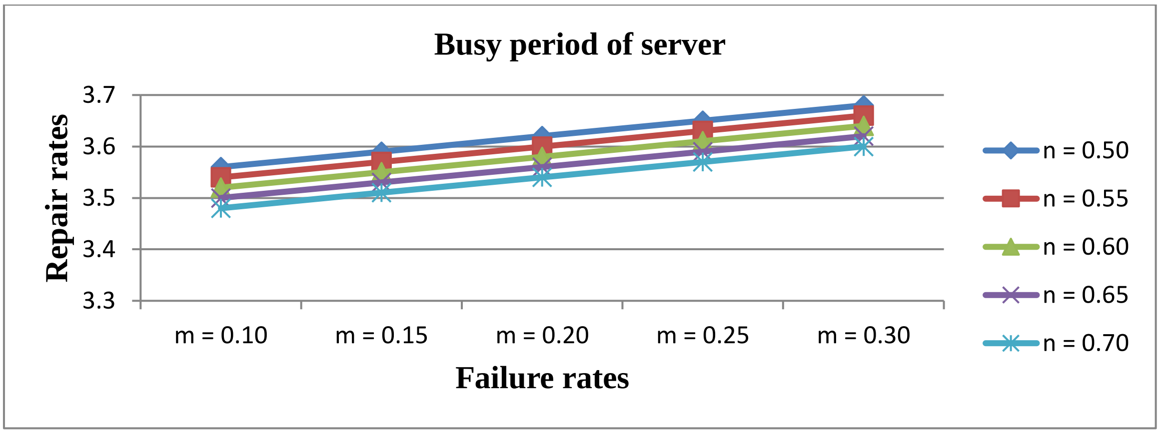

Figure 4: Busy period of server (B_0)

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

V_0	n = 0.50	n = 0.55	n = 0.60	n = 0.65	n = 0.70

m = 0.10	0.85	0.86	0.87	0.88	0.89
m = 0.15	0.86	0.87	0.88	0.89	0.90
m = 0.20	0.87	0.88	0.89	0.90	0.91
m = 0.25	0.88	0.89	0.90	0.91	0.92
m = 0.30	0.89	0.90	0.91	0.92	0.93

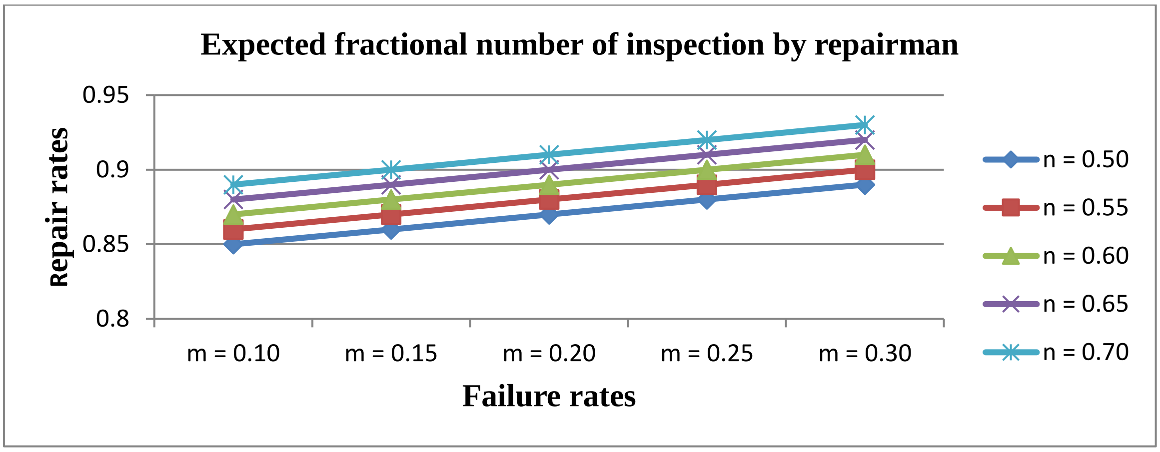

Figure 5: Expected Fractional Number of Inspections by Repairman (V_0)

Profit Function (P_0): The system can be done by utilized PF

$P_0 = D_1A_0 – D_2B_0 - D_3V_0,$

Table 7: Profit Function (P_0)

P_0	n = 0.50	n = 0.55	n = 0.60	n = 0.65	n = 0.70
m = 0.10	2682.50	2719.00	2755.50	2792.00	2828.50
m = 0.15	2567.50	2604.00	2640.50	2677.00	2713.50
m = 0.20	2452.50	2489.00	2525.50	2562.00	2598.50
m = 0.25	2328.50	2365.00	2401.50	2438.00	2474.50
m = 0.30	2222.50	2260.50	2295.50	2332.00	2368.50

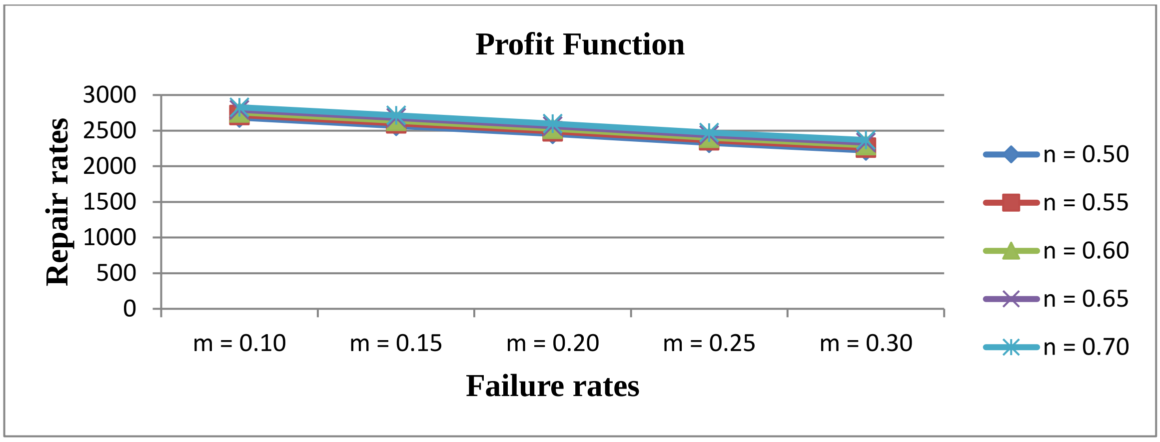

Figure 6: Profit Function (P_0)

8. Conclusion: -

Though, the education in the area of dependability has been regular at somewhat a faster speed, but mutual formulae in the secure form are not generated for semi Markov in which the conditions of the technique change giving to a partial, aperiodic and irreducible Markov chain, to total out the vital and key statistical parameters of the frameworks as MTSF, accessibility, server of busy period etc. of varied forms of replacements (under steady state circumstances). The association between Mean time to system failure and the unit's repair rate for different failure rates is revealed in table 3 and figure 2. As of the previous table, we may infer that Mean time to system failure rises with repair rates but falls with failure rates. Table 4 illustrates that handiness increases as repair rate increase and falls as disappointment rate rises, which is the predicted tendency. Furthermore, it can be deduced from Figure 3 that availability values exhibit the estimated trend aimed at various principles of failure rates by the help of availability increasing as rise in value of repair rate. As indicated by table 5 and figure 4 above, the server of busy period grows by increasing failure rate while decreasing growth in repair rate. A theory can be thought of as a logical collection of presumptions or claims made in an effort to explain a phenomenon. Table 6 shows that the expected number of waiter visits grows with increasing failure rates and falls with increasing repair rates. The graph 5 indicates that as the failure rates increase, expected number of server visits rises, and as repair rates increase, Expected Fractional Number of Inspections by Repairman reduces. For example, profit increases per an increase in repair rates and decreases with an increase in estimations of unit failure rates, as shown in Figure 6 and Table 7. Therefore, for the best Profit Function estimations, repairmen would be as effective as is rationally practicable in terms of repairs.

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