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Profit Analysis of System of a Refrigeration Plant using RPGT

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Abstract:
In the current investigation one have picked the Refrigeration Plant arranged in Rohtak District. A refrigeration unit consists of three main components namely Compressor, Condenser, and Expansion Device& Evaporator. A server is a type of repair facility that responds right away to system problems that arise during system operation. For failure and repair times of the system with various parameters, the most significant monotonically declining lifetime Lindley distribution is used. When two or more units fail, the system is in a failed condition. For random values of the shape parameter related to failure and repair times, the reliability measures' behavior has been graphically depicted. Graphs and tables are employed in order to demonstrate system behavior.

Keywords: -Availability, MTSF, Regenerative Point Graphical Technique (RPGT).

1. Introduction

The words 'reliable and reliability' are regularly used by each person in daily life. The reliability word has a high level of significance. The results of any un-reliable system failures are very dangerous. For example, in industrial accident in the Union Carbide Plant in Bhopal (1985) eight thousand people died and seven lakhs effected. In our daily life, many failure issues are associated with production, administration, and social development. On the off chance that one has a distinct idea about the issues and the adequate conditions, and solutions to these problems are possible using reliability technology.The reliability/unwavering quality of complex frameworks have risen as a thrust zone because of event of awful occasions in the industries. The process industries contain high complex systems/frameworks with sub-framework arranged in various designs. Modern industry has vital run from easy to complex; subsequently, bakery shop plants should have a quality structure with perfect accessibility and perfect framework parameters. The present-day bakery plants are to ensure ideal assembling expenses and least structure process duration to accomplish execution and unwavering quality. Present chapter discusses behavior and sensitivity analysis to break down transient conduct of repairable bakery producing plant utilizing RPGT, in considering Markov displaying for demonstrating system parameters conditions. Cost benefit analysis can benefit the industry as far as lower maintenance cost and higher productivity. This can also help the management to understand the impact of decreasing/ increasing the repair/failure rates of a component covers all system performance. 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. In this chapter reliability, availability, and behavioral analysis of three-unit system (A case study of refrigeration Unit of VITA MILK PLANT - Rohtak in Jat LAND of Haryana Region) using RPGT is discussed for system parameters. A refrigeration unit consists of four main components namely Compressor, Condenser, Expansion Device and Evaporator. This study involves only three subsystems namely Condenser A, Expansion Device B and Evaporator D which have higher failure rates in comparison to Compressor whose failure rate is negligible due to availability of better quality of electricity supply these days, hence not accounted for study, three subsystems under study have parallel subcomponents, hence the system can work in reduced capacity when one unit is working in reduced state. All the three units have different failure distributions; hence on failure of any unit system fails. Fuzzy logic is used to decide the failure of any unit. Graphs and tables are drawn to compare failure and repair rate their effect on the parameters values. The system consists of three non-identical units. Repairs are perfect. The repair order priority is unit A> unit B> unit D. The system is down when any of the units is in failed state, or two units are in reduced state. Failure and repairs are independent.The refrigeration plant can be run on a yearly basis as throughout the year. There is availability of many types or the other types of milk/fruits. Each plant can prepare the readymade packed milk/fruits of priority items. Refrigeration is made for fresh/ stored milk/fruits, for which these are many crushing/ pressing units available in a plant. If one or more crushing/ pressing units fail, then the whole of the system works in reduced capacity of the number of crushing / pressing units exceed a particular number, then the crushing unit fails causing the whole system failure. As the shelf life of fresh milk/fruit is very small, so to increase its storage life same preservative and other ingredients are added as per the requirements of a particular flavor, this process of addition of ingredients and preservatives is called processing, in large refrigeration plant there is number of processing units working in parallel. Failure of one or more but less than a particular level reduces the efficiency of the processing unit, hence that of the whole plant. In our study we have represented Condenser, Expansion Device and Evaporator units by A, B, D respectively and compressor study has not been included as failure rate of this unit is very-2 small say negligible, hence there is seldom repair requirement of this unit. (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.(Shakuntla et al., 2011) discussed the behavior analysis of polytube using supplementary technique. 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.The comparative analysis of the subsystem failed simultaneously was discussed by (Shakuntla et al. 2011). Taking failure /repair rates independent, constant and considering different probabilities, is drawn in Figure 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. The tables and graphs are created using analytical cases, and they are then discussed and concluded. Following the use of specific examples, the effect is expressed using tables and graphs as well as concluding remarks.

2. Assumption & Notation used in this study: -

1. There is a single repairman for repair of failed units and in reduced states.
2. The system is down when any of the units is in a failed state.
3. Failure and repair of subsystems follow general distributions and are independent.
4. Switching is perfect.
5. Nothing can fail when the system is in failed state,

$\left(i \xrightarrow{s_r} j\right)$: *r*-th directed simple path from *i*-state to j-state; r takes positive integral values for different paths from *i*-state to j-state.

$\left(\xi \xrightarrow{sff} i\right)$: A directed simple failure free path from ξ -state to i-state.

$V_{m,m}$: Probability factor of the state m reachable from the terminal state m of the M-cycle.

$V_{\overline{m,m}}$: Probability factor of the state m reachable from the terminal state m of the $m -\overline{cycle}$.

R_i (t) : Reliability of the system at time t, given that the system entered the good Regenerative state 'i' at t = 0.

A_i (t) : Probability of the system in up time at Time 't', given that the system enters Regenerative state 'i' at t = 0.

B_i (t) : Reliability that the server is busy for doing a particulars job at Time 't'; given, that the system entered regenerative state 'i' at t = 0.

V_i (t) : The expected no. of server visits for doing a job in (o, t] given that the system Entered regenerative state 'i' at t = 0.

'' : Dash denotes derivative.

μ_i : Mean sojourn time spent in state i, before visiting any other states.

$\mu_i = \int_0^\infty R_i(t)dt$

μ_i^1 : The total unconditional time spent before transiting to any other regenerative states, given that the system entered regenerative state 'i' at t=0.

n_i : Expected waiting time spent while doing a given job, given that the system entered regenerative state 'i' at t=0.

ξ : Base state of the system.

f_j : Fuzziness measure of the j-state.

$\alpha_i \rightarrow$ Failure Rates:

$\beta_i \rightarrow$ Repair Rates

3. Transition Diagram

Circle, ellipse and rectangle in transition diagram in Figure 1 represent full, reduce and failed states respectively.

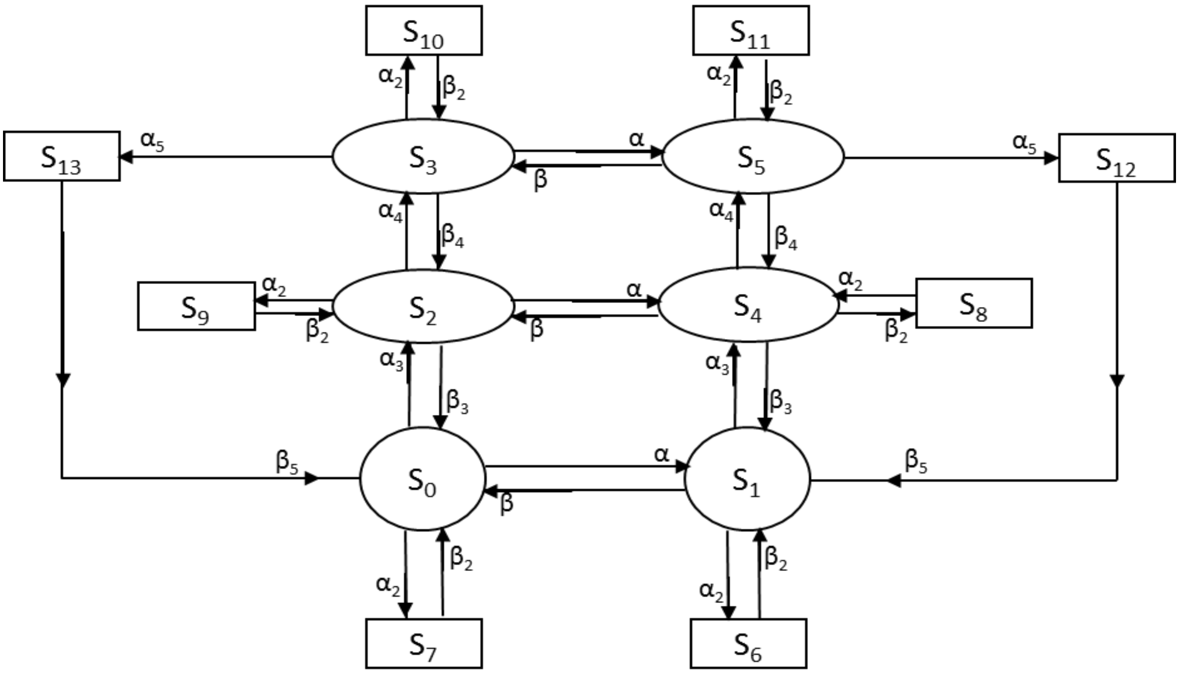

Figure 1: Transition Diagram

S_0 = ABD,	S_1 = (A)BD,	S_2 = ABD$_1$,	S_3 = ABD$_2$,
S_4 = (A)BD$_1$,	S_5 = (A)BD$_2$,	S_6 = (A)bD,	S_7 = AbD,
S_8 = (A)bD$_1$,	S_9 = AbD$_1$,	S_{10} = AbD$_2$,	S_{11} = (A)bD$_2$,
S_{12} = (A)Bd,	S_{13} = ABd		

4. Transition Probabilities

Table 1: Transition Probabilities

$q_{i,j}^{(t)}$	$P_{ij} = q^*_{i,j}{}^{(t)}$
$q_{0,1} = \alpha e^{-kt}$	$P_{0,1} = \alpha/k$
$q_{0,2} = \alpha_3 e^{-kt}$	$P_{0,2} = \alpha_3/k$
$q_{0,7} = \alpha_2 e^{-kt}$	$P_{0,7} = \alpha_2/k$
$q_{1,0} = \beta e^{-lt}$	$P_{1,0} = \beta/l$
$q_{1,4} = \alpha_3 e^{-lt}$	$P_{1,4} = \alpha_3/l$
$q_{1,6} = \alpha_2 e^{-lt}$	$P_{1,6} = \alpha_2/l$
$q_{2,0} = \beta_3 e^{-mt}$	$P_{2,0} = \beta_3/m$
$q_{2,3} = \alpha_4 e^{-mt}$	$P_{2,3} = \alpha_4/m$
$q_{2,4} = \alpha e^{-mt}$	$P_{2,4} = \alpha/m$
$q_{2,9} = \alpha_2 e^{-mt}$	$P_{2,9} = \alpha_2/m$

$q_{3,2}= \beta_4 e^{-nt}$	$P_{3,2}= \beta_4/n$
$q_{3,5}= \alpha e^{-nt}$	$P_{3,5}= \alpha/n$
$q_{3,10}= \alpha_2 e^{-nt}$	$P_{3,10}= \alpha_2/n$
$q_{3,13}= \alpha_5 e^{-nt}$	$P_{3,13}= \alpha_5/n$
$q_{4,1}= \beta_3 e^{-rt}$	$P_{4,1}= \beta_3/r$
$q_{4,2}= \beta e^{-rt}$	$P_{4,2}= \beta/r$
$q_{4,5}= \alpha_2 e^{-rt}$	$P_{4,5}= \alpha_2/r$
$q_{4,8}= \alpha_4 e^{-rt}$	$P_{4,8}= \alpha_4/r$
$q_{5,3}= \beta e^{-st}$	$P_{5,3}= \beta/s$
$q_{5,4}= \beta_4 e^{-st}$	$P_{5,4}= \beta_4/s$
$q_{5,11}= \alpha_2 e^{-st}$	$P_{5,11}= \alpha_2/s$
$q_{5,12}= \alpha_5 e^{-st}$	$P_{5,12}= \alpha_5/s$
$q_{i\ ,1}= \beta_2 e^{-\beta_2 t}$ i=6 to11	$p_{i,1} = 1$
$q_{12,1}= \beta_5 e^{-\beta_5 t}$	$p_{12,1} = 1$
$q_{13,0}= \beta_5 e^{-\beta_5 t}$	$p_{13,0} = 1$

4.1 Mean Sojourn Times(μ):

Table 2: Mean Sojourn Times

$R_i(t)$	$\mu_i=R_i^*(0)$
$R_0^{(t)}= e^{-kt}$	$\mu_0 = 1/k$
$R_1^{(t)}= e^{-lt}$	$\mu_1= 1/l$
$R_2^{(t)}= e^{-mt}$	$\mu_2= 1/m$
$R_3^{(t)}= e^{-nt}$	$\mu_3= 1/n$
$R_4^{(t)}= e^{-rt}$	$\mu_4= 1/r$
$R_5^{(t)}= e^{-st}$	$\mu_5= 1/s$
$R_i^{(t)}= e^{-\beta_2 t}$, i=6 to11	$\mu_6= 1/\beta_2$
$R_{12}^{(t)}= e^{-\beta_5 t}$	$\mu_{12}= 1/\beta_5$
$R_{13}^{(t)}= e^{-\beta_5 t}$	$\mu_{13}= 1/\beta_5$

5. Path Probabilities:

Transition probabilities from vertex '0' to other vertices of system (using the table q_i (t), p_i* (0) and sojourn times μ_i, we get

$V_{0,0}$ = 1 (verified), $V_{0,1} = p_{0,1} = [\alpha/k]$, $V_{0,2} = p_{1,2} = [\alpha_3/k]$

$V_{0,3}$ = = $[2\alpha_2\alpha_4^2(1+\alpha_3)(\beta\ \beta_5)]/[lkn^2]$

$V_{0,4}$ = ……….Continuous

6. Results

ATSF(T_0): The good states to which system maygo throughout from the base state 'i' = 0, are given by 'i' = 1,2,3,4,5, then ATSF is

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

$$= [\beta(\alpha_2+\alpha_3+\alpha)^2]+[(2\alpha_2+\beta_3+\alpha_4)/(3\alpha^2+3\beta+\beta\alpha_4+\alpha_2^3)]$$

Availability (A_0)of the System: The workingstatesare at vertices j = 0, 1, 2, 3, 4, 5 and using fuzzy logic, we get

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

$$=1/k+[\alpha/k(\beta_3+\alpha_2+\alpha+\alpha_4)]+[2\alpha_2\alpha_4^2(1+\alpha_3)(\beta\beta_5)]/[(\alpha_2+\alpha_3+\beta)(\alpha_2+\alpha_3+\alpha)$$

$$(\alpha+\alpha_2+\alpha_5+\beta_4)^2][1/n]+[\{\alpha_4^2\alpha_4(3+2\alpha_2)(1+\beta_4)(r+\alpha^2+\beta_3)(5+4\alpha_2+3\beta^2)\}/r]+[\{(\alpha_2\alpha_5\beta\beta_4)(2\beta+3\alpha^2)\}$$

$$/\{(3\alpha_4+\alpha_2+\beta)(\beta_4+2\alpha_2+5\alpha_3+\alpha)^2(\alpha_2+\alpha_3)\}]/s=$$

$$(3\alpha_2+5\beta+\alpha_2^2\beta_4+4\alpha)/[3\alpha_4+(\beta+\beta 4)^2+3\alpha_2^2\beta+4\alpha\beta_2)]$$

Busy Period of Server/Repairman (B_0): The server is busy for states 1≤j≤13 and taking initial state ξ = '0', the proportion of time for which server is repairing of faulty units.

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

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

$= (\sum V_{0,i} f_i \mu_i) \div (\sum V_{0,j} f_j \mu_j)$, Where $0 \leq i \leq 5$, $f_i = 1$ and $1 \leq j \leq 13, f_j = 0$, for $i \neq j$.

7 Particular Cases

Let $\alpha_i = \alpha$

$\beta_i = \beta$

Average time of System Failure (T_0):

Table 3:Average time of System Failure (T_0):

α↓\ β→	0.85	0.88	0.90
0.15	6.92	7.21	**9.24**
0.17	4.21	5.86	7.245
0.20	4.00	4.91	6.95

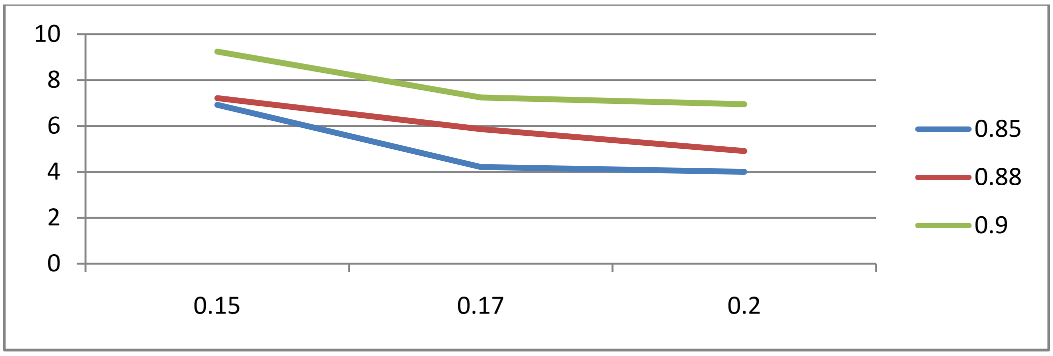

Figure 2:Average time of System Failure (T_0):

Availability of System (A_0):

Table 4:Availability of System (A_0)

α↓\ β→	0.85	0.88	0.90
0.15	0.85	0.87	0.91
0.17	0.59	0.63	0.68
0.20	0.43	0.46	0.52

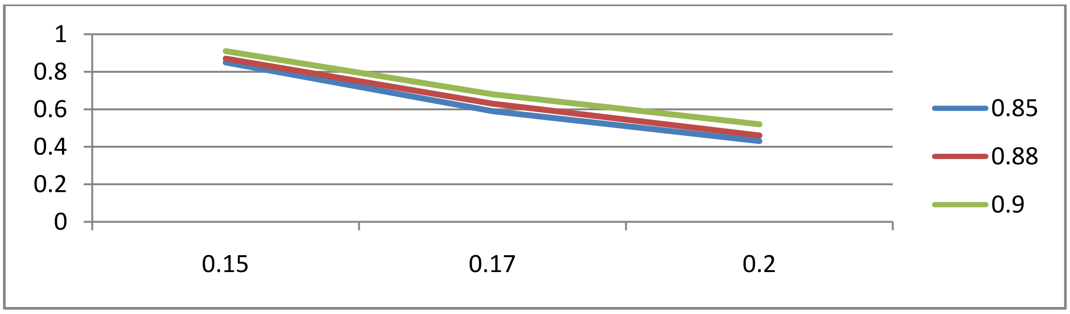

Figure 3: Availability of System (A_0):

Busy period of the server:

Table 5: Busy Period of the server

α ↓\ β→	0.85	0.88	0.90
0.15	0.61	0.57	0.53
0.17	0.73	0.69	0.66
0.20	0.85	0.80	0.77

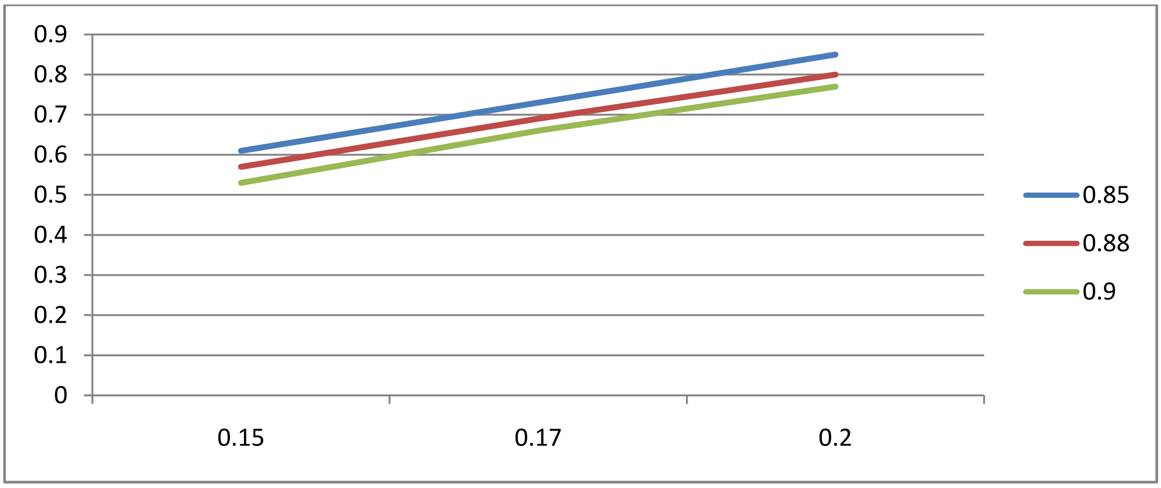

Figure: Busy Period of the server

Expected Fractional Number of Inspections by the Repairman (V_0):

Table 6: Expected Fractional Number of Inspections by the Repairman (V0)

α ↓\ β→	0.85	0.88	0.90
0.15	0.33	0.37	0.41
0.17	0.36	0.41	0.45
0.20	0.43	0.48	0.53

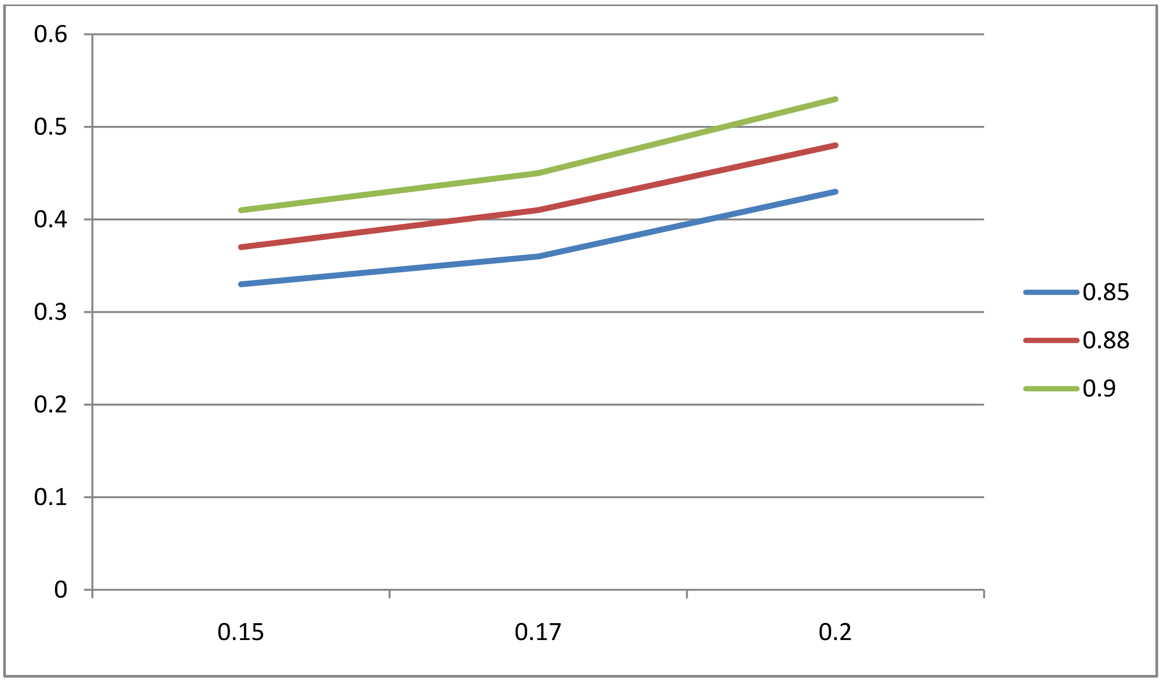

Figure: Expected Fractional Number of Inspections by the Repairman (V0)

PROFIT FUNCTION:- Profit Functioncan be done by utilizing the optimization function

$P_0 = C_1A_0 – C_2B_0 - C_3V_0$

Table 7: Profit Function

α↓\ β→	0.85	0.88	0.90
0.15	893	913	957
0.17	563	605	660
0.20	345	376	441

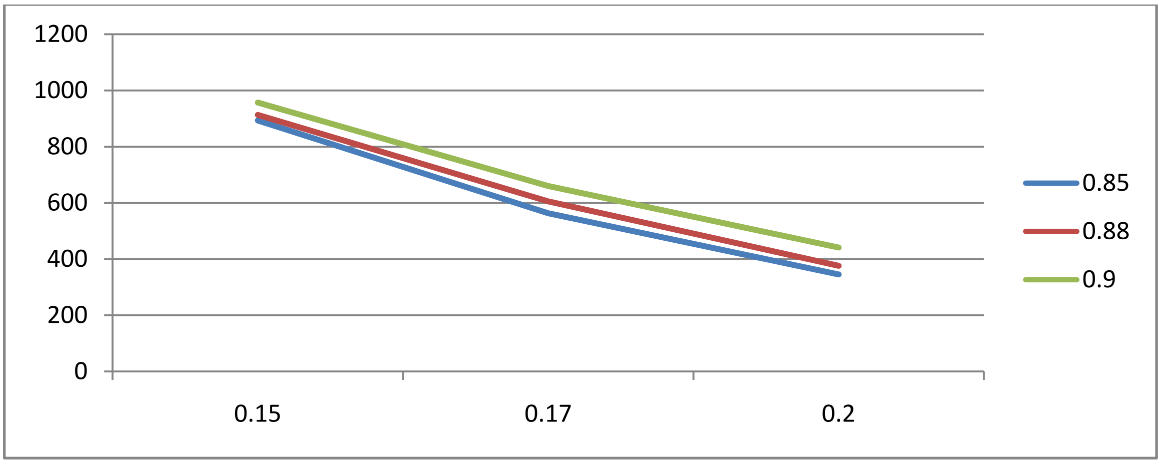

Figure 4:Profit Function Graph

6. Conclusion

Table 3 and figure 2 shows the behavior of the ATSF vs. the repair rate of the unit of the framework for various values of disappointment rate. It is determined that ATSF increases with rise in the values of repair rate and losses with rise in disappointment rate.Table 4 and figure 3 shows the performance of the Accessibility vs. Reparation rate of the unit of the framework for numerous values of the disappointment rate. It is determined that Accessibility rises with rise in values of the Reparation rate & reductions with the rise in disappointment rates. The optimum values of system parameters and profit are highlighted in table 7 and graph 4, which are also practically observed in industry corresponding to increasing failure &repair rates of units, similar results may be derived for other industries.

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