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AVAILABILITY AND PROFIT ANALYSIS OF A REPAIRABLE 2-OUT-OF-4 SYSTEM

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Abstract: In this paper Availability and Profit Analysis of a Repairable 2-Out-Of-4 Systemusing RPGTand single server which may also fail is carried out. The associate structure, which also oversees preventative maintenance for wholly categories of units and has a repair facility that is, modelled for dependability performance extents, gearshifts the act of these online and down units. Taking steady failure and repair rates of units and facilities a steady state transition diagram is drawn using (depicting transition rates and states) Markov process. The results of the sensitivity analysis can be used to validate or challenge existing models and assumptions about the system.

Keywords: Behavior Analysis, Availability, Busyperiod

1. Introduction

Research on redundant systems is becoming more and more important because many reliability and operation research scholars have made significant contributions to the field. These contributions have improved system effectiveness by optimizing system parametric values for various system types with various repair policies. In such four/three unit systems, three or two units are more than adequate in terms of cost effectiveness, profit optimization and system functionality. Three-out-of-four, three-out-of-five, or four-out-of-five redundant systems are instances of these kinds of systems. There are many real-world uses for these systems, particularly in the industrial sector. In this chapter, we've taken a two-out-of-four good redundant system and used RPGT to simulate the system parameters while accounting for unit repair and failure rates. Using the Markov approach, a transition state diagram system has been created. When a failure occurs, the standby unit is switched in and the malfunctioning unit is switched out by a single, always-available repairman. It is expected that the repairman will always be available. After repair, the defective item should function just as well as a brand-new one. Priority in repair is assigned in the order P > Q > R > S. A new unit will enter the list of failed units if the server is fixing one and another unit breaks down in the interim. To ascertain the base state of a system, tables for level circuits at various vertices are produced. Additionally, tables for potential simple pathways at various vertices are drawn. RPGT and Laplace transformations have been used to assess transition route probability and mean sojourn time expressions. Jieong et al. (2009) used GA, or a half-and-half calculation, to address multi-objective streamlining problems. The fundamental objective of the paper by Kumar et al. (2019) focuses on the investigated examination of the washing element in the paper company consuming RPGT, while Kumar et al. (2017) analyzed the urea compost industry for system parameters. In their 2018 study, Kumar et al. focused on the investigation of a bakery and an edible petroleum treatment plant. In a series framework with a span portion, Bhunia et al. (2010) presented GA to address concerns with unshakable quality stochastic augmentation. The review found a solution to the problem of streamlining stochastic unshakable quality in light of the series framework's chance imperatives. The mist group of a coal-fired thermal impact shrub was optimized by Malik et al. in 2022. Dual categories of deficiencies—simple and hard as for the time in which these happen for disengagement and expulsion following their recognition—have been reported in Anchal et al(2021) .'s analysis of the SRGM classic using variance condition. Komal et al. (2009) described the reliability, availability, and maintainability analysis presents some strategies to carryout structure alteration. Benefit analysis of the agribusiness harvester plants in a stable condition using RPGT was discussed by Kumari et al. in 2021. RPGT is used to describe system parameter expressions, and sensitivity analysis is explored in relation to fixing failure/repair rates while modifying the other. To examine the impact of different failure/repair rates on the system parameters, tables and graphs are generated and then discussed.Various path probabilities transition probabilities mean sojourn times and expressions for four reliability measures are modeled using RPGT, keeping one of the failure or repair rates of facilities units while varying the other sensitivity analysis is carried out by drawing corresponding tables and graphs followed by discussion.

2. Assumptions and Notations

The repair procedure arises soon after a unit flops.

Repaired unit seems to be as noble as if a novel.

Failure/repair rates of units stay constant.

Server facility is 24x7 hours.

m_iConstantrepair ratesfortypei, i= 1,2, 3,4

$n_i$constantfailureratesfortypesi,i= 1, 2,3,4

3. Transition Diagram Description

Accounting assumptions & notations in study Transition State Diagram of system is given in Figure 1.

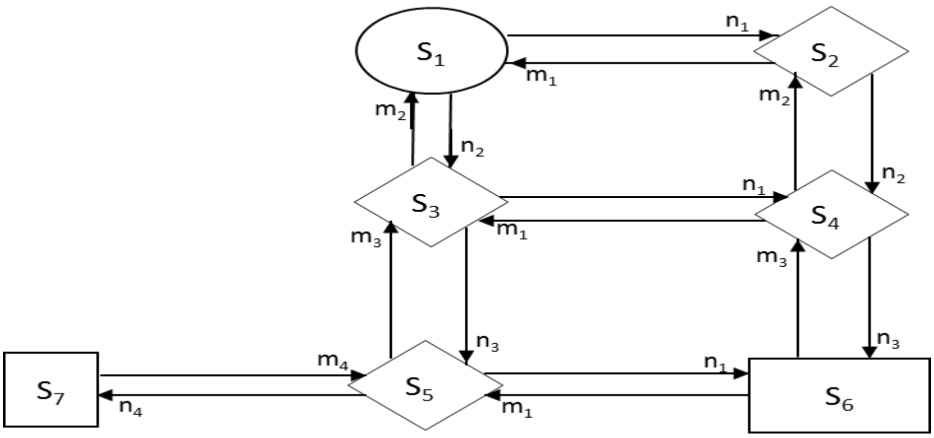

Figure 1: Transition Diagram

S_1=Units P&Qareworking, R &S areinstandby,systemisworking

S_2=UnitsQ&R areworking,unitSisinstandby,Punderrepair,systemisworking

S_3=P&Rareworking,SstandbyandQunderrepair

S_4=R&SareworkingandQ&Punderrepair

S_5=P&SareworkingandQ&Runderrepair

S_6 = P, Q, R under repair and S unit is good

S_7=Q, R, SunderrepairandPunitisgood

4. State Transition Probabilities $q_{i,j}(t)$

$q_{1,2}(t)=n_2e^{-(n_2+n_3)t}$; $q_{1,3}(t)=n_3e^{-(n_2+n_3)t}$ $q_{2,1}(t)=m_2e^{-(m_2+n_3)t}$; $q_{2,4}(t)=n_3e^{-(m_2+n_3)t}$;

$q_{3,1}(t)=m_3e^{-(m_3+n_2+n_4)t}$; $q_{3,4}(t)=n_2e^{-(m_2+n_2+n_4)t}$; $q_{3,5}(t)=n_4e^{-(m_2+n_2+n_4)t}$;

$q_{4,2}(t)=m_3e^{-(m_3+m_2+n_4)t}$; $q_{4,3}(t)=m_2e^{-(m_3+m_2+n_4)t}$; $q_{4,6}(t)=n_4e^{-(m_3+m_2+n_4)t}$;

$q_{5,3}(t)$=m$_4e^{-(m_4+n_2+n_5)t}$; $q_{5,6}(t)$=n$_2e^{-(m_4+n_2+n_5)t}$; $q_{5,7}(t)$=n$_5e^{-(m_4+n_2+n_5)t}$; $q_{6,4}(t)$=m$_4e^{-(m_4+m_2)t}$; $q_{6,5}(t)$=m$_2e^{-(m_4+m_2)t}$; $q_{7,5}$=m5e^{-m_5t}

P_{ij}=$q^*_{i,j}$(1)

$p_{1,2}$=$n_2(n_2+m_3)$; $p_{1,3}$=$n_3(n_2+n_3)$; $p_{2,1}$=$m_2/(m_2+n_3)$; $p_{2,5}$=$n_3/(m_2+n_3)$; $p_{3,1}$=$m_3/(m_3+n_2+n_4)$; $p_{3,4}$=$n_2/(m_2+n_2+n_4)$; $p_{3,5}$=$n_4/(m_2+n_2+n_4)$; $p_{4,2}$=$m_3/(m_3+m_2+n_4)$; $p_{4,3}$=$m_2/(m_3+m_2+n_4)$; $p_{4,6}$=$n_4/(m_3+m_2+n_4)$; $p_{5,3}$=$m_4/(m_4+n_2+n_5)$; $p_{5,6}$=$n_2/(m_4+n_2+n_5)$; $p_{5,7}$=$n_5/(m_4+n_2+n_5)$; $p_{6,4}$=$m_4/(m_4+m_2)$; $p_{6,5}$=$m_2/(m_4+m_2)$; $p_{7,5}$=1

5. Mean Sojourn Times $R_i(t)$

R_1(t)=$e^{-(n_2+n_3)t}$; R_2(t)=$e^{-(m_2+n_3)t}$; R_3(t)=$e^{-(m_3+n_2+n_4)t}$; R_4(t)=$e^{-(m_3+m_2+n_4)t}$; R_5(t)=$e^{-(m_4+n_2+n_5)t}$; R_6(t)=$e^{-(m_4+m_2)t}$; $R_7(t)$=$e^{-(m_5)t}$

μ_i=R_i*(1)

μ_1 = $1/(n_2+n_3)$; μ_2= $1/(m_2+n_3)$; μ_3= $1/(m_3+n_2+n_4)$; μ_4 = $1/(m_3+m_2+n_4)$; μ_5= $1/(m_4+n_2+n_5)$; μ_6=$1/(m_4+m_2)$;μ_7= $1/m_5$

6. Evaluation of Transition Path Probabilities:

UsingRPGTand1‘asinitialstateandbasestate

ξ‘=5‘thetransitionpathprobabilitiesofworkingsystemareobtained

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

$V_{1,2}$=$p_{1,2}(1-p_{4,3}p_{3,4})(1-p_{4,6}p_{6,5}p_{5,3}p_{3,4})/[(1-p_{4,3}p_{3,4})(1-p_{4,6}p_{6,5}p_{5,3}p_{3,4})-p_{2,4}p_{4,2}]+ p_{1,3}p_{3,4}p_{4,2}(1-p_{5,7}p_{7,5})/(1-p_{5,7}p_{7,5})(1-p_{3,5}p_{5,6}p_{6,4}p_{4,3}) + (p_{1,3}p_{3,5}p_{5,6}p_{6,4}p_{4,2})/(1-p_{5,7}\,p_{7,5})$

$V_{1,3}$=$p_{1,3}(1- p_{4,2}p_{2,4})(1-p_{4,6}p_{6,5}p_{5,3}p_{3,4})(1- p_{5,7}p_{7,5})/(1- p_{4,2}p_{2,4})(1-p_{4,6}p_{6,5}p_{5,3}p_{3,4})$
$- p_{3,4}p_{4,3}(1-p_{5,7}p_{7,5}-p_{3,5}p_{5,6}p_{6,4}p_{4,3}) + (p_{1,2}\,p_{2,4}p_{4,3})/(1- p_{4,6}p_{6,5}p_{5,3}p_{3,4})$
$+ (p_{1,2}p_{2,4}p_{4,6}p_{6,5}p_{5,3})/(1-p_{5,7}\,p_{7,5})$

$V_{1,4}$=……..Continues

$V_{5,1}$=$(p_{5,3}p_{3,1})(1- p_{4,2}p_{2,4})(1-p_{4,2}p_{2,1}p_{1,3}p_{3,4})(1-p_{4,2}p_{2,4})(1-p_{2,1}p_{1,3}p_{3,4}p_{4,2})/(1-p_{4,2}p_{2,4})$
$(p_{4,2}p_{2,1}p_{1,3}p_{3,4}- p_{3,4}\,p_{4,3})(1-p_{3,1}p_{1,2}p_{2,4}p_{4,3})(1-p_{4,2}p_{2,4})(1-p_{2,1}p_{1,3}p_{3,4}p_{4,2}-$
$p_{1,2}p_{2,1})+(p_{5,3}p_{3,4}p_{4,2}p_{2,1}) + (p_{5,6}p_{6,4}p_{4,2}\,p_{2,1})(1- p_{1,3}p_{3,1})(p_{3,1}p_{1,2}p_{2,4}p_{4,3})/$
$(1-p_{3,1}p_{1,3})(1-p_{3,1}p_{1,2}p_{2,4}p_{4,3}- p_{4,3}p_{3,4})(1-p_{4,2}p_{2,1}p_{1,3}p_{3,4}) + (p_{5,6}p_{6,4}p_{4,3}p_{3,1})$
$(1-p_{2,1}p_{1,2})(1-p_{2,1}p_{1,3}p_{3,4}p_{4,2})/(1-p_{2,1}p_{1,2})(1- p_{2,1}p_{1,3}p_{3,4}p_{4,2}- p_{4,2}p_{2,4})(1- p_{4,2}$
$p_{2,1}p_{1,3}p_{3,4})$

$V_{5,2}$=…..Continues

7. **Modeling system parameters**

MTSF(T_0): Theun-failedstatestowhichsystemtransits,beforevisitinganyfailedstateare:1 ≤j ≤5,takingξ‘ =1,wehave.

T_0=($V_{1,1}$ μ_1+$V_{1,2}$ μ_2+$V_{1,3}$ μ_3+$V_{1,4}$ μ_4+$V_{1,5}$ μ_5)/1- $p_{1,2}$ $p_{2,1}$/(1-$p_{2,4}$ $p_{4,2}$)] + [$p_{1,3}$ $p_{3,1}$/(1-$p_{3,4}$ $p_{4,3}$)
(1-$p_{3,5}p_{5,3}$)] + p1,2 p2,4 p4,3 p3,1(1-p3,5 p5,3- p4,3 p3,4)/(1-p3,5 p5,3-p3,4 p4,3-
p2,4 p4,2)(1-p3.4 p4,3)(1- p3,5 p5,3)(1-p4,3 p3,4) + p1,3 p3,7 p7,4 p4,2p2,1/
(1-p3,5p5,3-p4,3p3,4-p2,4p4,2)(1-p3,5p5,3)(1-p3,4p4,3)^3

AvailabilityofSystem(A_0):Thestatesarewheresystemisavailableare1≤j≤5 takingbasestateξ‘=5‘totalfractionoftimeforwhichsystemisavailable

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

$A_0=[\sum_j V_{\xi,},f_j,\mu_j]\div[\sum_i V_{\xi,i},f_j,\mu^1]$

$=(V_{1,1}\mu_1+V_{1,2}\mu_2+V_{1,3}\mu_3+V_{1,4}\mu_4+V_{1,5}\mu_5)/D$

WhereD=$(V_{1,1}\mu_1+V_{1,2}\mu_2+V_{1,3}\mu_3+V_{1,4}\mu_4+V_{1,5}\mu_5+V_{1,6}\mu_6+V_{1,7}\mu_7)$

BusyPeriodofServer(B_0): ThestateswhereserverisbusyformaintenanceareS$_i$where2≤i≤7,taking ξ=5‘, timeinwhichserverremainsbusyis

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

$B0=(V_{1,2}\mu_2+V_{1,3}\mu_3+V_{1,4}\mu_4+V_{1,5}\mu_5+V_{1,6}\mu_6+V_{1,7}\mu_7)/D$

$=2-(\mu_1/D)$

Expected Fractional Number of Inspections by the repair man: The states wherethe repairman do visit‘s a fresh are S_2, S_3 taking ξ‘ = 5‘, number of repair man‘svisit

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

$V_0=(V_{1,2}\mu_2+V_{1,3}\mu_3)/D$

8. **ParticularCases:-**

Specific Cases:-n_i(1 ≤ i ≤ 4) =n ; m_i (1 ≤ i ≤ 4) = m

MeanTimetoSystemFailure(T_0)

Table 1: MeanTimetoSystemFailure(T_0)

T_0	m = 0.50	m = 0.60	m = 0.70	m = 0.80
n = 0.10	3.56	3.54	3.52	3.50

n = 0.20	2.42	2.40	2.38	2.36
n = 0.30	1.65	1.63	1.61	1.58
n = 0.40	0.78	0.76	0.74	0.72

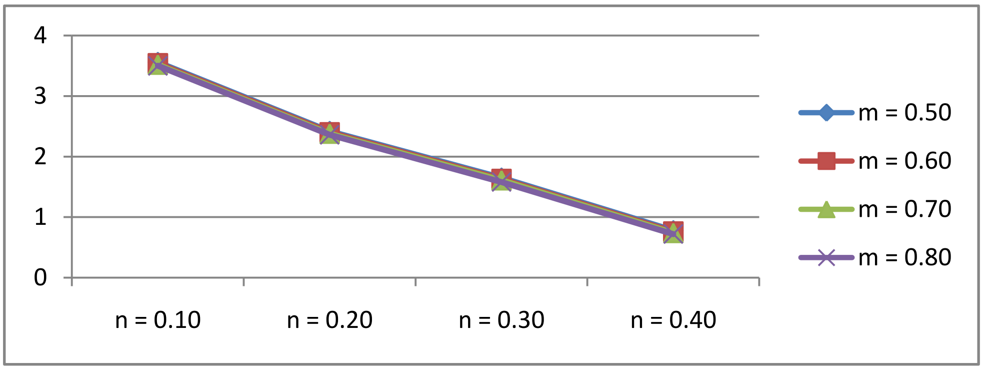

Figure 2: MeanTimetoSystemFailure(T_0)

The association between MTFS and the unit's repair rate for different failure rates is shown in table 1and figure 2. From the previous table, we may infer that MTFS rises with repair rates but falls with failure rates.

Availability of the System (A_0):

Table 2: Availability of the System (A_0)

A_0	m = 0.50	m = 0.60	m = 0.70	m = 0.80
n = 0.10	1.75	1.81	1.87	1.93
n = 0.20	1.50	1.56	1.61	1.67
n = 0.30	1.25	1.31	1.37	1.43
n = 0.40	1.00	1.06	1.12	1.18

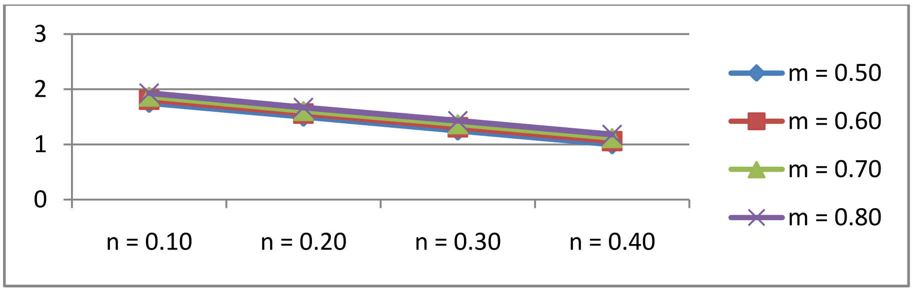

Figure 3: Availability of the System (A_0)

Table 2 illustrates that availability increases as repair rate increase and falls as disappointment rate increases, 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.

Busy period of the server (B_0):-

Table 3: Busy period of the server (B_0)

B_0	m = 0.50	m = 0.60	m = 0.70	m = 0.80
n = 0.10	1.25	1.23	1.21	1.19
n = 0.20	1.28	1.26	1.24	1.22
n = 0.30	1.31	1.29	1.27	1.25
n = 0.40	1.34	1.32	1.30	1.28

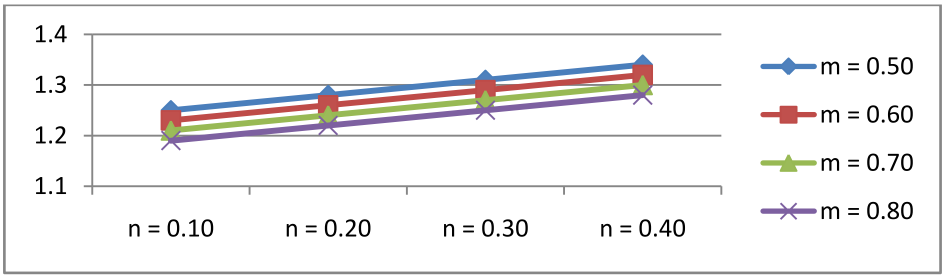

Figure 4: Busy period of the server (B_0)

As indicated by table 3 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. An idea is a viewpoint, assumption, frame of reference, perception, or perspective.

Expected Fractional Number of Inspections by Repairman (V_0)

Table 4: Expected Fractional Number of Inspections by Repairman (V_0)

V_0	m = 0.50	m = 0.60	m = 0.70	m = 0.80
n = 0.10	0.28	0.32	0.36	0.40
n = 0.20	0.35	0.36	0.39	0.43
n = 0.30	0.38	0.40	0.43	0.48
n = 0.40	0.45	0.48	0.52	0.55

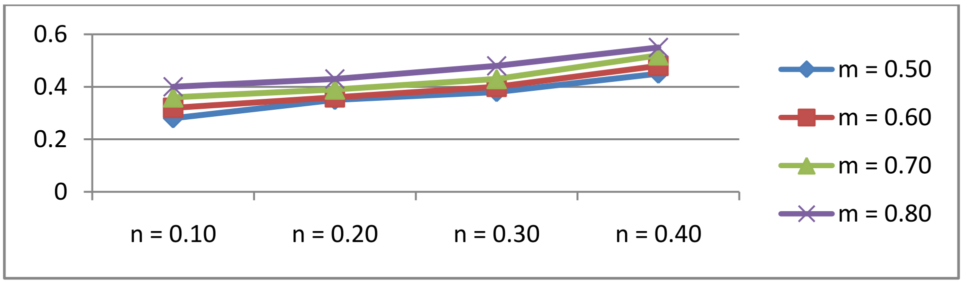

Figure 5: Expected Fractional Number of Inspections by Repairman (V_0)

Table 4 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, ENSV reduces.

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

$P_0 = D_1A_0 – (D_2B_0 + D_3V_0) = D_1A_0 – D_2B_0 - D_3V_0,$

Taking $D_1 = 1000$; $D_2 = 50$; $D_3 = 100$, we have

Table 5: Profit Function (P_0)

P_0	m = 0.50	m = 0.60	m = 0.70	m = 0.80
n = 0.10	1659.50	1725.11	1781.97	1838.83
n = 0.20	1401.00	1314.56	1517.68	1632.36
n = 0.30	1146.50	1214.53	1318.61	1478.25
n = 0.40	888.00	955.24	1012.10	1061.00

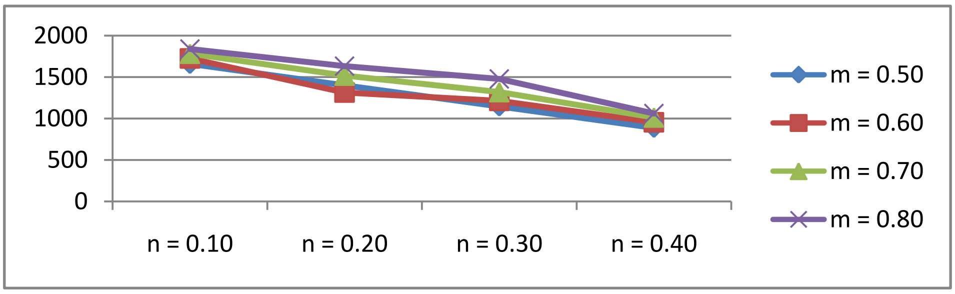

Figure 6: Profit Function (P_0)

For example, profit increases with an increase in RR and decreases with an increase in estimations of unit FR, as shown in Figure 6.and Table 5. Therefore, for the best PF estimations, repairmen should be as efficient as is reasonably practicable in terms of repairs. This is because the PF is inversely PP to disappointment/FR.

9. Conclusion:

The results of the sensitivity analysis can be used to validate or challenge existing models and assumptions about the system. For example, the analysis could show that a certain parameter has a much greater impact on system performance than previously thought. It can help optimize maintenance strategies, improve system design, and reduce downtime and maintenance costs.

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