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Relative Analysis of Reliability Models Consisting of Steam and Gas Turbine with Two Types of Repairman With or Without Random Inspection

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Abstract

This particular paper carry comparison between two models (Model1 and Model2) with two types of repairman with or without random inspection. Model1 consist of steam and gas turbine without random inspection while Model2 consist of gas and steam turbine with random inspection. Firstly, both steam and gas turbine are operative. As gas turbine fails, steam turbine fails and system goes to down state; when steam turbine fails, it possibly in down state or sustain in upstate coexisting gas turbine working only if buyer of power is glad to heir extra than usual rates. Firstly ordinary repairman repair the unit but if he is not able to completely renew the unit expert repairman will repair the unit. Comparative study between two models is made in order to see which one is better than the other with regard to probability of the system. Relative analysis have been carried out by using semi-Markov process and technique of regenerative point.

Keywords: Relative Analysis, Plant of Gas and Steam Turbine, Random Inspection, Up State, Down State, Failed State

I. INTRODUCTION

In modern society consumer wants more reliable products, so manufacturing of special equipments and tools are required. When equipments are not satisfactory reliable, production falls. To maintain the production we need to study comparative study of systems to enlarge profit. Various researchers contributed in the field of reliability modeling under different situation considering various concepts, but relative analysis is studied between two different systems is comparative less in literature. Several researchers have contributed by examining single or two-unit standby systems under different circumstances and assumptions working with rest and failed states only [1-5]. Singh, Singh and Meenaxi [6] study reliability and profit analysis of a Two-unit Non-identical standby system in snowstorm weather conditions. Singh, Singh and Saini [7] studied the cost-benefit analysis of two non-identical units cold standby system subject to heavy rain with partially operative after repair. Ke and Chu [8], Chen and Wang [9], Yusuf [10] made relative study with two models with different situations such as redundant reliable system, expert repairman and switching failures. Malhotra and Taneja [11] study comparative analysis of production depending on demand with two single unit systems. Singh and Taneja [12] make comparatively analysis comprising with two types of inspection. Arela and Gangil [13] make relative study to improve reliability of PV-Wind hybrid power system. Makhduomi, Keshtegar and Shahraki [14] analysis first order reliability of steel structures. Gupta [15] pairwise comparative analysis of reliability models with three types of repair policy.

Comparative study is necessary to determine, which model is better in which situation.

II. NOTATIONS

O_{gt} : Gas turbine under operation

O_{st} : Steam turbine under operation

u_{rgt1} : Gas turbine repaired by ordinary repairman

u_{rgt2} : Gas turbine repaired by expert repairman

u_{rst1} : Steam turbine repaired by ordinary repairman

u_{rst2} : Steam turbine repaired by expert repairman

d_{gt} : Gas turbine is in down mode

d_{st} : Steam turbine is in down mode

W_{rgt} : Gas turbine waits to restore

U_{Rst1} : Steam turbine under repair continued from previous state by ordinary repairman

U_{Rst2} : Steam turbine under repair continued from existing state by expert repairman

λ : Gas turbine's failure rate

α : Steam turbine's failure rate

a : Probability that the ordinary repairman completely repair the failed unit

b : Probability of not repairing the failed unit completely by ordinary repairman

p : Probability that customer is wants to pay extra than normal rates

q : 1-p i.e. Probability that the customer is not willing to give more than the standard rates

$g_1(t)$, $G_1(t)$: c.d.f and p.d.f of restore time of gas turbine by ordinary repairman

$g_2(t)$, $G_2(t)$: c.d.f and p.d.f of restore time of steam turbine by ordinary repairman

$g_3(t)$, $G_3(t)$: c.d.f and p.d.f of restore time of gas turbine by expert repairman

$g_4(t)$, $G_4(t)$: c.d.f and p.d.f of restore time of steam turbine by expert repairman

h(t), H(t) : p.d.f and c.d.f of time when system is under inspection

p_1 : Probability of need of minor maintenance unveil by inspection

p_2 : Probability of need of path maintenance unveil by inspection

p_3 : Probability of need of major maintenance unveil by inspection

i(t) : p.d.f of inspection time, to find the maintenance required is of which type

M_{Nm} : Minor maintenance

P_m : Path maintenance

M_{Jm} : Major maintenance

$h_1(t)$: p.d.f of time for acting minor maintenance

$h_2(t)$: p.d.f of time for acting path maintenance

$h_3(t)$: p.d.f of time for acting major maintenance

U_i : To disclose the type of failure under inspection of failed unit

III. MEASURES EFFECTIVENESS OF SYSTEM OF MODEL 1

Fig. 1 shows various states of Model1, here 0, 1, 2, 3, 4, 5, 6 and 9 are regenerative states and 7, 8 and 9 are failed states and 1, 3, 4, and 6 are down states. And 2 and 5 are in upstate working in single cycle.

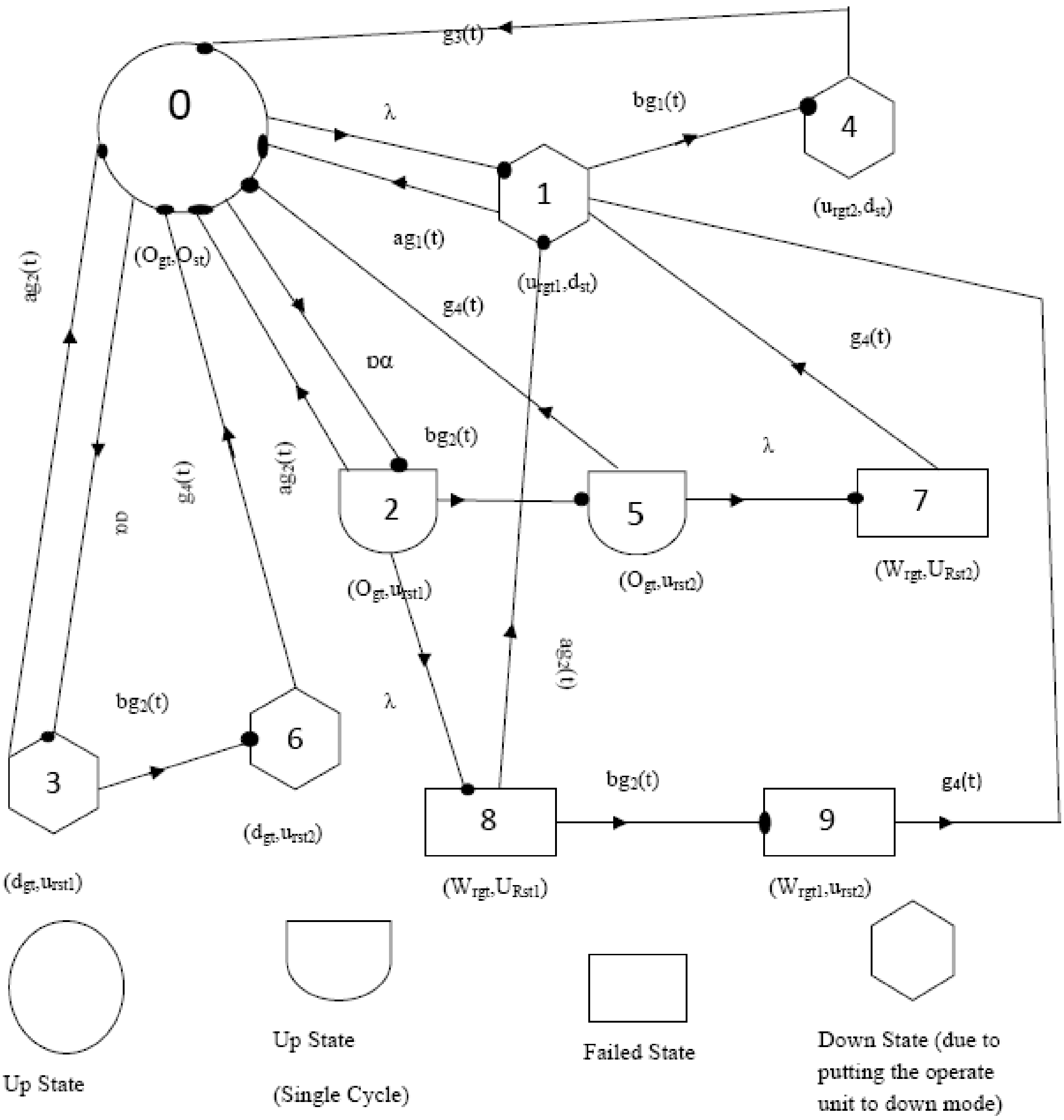

Fig.1 State Transition Diagram

The total Expected Profit1 = $C_0A_0+C_{01}A_{01}-C_{21}B_0-C_{22}B_{01}-C_{31}V_0-C_{32}V_{01}$

C_0 = Revenue per unit time when system working with full capacity

C_{01} = Revenue per unit time when system is working in single cycle

C_{21} = Cost per unit time for engaging the ordinary repairman for doing repair

C_{22} = Cost per unit time for engaging the expert repairman for doing repair

C_{31} = Cost per visit of the ordinary repairman

C_{32} = Cost per visit of the expert repairman

Where, $A_0=\frac{\mu_0}{D_1}$, $A_{01}=\frac{\mu2 - p25\mu5}{D_1}$, $B_0=\frac{\mu1[p01+p02-p02p20+p51(7)]+p02\mu2+p03\mu3}{D_1}$

$B_{01}=\frac{p02p25\mu5+\mu6(p03p36+p02p29(8))-\mu4[p01p14+p02p14(p21(8)+p29(8)+p25p51(7))]}{D_1}$

$V_0=\frac{1}{D_1}$, $V_{01}=\frac{p03p36+p01p14+p02(p25+p29(8))+p02p14(p21(8)+p29(8)+p25p51(7))}{D_1}$

$D_1=\mu_0+p_{01}\mu_1+p_{01}p_{14}\mu_4+p_{03}\mu_3+p_{03}p_{36}\mu_6+p_{02}[K_3+\mu_1(p_{21}^{(8)}+p_{25}p_{51}^{(7)})+p_{14}\mu_4(p_{21}^{(8)}+p_{29}^{(8)}+p_{25}p_{51}^{(7)})+p_{29}^{(8)}(\mu_6+\mu_1)+K_8+p_{25}\mu_6]$

$p_{01}=\frac{\lambda}{\lambda+\alpha}$, $p_{02}=\frac{p\alpha}{\lambda+\alpha}$, $p_{03}=\frac{(1-p)\alpha}{\lambda+\alpha}$, $p_{14}=a$, $p_{10}=1-a$, $p_{25}=\frac{(1-a)\alpha_2}{\lambda+\alpha_2}$,

$p_{29}^{(8)}=\frac{(1-a)\lambda}{\lambda+\alpha_2}$, $p_{20}=\frac{a\alpha_2}{\lambda+\alpha_2}$, $p_{21}^{(8)}=\frac{a\lambda}{\lambda+\alpha_2}$, $p_{28}=\frac{\lambda}{\lambda+\alpha_2}$, $p_{30}=a$, $p_{36}=1-a$,

$p_{40}=1$, $p_{50}=\frac{\alpha_4}{\lambda+\alpha_4}$, $p_{60}=1$, $p_{57}=\frac{\lambda}{\lambda+\alpha_4}$, $p_{71}=1$, $p_{51}^{(7)}=\frac{\lambda}{\lambda+\alpha_4}$, $p_{91}=1$,

$\mu_0=\frac{1}{\lambda+\alpha}$, $\mu_1=\frac{1}{\alpha_1}$, $\mu_2=\frac{1}{\alpha_2+\lambda}$, $\mu_3=\frac{1}{\alpha_2}$, $\mu_4=\frac{1}{\alpha_3}$, $\mu_5=\frac{1}{\alpha_4+\lambda}$, $\mu_6=\frac{1}{\alpha_4}$,

$\mu_9=\frac{1}{\alpha_4}$, $K_2=\frac{1}{\alpha_2+\lambda}$, $K_3=\frac{a}{\alpha_2}+\frac{(1-a)\alpha_2}{(\lambda+\alpha_2)^2}$, $K_5=\frac{1}{\alpha_4+\lambda}$, $K_8=\frac{(1-a)}{\alpha_2}-\frac{(1-a)\alpha_2}{(\lambda+\alpha_2)^2}$

Measures Effectiveness of System of Model 2

Fig.2 shows various states of Model2, here 0, 1, 2, 3, 4, 5, 6, 9, 10, 11, 12 and 13 are regenerative states and 7, 8 and 9 are failed states 10, 11, 12 and 13 are down states and inspection is going on. State 1, 3, 4, and 6 are down states as operable unit is put to down mode. State 2 and 5 are in upstate but working is going on in single cycle.

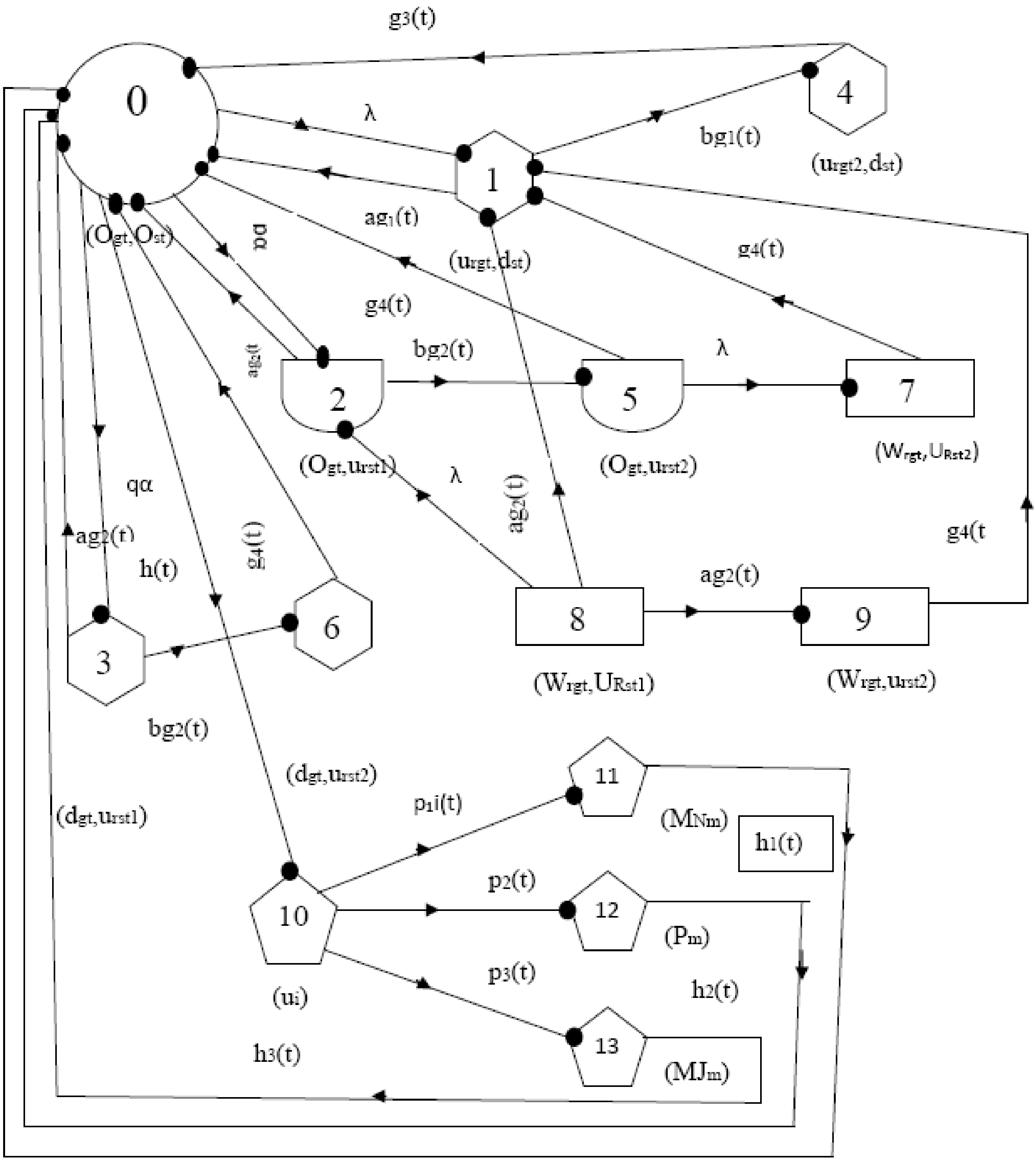

Fig.2 State Transition Diagram

Total Expected Profit 2 = $C_0A_0+C_{01}A_0^{(s)}-C_{11}MI_0-C_{12}PI_0-C_{13}MJ_0-C_{21}B_0^{I} - C_{22}B_0^{II} - C_{31}V_0^{I} - C_{32}V_0^{II}$

C_0 = Revenue per unit time when system working with full capacity

C_{01} = Revenue per unit time when system is working in single cycle

C_{11} = Cost per unit time in which the system is working under minor inspection

C_{12} = Cost per unit time in which the system is undergone for path inspection

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C_{13} = Cost per unit time in which the system is working under major inspection

C_{21} = Cost per unit time for engaging the ordinary repairman for doing repair

C_{22} = Cost per unit time for engaging the expert repairman for doing repair

C_{31} = Cost per visit of the ordinary repairman

C_{32} = Cost per visit of the expert repairman

$A_0 = \frac{\mu 0}{D_1}$, $A_0^{(s)} = \frac{p02\,(\mu 2 - p25\mu 5)}{D_1}$, $MI_0 = \frac{p0,10p10,11\mu 113}{D_1}$, $PI_0 = \frac{p0,10p10,12\mu 12}{D_1}$,

$MJ_0 = \frac{p0,10p10,13\mu 13}{D_1}$, $B_0^I = \frac{\mu 1[p01+p21(8)+p02p29(8)-p02p25p51(7)]+p02\mu 2+p03\mu 3}{D_1}$

$B_0^{II} = \frac{p01p14+p02p14\mu 4[p29(8)+p21(8)+p25p51(7)]+\mu 6[p02p25+p03p36+p02p29(8)]}{D_1}$

$V_0^I = \frac{1}{D_1}$, $V_0^{II} = \frac{p03p36+p01p14+p02(p25+p29(8))+p02p14(p21(8)+p29(8)+p25p51(7))}{D_1}$

$D_1=\mu_0+p_{01}\mu_1+p_{01}p_{14}\mu_4+p_{03}\mu_3+p_{03}p_{36}\mu_6+p_{02}[K_3+\mu_1(p_{21}^{(8)}+p_{25}p_{51}^{(7)})+p_{14}\mu_4(p_{21}^{(8)}+p_{29}^{(8)}+p_{25}p_{51}^{(7)})$

$+p_{29}^{(8)}(\mu_6+\mu_1)+K_8+p_{25}\mu_6]+p_{0,10}[p_{10,13}\mu_{13}+p_{10,12}\mu_{12}+p_{10,11}\mu_{11}+\mu_{10}]$

$p_{01}=\frac{\lambda}{\lambda+\alpha+\beta}$, $p_{02}=\frac{p\alpha}{\lambda+\alpha+\beta}$, $p_{03}=\frac{(1-p)\alpha}{\lambda+\alpha+\beta}$, $p_{0,10}=\frac{\beta}{\beta+\lambda+\alpha}$, p_{10} = a, p_{14} = 1-a

$p_{25}=\frac{(1-a)\delta_2}{\lambda+\delta_2}$, $p_{29}^{(8)}=\frac{(1-a)\lambda}{\lambda+\delta_2}$, $p_{20}=\frac{a\delta_2}{\lambda+\delta_2}$, $p_{21}^{(8)}=\frac{a\lambda}{\lambda+\delta_2}$, $p_{28}=\frac{\lambda}{\lambda+\delta_2}$,

p_{30} = a, p_{36} = 1-a, p_{40} = 1, $p_{50}=\frac{\delta_4}{\lambda+\delta_4}$, p_{60} = 1, $p_{57}=\frac{\lambda}{\lambda+\delta_4}$, p_{71} = 1, $p_{12,0}$ = 1,

$p_{51}^{(7)}=\frac{\lambda}{\lambda+\delta_4}$, p_{91} = 1, $p_{10,11}=p_1$, $p_{10,12}=p_2$, $p_{10,13}=p_3$, $p_{11,0}$ =1, $p_{13,0}$ =1

$\mu_0=\frac{1}{\lambda+\alpha+\beta}$, $\mu_1=\frac{1}{\delta_1}$, $\mu_2=\frac{1}{\delta_2+\lambda}$, $\mu_3=\frac{1}{\delta_2}$, $\mu_4=\frac{1}{\delta_3}$, $\mu_5=\frac{1}{\delta_4+\lambda}$

$\mu_6=\frac{1}{\delta_4}$, $\mu_9=\frac{1}{\delta_4}$, $\mu_{10}=\frac{1}{\gamma}$, $\mu_{11}=\frac{1}{\gamma_4}$, $\mu_{12}=\frac{1}{\gamma_5}$, $\mu_{13}=\frac{1}{\gamma_6}$

$K_1=\frac{a}{\delta_2}+\frac{(1-a)\delta_2}{(\lambda+\delta_2)^2}$, $K_2=\frac{1}{\delta_2+\lambda}$, $K_5=\frac{1}{\delta_4+\lambda}$

$K_3=\frac{a}{\delta_2}-\frac{a\delta_2}{(\lambda+\delta_2)^2}$, $K_8=\frac{(1-a)}{\delta_2}+\frac{a\delta_2}{(\lambda+\delta_2)^2}$

Relative Analysis of Two Models

Fig.3 shows the nature of difference of profits (Profit1-Profit2) vs revenue cost in combined cycle (C_0) with distinct cost values of ordinary repairman's busy period (C_{21}). It is clear from graph that when revenue cost in combined cycle (C_0) increases, the PROFIT1-PROFIT2 decreases having higher values for higher values of cost of busy period by ordinary repairman.

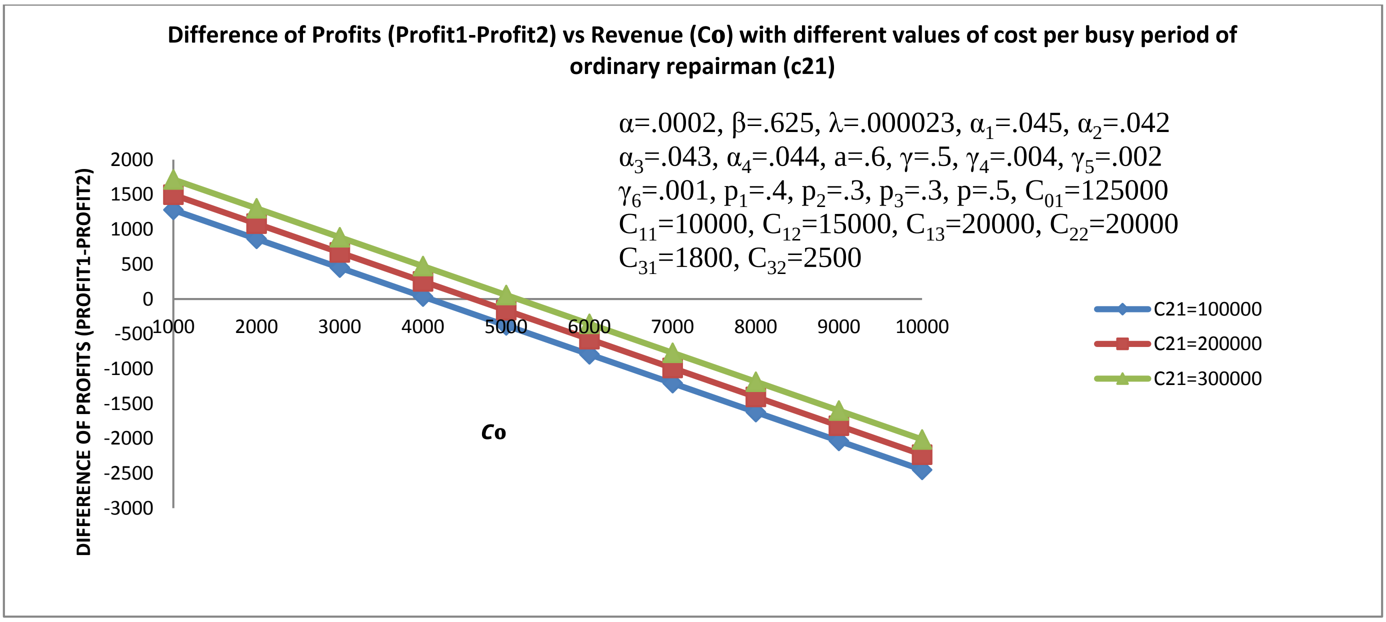

Figure 3

Figure 4 sketch the difference of profits (PROFIT1-PROFIT2) versus revenue cost in single cycle (C_{01}) with different cost values per visit by expert repairman (C_{32}). It shows that revenue cost in single cycle (C_{01}) increases the difference in profits decreases and have greater values of cost per visit by expert repairman C_{32}.

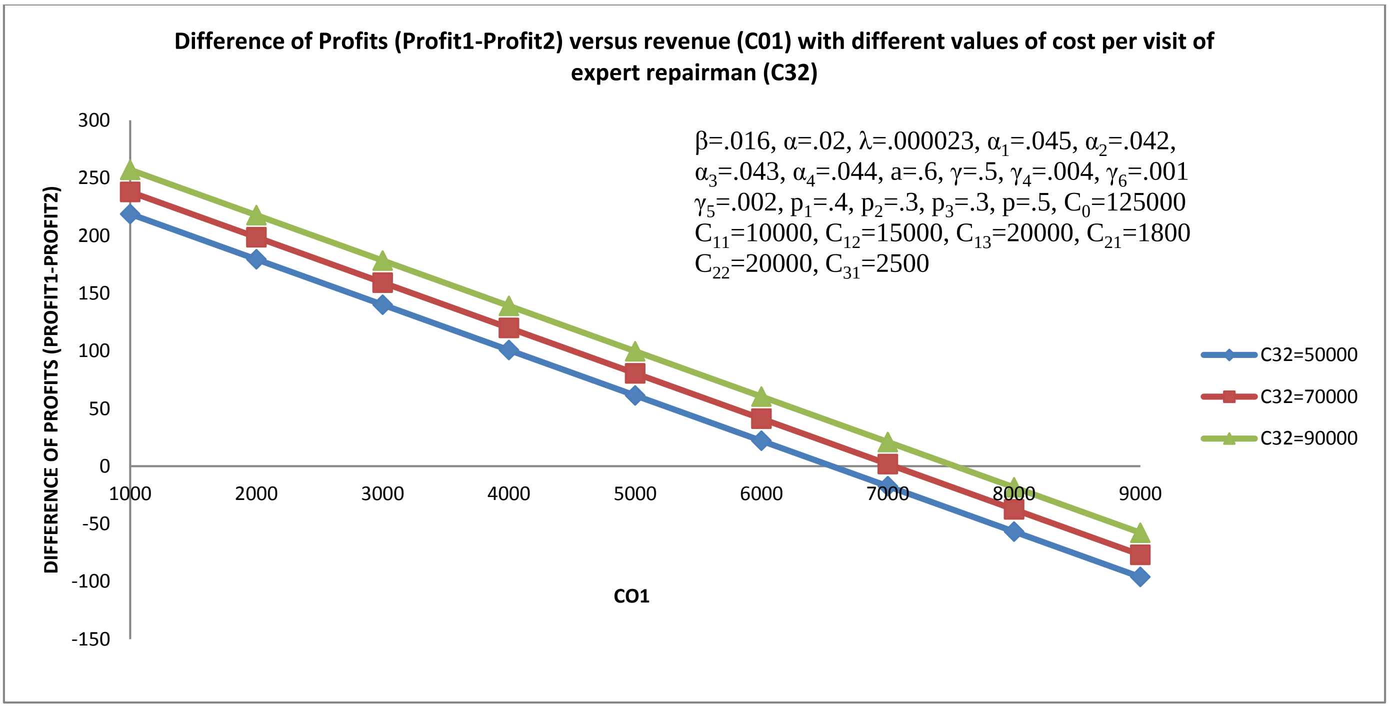

Figure 4

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Figure 5 shows the profit (Profit1,Profit 2) versus requirement of probability for Minor Inspection (p_1) .

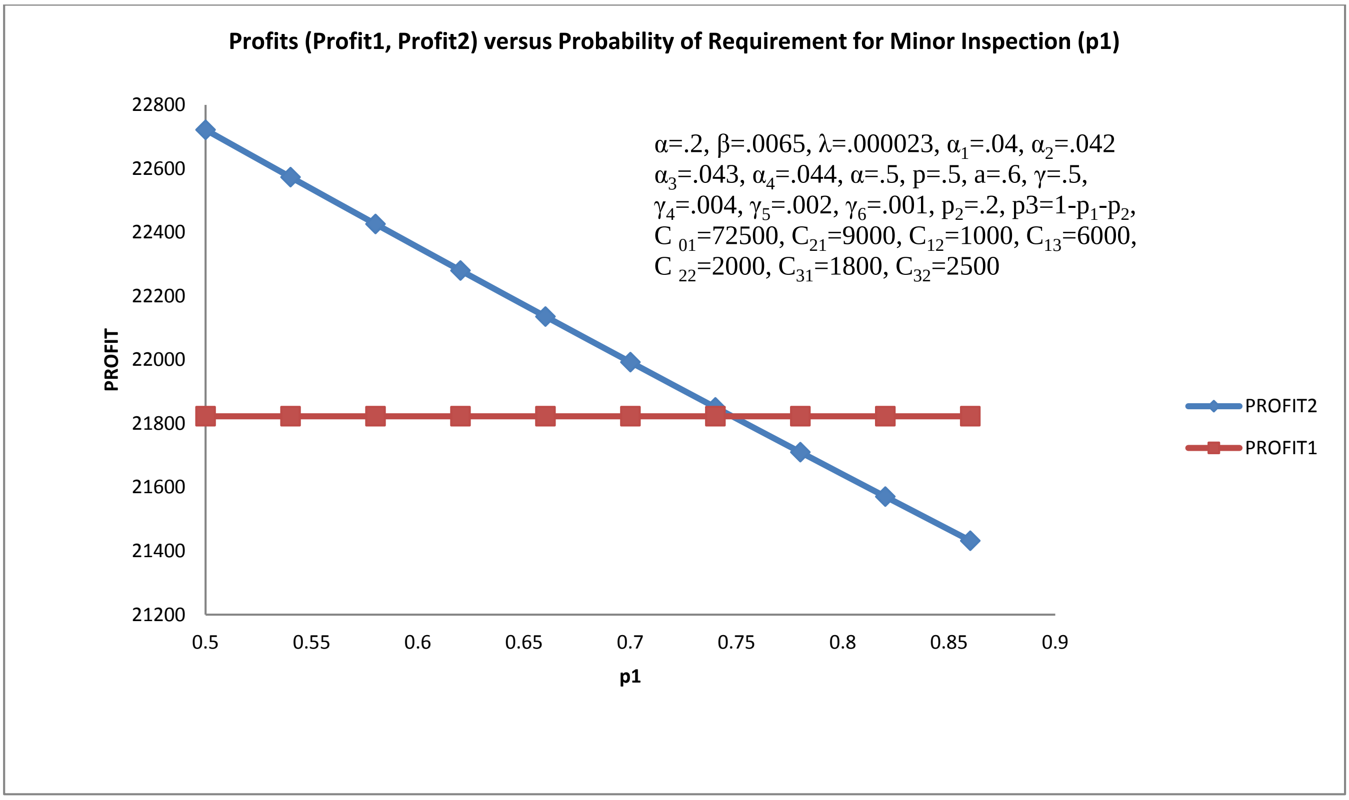

Figure 5

Figure 6 depicts the behavior of profits (Profit 1, Profit 2) with respect to probability of requirement for path inspection (p_1).

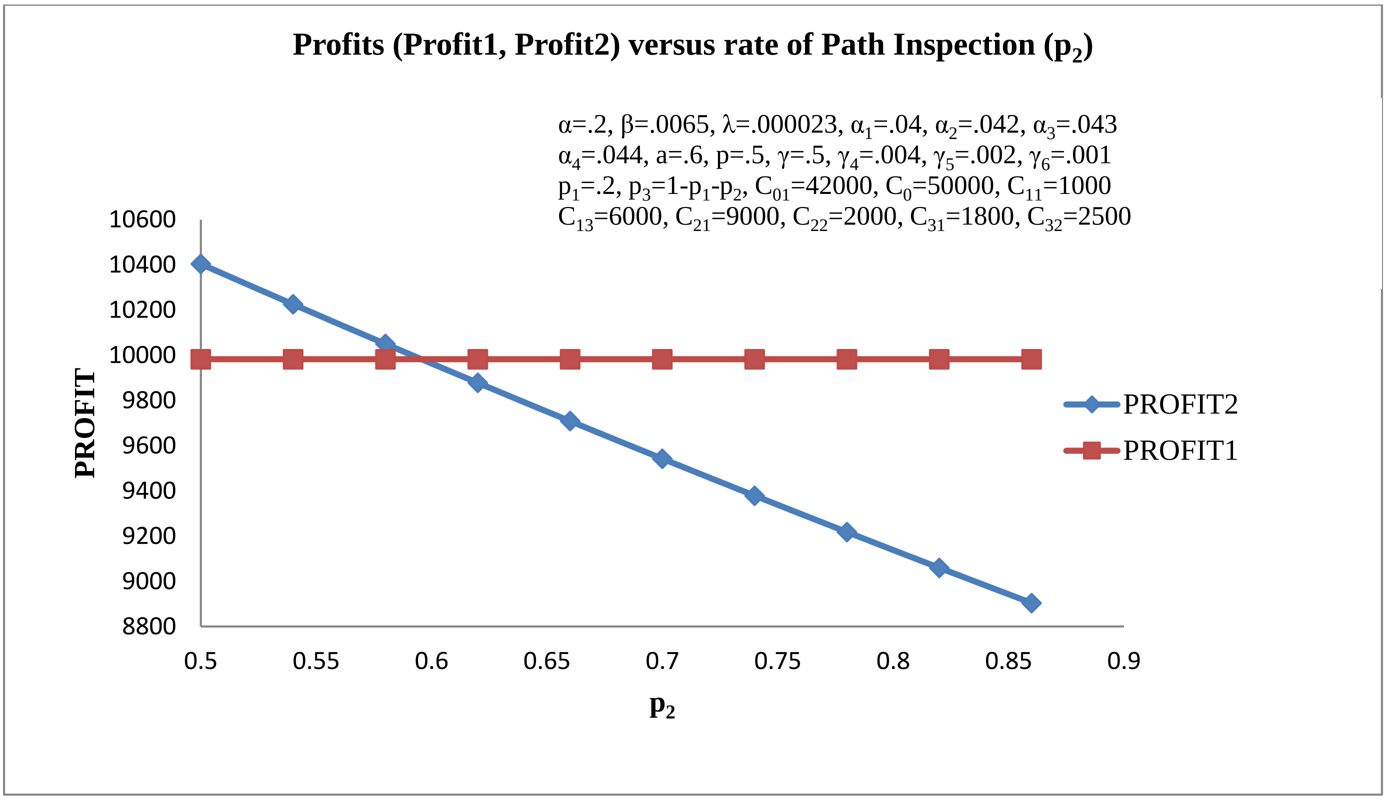

Figure 6

Table 1. Relative Analysis of Model 1 and Model 2

Figure Number	Comparison with respect to	Which Model is better in which situation		
		Model 1 is Better if	Model 2 is Better if	Both are equally good
3	Cost of revenue (C_0) with full capacity When C_{21}=100000 C_{21}=200000 C_{21}=300000	C_0< 4,331.22 C_0<4,499.52 C_0<5,499.52	C_0>4,331.22 C_0>4,499.52 C_0>5,499.52	C_0=4,331.22 C_0=4,499.52 C_0=5,499.52
4	Cost of revenue (C_{01}) in single cycle When C_{32}=50000 C_{32}=70000 C_{32}=90000	C_{01}<6,499.52 C_{01}<7,046.52 C_{01}<7,499.52	C_{01}>6,499.52 C_{01}>7,046.52 C_{01}>7,499.52	C_{01}=6,499.52 C_{01}=7,046.52 C_{01}=7,499.52
5	Minor Inspection (p_1)	p_1>0.74705	p_1<0.74705	p_1=0.74705
6	Path Inspection (p_2)	p_2>0.59557	p_2<0.59557	p_2=0.59557

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