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A Realibility Model of Two- Unit Non-identical Cold Standby System under the Influence of Snow Storm Causing Rescue Operation

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Abstract

This paper, presents mathematical model to predict two unit non-identical cold standby system under snowstorm as abnormal weather conditions. Failed unit cannot be possible to make operative directly, so after snowstorm is over, rescue operation starts first digging out start after complete the digging out snow removing starts and then hospitalization of the system starts as repair. Failure rates of system due to snowstorm as constant while repair time distribution are general. Semi-Markov process and the technique of regenerative point are applied to get mean time to system failure and others reliability characteristics.

Keywords: Non-identical cold stand by system, rescue operation, snow removing, hospitalization.

INTRODUCTION

In literature, various researchers have discussed the concepts of reliability modeling of standby systems including [1-4].Wang 2009 [5] and Wang 2012 [6] describes comparative analysis of the availability between systems. Yusuf 2015 studied modeling and availability and assessment of a reliable system subject to slight deterioration in case of imperfect repairs[7] .

The climate has a major impact on system performance. It is said that the climatic conditions that have a great effect on the system component are abnormal meteorological conditions, just like as high snow, high temperatures, dust storm, thunderstorms, heavy rainfall.Connections can be distributed in anomalous weather conditions when television antennas, etc. storms The study of the effects of climate on systems had aroused the curiosity of several researchers depend upon the reliability, among which Goel et al. [8], Gupta and Goel [9] and Goel, Kumar and Rastogi [10] have explained reliability measures of systems with various weather conditions. Nailwal and Singh [12] analyzed reliability and sensitivity in different weather conditions. Sheetal, Singh and Taneja[13] studied reliability and profit of a system effect of temperature on operation.

Singh ,N. et al. [11] discuss the paper for identical system in snowstorms as abnormal weather conditions .Taking into account the facts and situations of paper [11] in this paper we consider the snowstorms as a abnormal weather condition for two unit non-identical cold standby system. Failed unit cannot be possible to make operative directly, so after snowstorm is over, rescue operation starts first digging out start after complete the digging out snow removing starts and then hospitalization of the system starts as repair. Mean time to system failure, availability analysis, busy period analysis of rescue team during digging out, snow removing and hospitalization and profit analysis are computed.

The following are the assumption for the model:

- Non- identical units are considered
- cold stand by system
- the unit of the system fail due to snow strom
- first the failed unit digging out from snow storm after the excavation snow removing starts after then hospitalization for repairs
- the unit becomes operative after complete the hospitalization

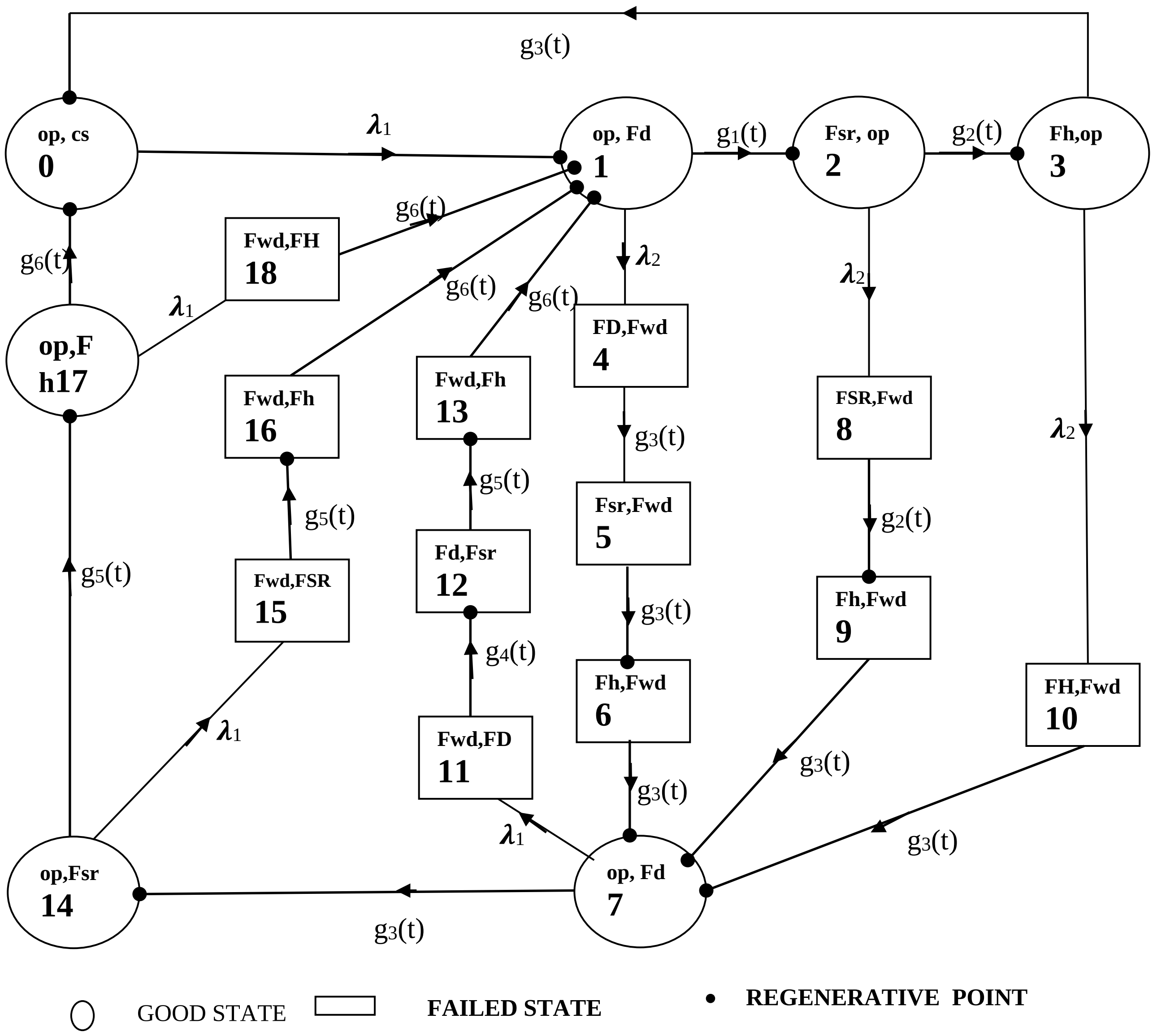

Figure 1. State Transition Diagram

2. NOTATIONS

λ	Failure rate of operative unit due to snow strom
⬭	up state
▭	failed state
$G_1(t)$, $G_2(t)$, $G_3(t)$, $g_1(t)$ $g_2(t)$ $g_3(t)$:	Cumulative density function and probability density function of the rate of digging out, snow removing and hospitability time of first failed unit respectively.
$G_4(t)$, $G_5(t)$, $G_6(t)$, $g_4(t)$ $g_5(t)$ $g_6(t)$:	Cumulative density function and probability density function of the rate of digging out, snow removing and hospitability time of second failed unit respectively.

Op	operative unit
cs	cold standby
Fd	failed unit is under digging out
FD	failed unit is under digging out continuing on the unit
Fsr	failed unit is under snow removing
FSR	failed unit is under snow removing continuing on the unit
Fh	failed unit is under hospitalization after snow removing
FH	failed unit is under hospitalization continuing after snow removing
Fwd	waiting for digging out

Transition Probabilities :-

In the figure 1. states 4, 8, 10,11,15 and 18 are non-regenerative and remaining others are regenerative states.

$dQ_{01}(t) = \lambda_1 e^{-\lambda_2 t}$dt
$dQ_{12}(t) = e^{-\lambda_2 t} g_1(t)dt$
dQ_{14}(t) $= \lambda_2\ e^{-\lambda_2 t}\ \overline{G}_1$(t) dt
$dQ_{15}^{(4)}$(t) $= (\lambda_2\ e^{-\lambda_2 t} ©1) g_1(t)dt$
$dQ_{23}(t) = e^{-\lambda_2 t} g_2(t)dt$
dQ_{28}(t) $= \lambda_2\ e^{-\lambda_2 t} \overline{G}_2$(t) dt
$dQ_{29}^{(8)} = (\lambda_2\ e^{-\lambda_2 t} ©1) g_2(t)dt$
$dQ_{30}(t) = e^{-\lambda_2 t}\ g_3(t)dt$
dQ_{310}(t) $= \lambda_2\ e^{-\lambda_2 t}\ \overline{G}_3$(t) dt
$dQ_{37}^{(10)}$(t) $= (\lambda_2\ e^{-\lambda_2 t} ©1) g_3(t)dt$
$dQ_{56}(t) = g_2(t)dt$
$dQ_{67}(t) = g_3(t)dt$
dQ_{714}(t) $= e^{-\lambda_1 t}\ g_4(t)$
$dQ_{712}^{(11)}$(t) $= (\lambda_1 e^{-\lambda_1 t} ©1) g_4(t)dt$
$dQ_{97}(t) = g_3(t)dt$
$dQ_{1213}(t) = g_5(t)dt$
$dQ_{131}(t) = g_6(t)dt$
dQ_{1417}(t) $= e^{-\lambda_1 t} g_5(t)$ dt
$dQ_{1416}^{(15)}$(t) $= (\lambda_1 e^{-\lambda_1 t} ©1) g_5(t)dt$
$dQ_{161}(t) = g_6(t)dt$
dQ_{170}(t) $= e^{-\lambda_1 t} g_6(t)$ dt
$dQ_{171}^{(18)}$(t) $= (\lambda_1 e^{-\lambda_1 t} ©1) g_6(t)dt$

Taking Laplace Stieltjes Transformation we get

$p_{ij} = \lim_{t\to\infty} Q_{ij}$(t) $= \lim_{s\to 0} Q_{ij}^{**}$ (s)

p_{01} =1,

$p_{12=} g_1^*(\lambda_2)$, p_{14}= (1- $g_1^*(\lambda_2)$), p_{15}^4= (1- $g_1^*(\lambda_2)$)

$p_{23=} g_2^*(\lambda_2)$, p_{28}= (1- $g_2^*(\lambda_2)$), p_{29}^8= (1- $g_2^*(\lambda_2)$)

$p_{30=} g_3^*(\lambda_2)$, p_{310}= (1- $g_3^*(\lambda_2)$), p_{37}^{10}= (1- $g_3^*(\lambda_2)$)

$p_{56} = g_2^*(0) = 1$

$p_{67} = g_3^*(0) = 1$

$p_{714=} g_4^*(\lambda_1)$, p_{712}^{11}= (1- $g_4^*(\lambda_1)$),

$p_{97} = g_3^*(0) = 1$, $p_{1213} = g_5^*(0) = 1$, $p_{131} = g_6^*(0) = 1$

$p_{1417=} g_5^*(\lambda_1)$, p_{1416}^{15}= (1- $g_4^*(\lambda_1)$), $p_{161} = g_6^*(0) = 1$

$p_{170=} g_6^*(\lambda_1)$, p_{171}^{18}= (1- $g_6^*(\lambda_1)$)

By these transition probabilities, it can be verified that

p_{01}= 1

$p_{12} + p_{15}^{(4)} = p_{12} + p_{14} = 1$

$p_{23} + p_{26}^{(7)} = p_{23} + p_{27} = 1$

$p_{30} + p_{37}^{(10)} = p_{30} + p_{310} = 1$

p_{67}= 1= $p_{56} = p_{91} = p_{1213} = p_{131} = p_{161}$

$p_{714} + p_{712}^{(11)} = p_{1417} + p_{1416}^{(15)} = p_{170} + p_{171}^{(18)} = 1$

μ_i is the mean sojourn time at the regenerative state 'i' then mathematically is defined as

μ_i=E(T)=Pr(T>t)

$\mu_0 = \frac{1}{\lambda_1}$

$\mu_1 = \frac{1}{\lambda_2}\{1- g_1^*(\lambda_2)\}$

$\mu_2 = \frac{1}{\lambda_2}\{1- g_2^*(\lambda_2)\}$

$\mu_3 = \frac{1}{\lambda_2}\{1- g_3^*(\lambda_2)\}$

$\mu_5 = -g_2^{*'}(0)$, $\mu_6 = -g_3^{*'}(0)$,

$\mu_9 = -g_3^{*'}(0)$, $\mu_{12} = -g_5^{*'}(0)$,

$\mu_{13} = -g_6^{*'}(0)$, $\mu_{16} = -g_6^{*'}(0)$,

$\mu_7 = \frac{1}{\lambda_1}\{1- g_4^*(\lambda_1)\}$

$\mu_{14} = \frac{1}{\lambda_1}\{1- g_5^*(\lambda_1)\}$

$\mu_{17} = \frac{1}{\lambda_1}\{1- g_6^*(\lambda_1)\}$

m_{ij} is the unconditional mean time and mathematically is defined as:

$m_{ij} = \int_0^\infty t\ q_{ij}$(t)dt = -$q_{ij}^{*'}(0)$

$m_{01} = \mu_0 = \frac{1}{\lambda_1}$

$m_{12} + m_{15}^4 = -g_1^{*'}(0) = k_1$(say), $m_{12} + m_{14} = \mu_1$

$m_{23} + m_{29}^8 = -g_2^{*'}(0) = k_2(say)$, $m_{27} + m_{23} = \mu_2$

$m_{30} + m_{37}^{10} = -g_3^{*'}(0) = k_3(say)$, $m_{30} + m_{310} = \mu_3$

$m_{714} + m_{712}^{11} = -g_4^{*'}(0) = k_4(say)$,

$m_{1417} + m_{1416}^{15} = -g_5^{*'}(0) = k_5(say)$,

$m_{170} + m_{171}^{18} = -g_6^{*'}(0) = k_6(say)$,

$m_{67} = k_3$, $m_{56} = k_2$, $m_{97} = k_3$, $m_{1213} = k_5$, $m_{131} = k_6$

$m_{161} = k_6$,

4. ANALYSIS OF MEAN TIME TO SYSTEM FAILURE

Applying the concept of regenerative processes and consider the failed states as absorbing states the following recursive relation for $\phi_i(t)$ are obtained

$$\phi_0(t) = Q_{01}(t) Ⓢ \phi_1(t)$$
$$\phi_1(t) = Q_{14}(t) + Q_{12}(t) Ⓢ \phi_2(t)$$
$$\phi_2(t) = Q_{28}(t) + Q_{23}(t) Ⓢ \phi_3(t)$$
$$\phi_3(t) = Q_{310}(t) + Q_{30}(t) Ⓢ \phi_0(t)$$

these non homogenous system of equation can be solved by using Laplace- Stieltjes Transforms (L.S.T) and matrix method for $\phi_0^{**}(s) = \frac{N(S)}{D(S)}$

Where,

$$N(S) = Q_{01}^{**}(s)(Q_{14}^{**}(s)+ Q_{12}^{**}(s)\, Q_{23}^{**}(s)\, Q_{310}^{**}(s)+ Q_{12}^{**}(s)\, Q_{28}^{**}(s))$$
$$D(S)=1-Q_{01}^{**}(s)\; Q_{12}^{**}(s)\, Q_{23}^{**}(s)\, Q_{30}^{**}(s)$$

Now, MTSF from the state '0' is

$$T_0 = \lim_{s\to 0} \frac{1-\phi_0^{**}(s)}{s} = \lim_{s\to 0} \frac{1-\frac{N(S)}{D(S)}}{s} = \lim_{s\to 0} \frac{D(s)-N(s)}{sD(s)} = \frac{D'(0)-N'(0)}{D(0)} = \frac{N}{D}$$

Where $N = \mu_0 + \mu_1 + p_{12}\mu_2 + p_{12}p_{23}\mu_3$

And

$D=1-p_{12}p_{23}p_{30}$

5. AVAILABILITY ANALYSIS

$A_i(t)$ denotes availability and by using the probability theory the following relations are obtained.

$$A_0(t) = M_0(t)+ q_{01}(t)© A_1(t)$$
$$A_1(t) = M_1(t) + q_{12}(t)© A_2(t) +q_{15}^{(4)}(t))© A_5(t)$$
$$A_2(t) = M_2(t) + q_{23}(t)© A_3(t) +q_{29}^{(8)}(t))© A_9(t)$$
$$A_3(t) = M_3(t) + q_{30}(t)© A_0(t) +q_{37}^{(10)}(t))© A_7(t)$$
$$A_5(t) = q_{56}(t) © A_6(t)$$
$$A_6(t) = q_{67}(t) © A_7(t)$$
$$A_7(t) = M_7(t) + q_{714}(t)© A_{14}(t) +q_{37}^{(10)}(t))© A_7(t)$$
$$A_9(t) = q_{97}(t) © A_7(t)$$
$$A_{12}(t) = q_{1213}(t) © A_{13}(t)$$
$$A_{13}(t) = q_{131}(t) © A_1(t)$$
$$A_{14}(t) = M_{14}(t) + q_{1417}(t)© A_{17}(t) +q_{1416}^{(15)}(t))© A_{16}(t)$$
$$A_{16}(t) = q_{161}(t) © A_1(t)$$
$$A_{17}(t) = M_{17}(t) + q_{170}(t)© A_0(t) +q_{171}^{(18)}(t))© A_1(t)$$

Where

$M_0(t)= e^{-\lambda_1 t}dt$, $M_1(t)= e^{-\lambda_2 t}\overline{G_1}(t)dt$, $M_2(t)= e^{-\lambda_2 t}\overline{G_2}(t)dt$,

$M_3(t)= e^{-\lambda_2 t}\overline{G_3}(t)dt$, $M_7(t)=e^{-\lambda_2 t}\overline{G_4}(t)dt$,
$M_{14}(t)=e^{-\lambda_2 t}\overline{G_5}(t)dt$, $M_{17}(t)=e^{-\lambda_2 t}\overline{G_6}(t)dt$

These non homogenous system of equation can be solved by using Laplace Transforms (L.T.) and matrix method for $A_0^*(s)$, we obtain

$$A_0^*(s)= \frac{N_1(s)}{D_1(s)}$$

Where,

$$N_1(s) = M_0^*(s)+ M_1^*(s)$$
$$q_{01}^*(s)+M_2^*(s)q_{01}^*(s)q_{12}^*(s) + M_3^*(s)q_{01}^*(s)q_{12}^*(s)q_{23}^*(s) -$$
$$M_0^*(s)q_{12}^*(s)q_{23}^*(s)q_{15}^{*(4)}q_{712}^*(s)q_{1213}^*(s)q_{131}^*(s) -$$
$$M_0^*(s)q_{15}^{*(4)}q_{56}^*(s)q_{67}^*(s)q_{15}^{*(4)}q_{1213}^*(s)q_{131}^*(s) + M_{14}^*(s)q_{01}^*(s)q_{12}^*(s)q_{23}^*(s)q_{15}^{*(4)}q_{714}^*(s) -$$
$$q_{15}^{*(4)}(s)\, q_{56}^*(s)\, q_{61}^*(s)) -M_0^*(s)q_{12}^*(s)q_{26}^{*(7)}(s)\, q_{61}^*(s) - q_{12}^*(s)q_{23}^*(s)q_{31}^{*(8)}M_0^*(s) + M_1^*(s)q_{01}^*(s) +$$
$$q_{01}^*(s)q_{12}^*(s)M_2^*(s)+q_{01}^*(s)q_{12}^*(s)q_{23}^*(s)M_3^*(s)$$
$$D_1(s) =1 - q_{15}^{*(4)}(s)\, q_{56}^*(s)\, q_{61}^*(s) - q_{12}^*(s)q_{26}^{*(7)}(s)q_{61}^*(s) - q_{01}^*(s)q_{12}^*(s)q_{23}^*(s)q_{30}^*(s)-$$
$$q_{12}^*(s)q_{23}^*(s)q_{31}^{*(8)}(s)$$
$$M_{17}^*(s)q_{01}^*(s)q_{12}^*(s)q_{23}^*(s)q_{714}^*(s)q_{1417}^*(s) - M_0^*(s)q_{12}^*(s)q_{23}^*(s)q_{714}^*(s)q_{161}^*(s)$$
$$- M_0^*(s)q_{12}^*(s)q_{23}^*(s)q_{714}^*(s)q_{1417}^*(s)q_{171}^*(s)$$
$$+ M_{14}^*(s)q_{01}^*(s)q_{56}^*(s)q_{67}^*(s)q_{714}^*(s)$$
$$+ M_{17}^*(s)q_{01}^*(s)q_{56}^*(s)q_{67}^*(s)q_{714}^*(s)q_{1417}^*(s) - q_{12}^*(s)q_{12}^*(s)q_{12}^*(s)q_{12}^*(s)q_{12}^*(s)$$

The steady state availability of the system is given by

$$A_0 = \lim_{s\to 0}(sA_0^*(s)) = \lim_{s\to 0}\left(s\frac{N_1(s)}{D_1(s)}\right) = \frac{N_1(0)}{D_1'(0)} = \frac{N_1}{D_1}$$

$$N_1 = \mu_3 p_{12}p_{23} + \mu_1 + \mu_2 p_{12} + \mu_0 p_{12}p_{23}p_{30}$$
$$D_1 = k_1 + p_{12}k_2 + \mu_0 p_{12}p_{20} + \mu_0 p_{12}p_{23}p_{30} + p_{12}p_{23}k_3 + p_{15}^{(4)}(\mu_5 + \mu_6) + p_{12}p_{26}^{(7)}\mu_6$$

Where, k_1, k_2 and k_3 already mentioned.

6. BUSY PERIOD ANALYSIS OF RESCUE TEAM DURING DIGGING OUT

B_i^R (t) = Probability that rescue team is busy during digging out at instant t, when system entered regenerative state I at t=0,

$$B_0^R(t) = q_{01}(t) © B_1^R(t)$$
$$B_1^R(t) = W_1(t) + q_{12}(t) © B_2^R(t) +q_{15}^{(4)}(t))© B_5^R(t)$$
$$B_2^R(t) = q_{23}(t) © B_3^R(t) +q_{26}^{(7)}(t))© B_6^R(t)$$
$$B_3^R(t) = q_{30}(t) © B_0^R(t) +q_{31}^{(8)}(t))© B_1^R(t)$$
$$B_5^R(t) = q_{56}(t) © B_6^R(t)$$
$$B_6^R(t) = q_{61}(t) © B_1^R(t)$$
$$B_7^R(t) = W_7(t) + q_{714}(t) © B_{14}^R(t) +q_{712}^{(11)}(t))© B_{12}^R(t)$$
$$B_9^R(t) = q_{97}(t) © B_7^R(t)$$
$$B_{12}^R(t) = q_{1213}(t) © B_{13}^R(t)$$
$$B_{13}^R(t) = q_{131}(t) © B_1^R(t)$$
$$B_{14}^R(t) = q_{1417}(t) © B_{17}^R(t) +q_{1416}^{(15)}(t))© B_{16}^R(t)$$
$$B_{16}^R(t) = q_{161}(t) © B_1^R(t)$$
$$B_{17}^R(t) = q_{170}(t) © B_0^R(t) +q_{171}^{(18)}(t))© B_1^R(t)$$

Where $W_1(t)= e^{-\lambda t}\overline{G_1}(t)dt+\lambda\, e^{-\lambda t}\overline{G_1}(t)dt$ and $W_7(t)= e^{-\lambda t}\overline{G_4}(t)dt+\lambda\, e^{-\lambda t}\overline{G_4}(t)dt$

these non homogenous system of equation can be solved by using Laplace Transforms (L.T.) and matrix method for

B_0^{*R} (s), we obtain

$$B_0^{*R}(s)= \frac{N_2(s)}{D_1(s)}$$

Where

$N_2(s)= q_{01}^*(s)\, W_1^*(s)$

And $D_1(s)$ is already mentioned.

$B_0 = \lim_{s\to 0}(sB_0^{*R}s)) = \lim_{s\to 0}(s\frac{N_2(s)}{D_1(s)}) = \frac{N_2(0)}{D_1^{'}(0)} = \frac{N_2}{D_1}$

Where,

N_2=W$_1$

WhereW_1=W_1^*(0) and D_1 is already specified.

7. BUSY PERIOD ANALYSIS OF RESCUE TEAM DURING SNOW REMOVING IN RESCUE OPERATION

B_i^{SC} (t) = Probability that the rescue team is busy under snow cutting/removing operation at instant t, given that the system entered regenerative state i at t=0,

$B_0^{SC}(t) = q_{01}(t) © B_1^{SC}(t)$
$B_1^{SC}(t) = q_{12}(t) © B_2^{SC}(t) + q_{15}^{(4)}(t)) © B_5^{SC}(t)$
$B_2^{SC}(t) = W_2(t) + q_{23}(t) © B_3^{SC}(t) + q_{26}^{(7)}(t)) © B_6^{SC}(t)$
$B_3^{SC}(t) = q_{30}(t) © B_0^{SC}(t) + q_{31}^{(8)}(t)) © B_1^{SC}(t)$
$B_5^{SC}(t) = W_5(t) + q_{56}(t) © B_6^{SC}(t)$
$B_6^{SC}(t) = q_{61}(t) © B_1^{SC}(t)$
$B_7^{SC}(t) = W_7(t) + q_{714}(t) © B_{14}^{SC}(t) + q_{712}^{(11)}(t)) © B_{12}^{SC}(t)$
$B_9^{SC}(t) = q_{97}(t) © B_7^{SC}(t)$
$B_{12}^{SC}(t) = W_{12}(t) + q_{1213}(t) © B_{13}^{SC}(t)$
$B_{13}^{SC}(t) = q_{131}(t) © B_1^{SC}(t)$
$B_{14}^{SC}(t) = W_{14}(t) + q_{1417}(t) © B_{17}^{SC}(t) + q_{1416}^{(15)}(t)) © B_{16}^{SC}(t)$
$B_{16}^{SC}(t) = q_{161}(t) © B_1^{SC}(t)$
$B_{17}^{SC}(t) = q_{170}(t) © B_0^{SC}(t) + q_{171}^{(18)}(t)) © B_1^{SC}(t)$

Where W_2(t)= $e^{-\lambda_2 t}\overline{G_2}$(t)dt+$\lambda_2$ $e^{-\lambda_2 t}\overline{G_2}$(t)dt , W_5(t)= $\overline{G_2}$(t)dt,

W_{14}(t)= $e^{-\lambda_2 t}\overline{5}$(t)dt+$\lambda_1$ $e^{-\lambda_1 t}\overline{G_5}$(t)dt and W_{12}(t)= $\overline{G_5}$(t)dt

these non homogenous system of equation can be solved by using Laplace Transforms (L.T.) and matrix method for B_0^{*sc} (s), we obtain

B_0^{*sc} (s)= $\frac{N_3(s)}{D_1(s)}$

Where

$N_3(s)$= $q_{01}^*(s)$ $q_{15}^{*(4)}(s)$ $W_5^*(s)$ +$q_{01}^*(s)q_{12}^*(s)$ $W_2^*(s)$

And $D_1(s)$ is already mentioned.

$B_0^{sc} = \lim_{s\to 0}(sB_0^{*sc}(s)) = \lim_{s\to 0}(s\frac{N_3(s)}{D_1(s)}) = \frac{N_3(0)}{D_1^{'}(0)} = \frac{N_3}{D_1}$

Where,

N_3=$W_5 p_{15}^{(4)} + p_{12}W_2$

Where W_2=W_2^*(0) , W_5=W_5^*(0) and D_1 is already mentioned.

8. BUSY PERIOD ANALYSIS OF RESCUE TEAM DURING HOSPITALIZATION IN RESCUE OPERATION

B_i^H (t) = Probability that rescue team is busy during hospitalization given that the system entered regenerative state i at t=0,

$B_0^H(t) = q_{01}(t) © B_1^H(t)$
$B_1^H(t) = q_{12}(t) © B_2^H(t) + q_{15}^{(4)}(t)) © B_5^H(t)$
$B_2^H(t) = q_{23}(t) © B_3^H(t) + q_{26}^{(7)}(t)) © B_6^H(t)$
$B_3^H(t) = W_3(t) + q_{30}(t) © B_0^H(t) + q_{31}^{(8)}(t)) © B_1^H(t)$
$B_5^H(t) = q_{56}(t) © B_6^H(t)$
$B_6^H(t) = W_6(t) + q_{61}(t) © B_1^H(t)$
$B_7^H(t) = q_{714}(t) © B_{14}^H(t) + q_{712}^{(11)}(t)) © B_{12}^H(t)$
$B_9^H(t) = W_9(t) + q_{97}(t) © B_7^H(t)$
$B_{12}^H(t) = q_{1213}(t) © B_{13}^H(t)$
$B_{13}^H(t) = W_{13}(t) + q_{131}(t) © B_1^H(t)$
$B_{14}^H(t) = q_{1417}(t) © B_{17}^H(t) + q_{1416}^{(15)}(t)) © B_{16}^H(t)$
$B_{16}^H(t) = W_{16}(t) + q_{161}(t) © B_1^H(t)$
$B_{17}^H(t) = W_{17}(t) + q_{170}(t) © B_0^H(t) + q_{171}^{(18)}(t)) © B_1^H(t)$

Where W_3(t)= $e^{-\lambda_2 t}\overline{G_3}$(t)dt+$\lambda_2$ $e^{-\lambda_2 t}\overline{G_3}$(t)dt , W_6(t)= $\overline{G_3}$(t)dt

W_{17}(t)= $e^{-\lambda_2 t}\overline{G_6}$(t)dt+$\lambda_2$ $e^{-\lambda_2 t}\overline{G_6}$(t)dt , W_9(t)= $\overline{G_3}$(t)dt,

W_{13}(t)= $\overline{G_6}$(t)dt and W_{16}(t)= $\overline{G_6}$(t)dt

these non homogenous system of equation can be solved by using Laplace Transforms (L.T.) and matrix method for B_0^{*H} (s), we obtain

B_0^{*H} (s)= $\frac{N_4(s)}{D_1(s)}$

Where

$N_4(s)$= $q_{01}^*(s)q_{12}^*(s)q_{23}^*(s)W_3^*(s) + q_{01}^*(s)\ q_{15}^{*(4)}(s)\ q_{56}^*(s)$ +$q_{01}^*(s)q_{12}^*(s)q_{26}^{*(7)}(s)$ $W_6^*(s)$

And $D_1(s)$ is already mentioned.

$B_0^H = \lim_{s\to 0}(sB_0^{*H}(s)) = \lim_{s\to 0}(s\frac{N_4(s)}{D_1(s)}) = \frac{N_4(0)}{D_1^{'}(0)} = \frac{N_4}{D_1}$

Where,

N_4=$p_{12}p_{23}W_3 + p_{15}^{(4)}p_{56}w_6 + p_{12}p_{26}^{(7)}w_6$

WhereW_3=W_3^*(0) , W_6=W_6^*(0) and D_1 is already mentioned.

9. MEAN NUMBER OF VISITS BY THE REPAIR MAN

We define

$V_0(t)$ = Mean number of visits by the rescue team in (0,t], given that the system started from the regenerative state i at t=0

$V_0(t) = q_{01}(t) \circledS (1+V_1(t))$
$V_1(t) = q_{12}(t) \circledS V_2(t) + q_{15}^{(4)}(t)) \circledS V_5(t)$
$V_2(t) = q_{23}(t) \circledS V_3(t) + q_{26}^{(7)}(t)) \circledS V_6(t)$
$V_3(t) = q_{30}(t) \circledS V_0(t) + q_{31}^{(8)}(t)) \circledS V_1(t)$
$V_5(t) = q_{56}(t) \circledS V_6(t)$
$V_6(t) = q_{61}(t) \circledS V_1(t)$
$V_7(t) = q_{714}(t) \circledS V_{14}(t) + q_{712}^{(11)}(t)) \circledS V_{12}(t)$
$V_9(t) = q_{97}(t) \circledS V_7(t)$
$V_{12}(t) = q_{1213}(t) \circledS V_{13}(t)$
$V_{13}(t) = q_{131}(t) \circledS V_1(t)$
$V_{14}(t) = q_{1417}(t) \circledS V_{17}(t) + q_{1416}^{(15)}(t)) \circledS V_{16}(t)$
$V_{16}(t) = q_{161}(t) \circledS V_1(t)$
$V_{17}(t) = q_{170}(t) \circledS V_0(t) + q_{171}^{(18)}(t)) \circledS V_1(t)$

these non homogenous system of equation can be solved by using Laplace- Stieltjes Transforms (L.S.T) and matrix method for $V_0^{**}(s)$, we obtain

$$V_0^{**}(s) = \frac{N_5(s)}{D_1(s)}$$

Where

$$N_5(s) = Q_{01}^{**}(s) - Q_{01}^{**}(s)\, Q_{12}^{**}(s) Q_{23}^{**}(s) Q_{31}^{**(8)}(s) - Q_{01}^{**}(s)\, Q_{15}^{**(4)}(s)\, Q_{56}^{**}(s) Q_{61}^{**}(s) - Q_{01}^{**}(s) Q_{12}^{**}(s)\;\; Q_{26}^{**(7)}(s) Q_{61}^{**}(s)$$

And $D_1(s)$ is already mentioned

$$V_0 = \lim_{s\to 0}(sV_0^{*}(s)) = \lim_{s\to 0}\left(s\frac{N_5(s)}{D_1(s)}\right) = \frac{N_5(0)}{D_1^{'}(0)} = \frac{N_5}{D_1}$$

Where,

$N_5 = p_{12}p_{23}p_{30}$ and D_1 is above mentioned.

10. COST- BENEFIT ANALYSIS

The total expected benefit for the system in a stable state is given by

$$P = C_0A_0 - C_{11}B_0^R - C_{12}B_0^{SC} - C_{13}B_0^H - C_2V_0$$

Where

C_0 is revenue per unit up time of the system , C_{11}, C_{12}, C_{13} are the cost per unit time for which rescue team is busy during digging out, snow cutting and hospitalization respectively and C_2 is cost per visit of rescue team.

11. NUMERICAL RESULTS

Numerical result for the particular cases the following case is considered.

$g_1(t) = \alpha_1 e^{-\alpha_1 t}$, $g_2(t) = \alpha_2 e^{-\alpha_2 t}$ and $g_3(t) = \alpha_3 e^{-\alpha_3 t}$

$g_4(t) = \alpha_4 e^{-\alpha_4 t}$, $g_5(t) = \alpha_5 e^{-\alpha_5 t}$ and $g_6(t) = \alpha_6 e^{-\alpha_6 t}$

12. GRAPHICAL INTERPRETATION

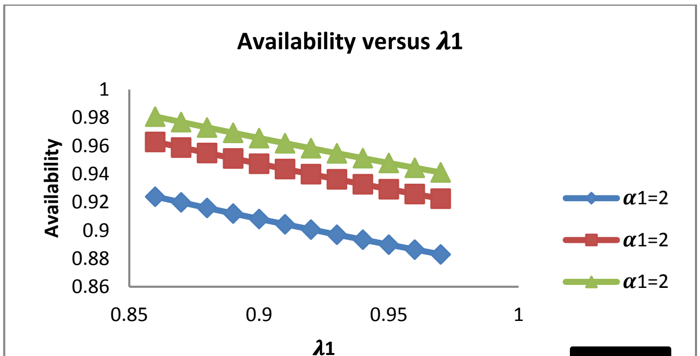

Fig.2

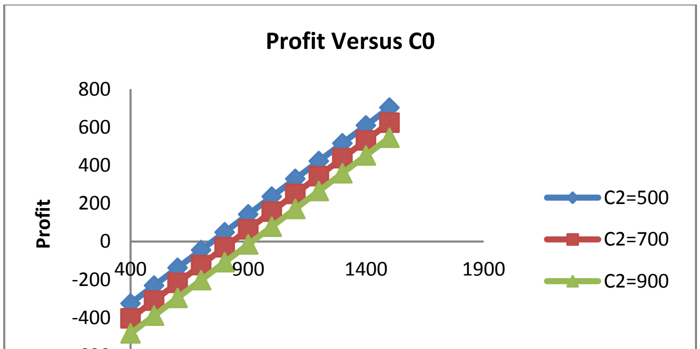

Fig.3.

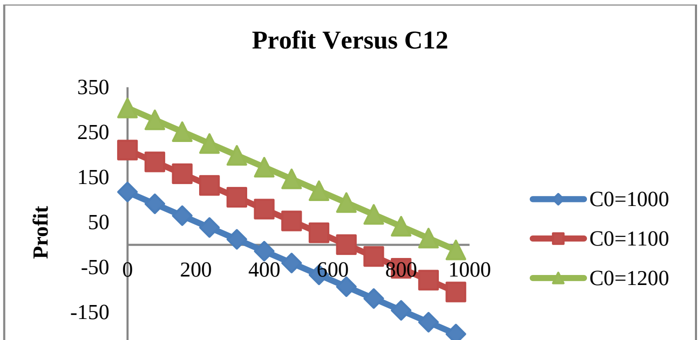

Fig.4.

Figure 2. shows that with increase the failure rate the availability of the system is decreases. Availability has more value to get more value from the repair rate. The aspect of profitability has been studied graphically in relation to

different parameters and using the expressions for various measures of system effectiveness, as shown in Figures 3 to 4.

Fig.No.	Graphs	Other fixed Parameters	Profit		For	Profit≥0
			Increases	Decreases		
3	Profit Versus C_0	λ_1=.7, λ_2=.9, α_1=1.5,α_2=2, α_3=3, α_2=3.4, α_5=3.5, α_6=3.6, C_{11}=600,C_{12}=800,C_{13}=900	With increases C_0	With increases C_2	C_2=500	$C_0 \geq 747.021$
					C_2=700	$C_0 \geq 831.85$
					C_2=900	$C_0 \geq 916.17$
4	Profit Versus C_{12}	λ_1=.7, λ_2=.9, α_1=1.5,α_2=2, α_3=3, α_2=3.4, α_5=3.5, α_6=3.6, C_{11}=600, C_{13}=900,C_2=800	With increases C_0	With increases C_{12}	C_0=1000	$C_{12} \leq 356.62$
					C_0=1100	$C_{12} \leq 640.85$
					C_0=1200	$C_{12} \leq 925.148$

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