Research Article

Cost-benefit analysis of a two similar cold standby system with failure due to crash of aircraft caused by communication misunderstanding and dense fog

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Abstract

Tenerife: The Tenerife disaster, which happened on March 27, 1977, remains the accident with the highest number of airliner passenger fatalities. 583 people died when a KLM Boeing 747 attempted to take off without clearance, and collided with a taxiing Pan Am 747 at Los Rodeos Airport on the Canary Island of Tenerife, Spain. There were no survivors from the KLM aircraft; 61 of the 396 passengers and crew on the Pan Am aircraft survived. Pilot error was the primary cause. Due to a communication misunderstanding, the KLM captain thought he had clearance for takeoff. Another cause was dense fog, meaning the KLM flight crew was unable to see the Pan Am aircraft on the runway until immediately prior to the collision. The accident had a lasting influence on the industry, particularly in the area of communication. An increased emphasis was placed on using standardized phraseology in air traffic control (ATC) communication by both controllers and pilots alike, thereby reducing the chance for misunderstandings. As part of these changes, the word "takeoff" was removed from general usage, and is only spoken by ATC when actually clearing an aircraft to take off. We have taken units Failure due to Communication Misunderstanding and due to Dense Fog with failure time distribution as exponential and repair time distribution as General. We have find out MTSF, Availability analysis, the expected busy period of the server for repair when the failure caused due to Failure due to Communication Misunderstanding in (0,t], expected busy period of the server for repair in(0,t], the expected busy period of the server for repair when failure caused due to Dense Fog in (0,t], the expected number of visits by the repairman for failure of units due to Failure due to Communication Misunderstanding in (0,t], the expected number of visits by the repairman for Dense Fog in (0,t] and Cost-Benefit analysis using regenerative point technique[1,3]. A special case using failure and repair distributions as exponential is derived and graphs have been drawn.

Keyword: Cold Standby, Failure due to Bug in Radar and Tracking Software, Failure caused due to Battery problem, MTSF, Availability, Busy period, Cost-Benefit Analysis.

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Received Date: 20/10/2014 Accepted Date: 30/10/2014

Access this article online	
Quick Response Code:	Website: www.statperson.com
	DOI: 30 October 2014

INTRODUCTION

JAL Flight 123: The crash of Japan Airlines Flight 123 on August 12, 1985 is the single-aircraft disaster with the highest number of fatalities: 520 died on board a Boeing 747. The aircraft suffered an explosive decompression from an incorrectly repaired aft pressure bulkhead, which failed in mid flight, destroying most of its vertical stabilizer and severing all of the hydraulic lines, making the 747 virtually uncontrollable. Pilots were able to keep the plane flying for 20 minutes after departure before crashing into a mountain. Remarkably, several people survived, but by the time the Japanese rescue teams arrived at the crash site, all but four had succumbed to their injuries. On November 12, 1996, the world's deadlies mid-air collision was the 1996 Charkhi Dadri mid-air collision involving Saudia Flight 763 and Air Kazakhstan Flight 1907 over Haryana, India. The crash was mainly the result of the Kazakh pilot flying lower than the assigned clearance altitude. All 349 passengers

How to site this article: Ashok Kumar Saini. Cost-benefit analysis of a two similar cold standby system with failure due to crash of aircraft caused by communication misunderstanding and dense fog. *International Journal of Statistika and Mathemtika* Nov 2014 to Jan 2015; 12(1): 50-54. http://www.statperson.com (accessed 01 November 2014).

and crew on board both aircraft died. The Ramesh Chandra Lahoti Commission, empowered to study the causes, recommended the creation of "air corridors" to prevent aircraft from flying in opposite directions at the same altitude. The Civil Aviation Authorities in India made it mandatory for all aircraft flying in and out of India to be equipped with a Traffic Collision Avoidance System (TCAS), setting a world wide precedent for mandatory use of TCAS. In this paper, we have Failure due to Communication Misunderstanding and failure due to Dense Fog which are non-instantaneous in nature. Here, we investigate a two identical cold standby –a system in which offline unit cannot fail. The failure is due to Dense Fog and due to Communication Misunderstanding. When there is Failure due to Dense Fog to less degree, that is, within specified limit, it operates as normal as before but if these are beyond the specified degree the operation of the unit is stopped to avoid excessive damage of the unit and as the Failure due to Dense Fog continues going on some characteristics of the unit change which we call failure of the unit. After failure due to Failure due to Dense Fog the failed unit undergoes repair immediately according to first come first served discipline.

ASSUMPTIONS

1. The system consists of two similar cold standby units. The failure time distributions of the operation of the unit stopped automatically, the Failure due to Communication Misunderstanding and failure caused due to Dense Fog are exponential with rates $\lambda_{1,}\lambda_2$ and λ_3 whereas the repairing rates for repairing the failed system due to Communication Misunderstanding and due to Dense Fog are arbitrary with CDF $G_1(t)$ and $G_2(t)$ respectively.
2. When there is Failure due to Dense Fog to less degree that is within specified limit, it operates as normal as before but if these are beyond the specified degree the operation of the unit is avoided and as the Failure due to Dense Fog continues goes on some characteristics of the unit change which we call failure of the unit.
3. The Failure due to Dense Fog actually failed the units. The Failure due to Dense Fog is non-instantaneous and it cannot occur simultaneously in both the units.
4. The repair facility works on the first fail first repaired (FCFS) basis.
5. The switches are perfect and instantaneous.
6. All random variables are mutually independent.

Symbols for states of the System

Superscripts: O, CS, SO, FCMU, FDF

Operative, cold Standby, Stops the operation, Failure due to **Communication Misunderstanding**, failed due to **Dense Fog** respectively

Subscripts: ndf, udf, cm, ur, wr, uR

No Failure due to **Dense Fog**, under Failure due to **Dense Fog**, **Communication Misunderstanding**, under repair, waiting for repair, under repair continued respectively

Up states: 0, 1, 3;

Down states: 2, 4,5,6,7

STATES OF THE SYSTEM

0(O_{ndf}, CS_{ndf})

One unit is operative and the other unit is cold standby and there is no **Failure due to Dense Fog** in both the units.

1(SO_{udf}, O_{ndf})

The operation of the first unit stops automatically due to **Failure due to Dense Fog** and cold standby unit starts operating with no **Failure due to Dense Fog.**

2(SO_{udf}, $FCMU_{ndf,cm,ur}$)

The operation of the first unit stops automatically Failure due to **Dense Fog** and the other unit fails due to **Communication Misunderstanding** and undergoes repair.

3($FCMU_{ur}$, O_{udf})

The first unit fails due to **Failure due to Communication Misunderstanding** and undergoes repair and the other unit continues to be operative with no **Failure due to Dense Fog.**

4($FCMU_{ur}$, SO_{udf})

The one unit fails due to **Failure due to Communication Misunderstanding** and undergoes repair and the other unit also stops automatically Failure **due to Dense Fog.**

5($FCMU_{uR}$, $FCMU_{wr}$)

The repair of the first unit is continued from state 4 and the other unit failed due to **Failure due to Communication Misunderstanding** is waiting for repair.

6($FCMU_{uR}$, SO_{udf})

The repair of the first unit is continued from state 3 and unit fails **Failure due to Communication Misunderstanding** and operation of other unit stops automatically **Failure due to Dense Fog.**

7($FCMU_{wr}$, $FDF_{bp,\ uR}$)

The repair of failed unit due to **Dense Fog** is continued from state 2 and the first unit is failed due to **Failure due to Communication Misunderstanding** is waiting for repair.

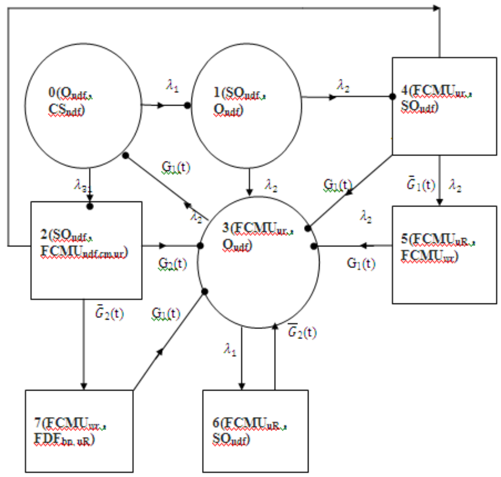

Figure 1: The State Transition Diagram

● Rregeneration point ◯ Up State ☐ Down State

TRANSITION PROBABILITIES

Simple probabilistic considerations yield the following expressions :

$p_{01} = \frac{\lambda 1}{\lambda 1+\lambda 3}$, $p_{02} = \frac{\lambda 3}{\lambda 1+\lambda 3}$

$p_{13} = \frac{\lambda 2}{\lambda 1+\lambda 2}$, $p_{14} = \frac{\lambda 1}{\lambda 1+\lambda 2}$

$p_{23}= \lambda_1 G_2^*(\lambda_2)$, $p_{23}^{(7)} = \lambda_2 G_2^*(\lambda_2)$, $p_{24}= \overline{G}_2^*(\lambda_2)$,

$p_{30}= G_1^*(\lambda_1)$, $p_{33}^{(6)}= \overline{G}_1^*(\lambda_1)$

$p_{43} = G_1^*(\lambda_2)$, $p_{43}^{(5)} = G_1^*(\lambda_2)$ (1)

we can easily verify that

$p_{01} + p_{02} = 1$, $p_{13} + p_{14} = 1$, $p_{23} + p_{23}^{(7)} + p_{24}= 1$, $p_{30} + p_{33}^{(6)} = 1$,

$p_{43}+ P_{43}^{(5)} = 1$ (2)

And mean sojourn time are

$\mu_0 = E(T) = \int_0^\infty P[T > t]dt = -1/\lambda_1$

Similarly

$\mu_1 = 1/\lambda_2$, $\mu_2 = \int_0^\infty e^-\lambda 1\overline{G}1(t)dt$,

$\mu_4 = \int_0^\infty e^-\lambda 2\overline{G}1(t)dt$ (3)

Mean Time To System Failure

We can regard the failed state as absorbing

$\theta_0(t) = Q_{01}(t)[s]\theta_1(t) + Q_{02}(t)$

$\theta_1(t) = Q_{13}(t)[s]\theta_3(t) + Q_{14}(t)$,

$\theta_3(t) = Q_{30}(t)[s]\theta_0(t) + Q_{33}^{(6)}(t)$ (4-6)

Taking Laplace-Stieltjes transforms of eq. (4-6) and solving for

$Q_0^*(s) = N_1(s) / D_1(s)$ (7)

Where

$N_1(s) = Q_{01}^*(s) \{ Q_{13}^*(s) Q_{33}^{(6)*}(s) + Q_{14}^*(s) \} + Q_{02}^*(s)$

$D_1(s) = 1 - Q_{01}^*(s) \quad Q_{13}^*(s) Q_{30}^*(s)$

Making use of relations (1) and (2) it can be shown that $Q_0^*(0) =1$, which implies that $\theta_1(t)$ is a proper distribution.

$MTSF = E[T] = \frac{d}{ds}\theta_0(s) \Big|_{s=0} = (D_1'(0) - N_1'(0)) / D_1(0)$

$= (\mu_0 + p_{01}\, \mu_1 + p_{01}\, p_{13}\, \mu_3) / (1 - p_{01}\, p_{13}\, p_{30})$ (8)

Where

$\mu_0 = \mu_{01} + \mu_{02}$, $\mu_1 = \mu_{13} + \mu_{14}$, $\mu_2 = \mu_{23} + \mu_{23}^{(1)} + \mu_{24}$,,

$\mu_3 = \mu_{30} + \mu_{33}^{(6)}$

$\mu_4 = \mu_{43} + \mu_{43}^{(5)}$

AVAILABILITY ANALYSIS

Let $M_i(t)$ be the probability of the system having started from state i is up at time t without making any other regenerative state. By probabilistic arguments, we have

The value of $M_0(t)= e^-\lambda_1 t\, e^-\lambda_3 t$, $M_1(t)= e^-\lambda_1 t\, e^-\lambda_2 t$

$M_3(t)= e^-\lambda_1\overline{G}_1(t)$. (9)

The point wise availability $A_i(t)$ have the following recursive relations

$A_0(t) = M_0(t) + q_{01}(t)[c]A_1(t) + q_{02}(t)[c]A_2(t)$

$A_1(t) = M_1(t) + q_{13}(t)[c]A_3(t) + q_{14}(t)[c]A_4(t)$,

$A_2(t) = \{q_{23}(t) + q_{23}^{(7)}(t)\}[c]A_3(t) + q_{33}^{(6)}(t) [c]A_3(t)$

$A_4(t) = \{q_{43}(t) + q_{43}^{(5)}(t)[c]A_3(t)$ (10 - 14)

Taking Laplace Transform of eq. (10-14) and solving for $\hat{A}_0(s)$

$\hat{A}_0(s) = N_2(s) / D_2(s)$ (15)

where

$N_2(s) = (1 - \hat{q}_{33}^{(6)}(s))\ \widehat{M}_0(s) +[\ \hat{q}_{01}(s)\{\widehat{M}_1(s) + (\hat{q}_{13}(s)+ \hat{q}_{14}(s)\ (\hat{q}_{43}(s) + \hat{q}_{43}^{(5)}(s)\ ))\} + \hat{q}_{02}(s)\{\ \hat{q}_{23}(s)) + \hat{q}_{23}^{(1)}(s)) + \hat{q}_{24}(s)(\hat{q}_{43}(s) + \hat{q}_{43}^{(5)}(s))\}]$

$\widehat{M}_3(s)$

$D_2(s) = (1 - \hat{q}_{33}^{(6)}(s)) - \hat{q}_{30}(s)\ [\hat{q}_{01}(s)\{ \hat{q}_{13}(s)+ \hat{q}_{14}(s)\ (\hat{q}_{43}(s) + \hat{q}_{43}^{(5)}(s))\ \}+ \hat{q}_{20}(s)\{ \hat{q}_{23}(s)+\hat{q}_{23}^{(7)}(s)+ \hat{q}_{24}(s)(\hat{q}_{43}(s)) + \hat{q}_{43}^{(5)}(s)\ )\}]$

The steady state availability

$A_0 = \lim_{t\to\infty}[A_0(t)] = \lim_{s\to 0}[s\,\hat{A}_0(s)] = \lim_{s\to 0}\frac{s\,N_2(s)}{D_2(s)}$

Using L' Hospitals rule, we get

$A_0 = \lim_{s\to 0}\frac{N_2(s)+s\ N_2'(s)}{D_2'(s)} = \frac{N_2(0)}{D_2'(0)}$ (16)

Where

$N_2(0)= p_{30}\,\widehat{M}_0(0) + p_{01}\widehat{M}_1(0)\ \widehat{M}_3(0)\ )$

$D_2'(0) = \mu_3 + [\ \mu_0 + p_{01}\ (\mu_1 + p_{14}\ \mu_4 + p_{02}(\mu_2 + p_{24}\ \mu_4\ )]\ p_{30}$

The expected up time of the system in (0, t] is

$\lambda_u(t) = \int_0^{\infty} A_0\,(z)dz$ So that $\widehat{\lambda_u}\ (s) = \frac{\hat{A}_0\,(s)}{s} = \frac{N_2(S)}{SD_2(S)}$ (17)

The expected down time of the system in (0, t] is and

$\lambda_d(t) = t- \lambda_u(t)$ So that $\widehat{\lambda_d}\ (s) = \frac{1}{s^2} - \widehat{\lambda_u}\ (s)$ (18)

The expected busy period of the server when the operation of the unit stops automatically failed unit under Failure due to Dense Fog in (0, t]

$R_0(t) = q_{01}(t)[c]R_1(t) + q_{02}(t)[c]R_2(t)$

$R_1(t) = S_1(t) + q_{13}(t)[c]R_3(t) + q_{14}(t)[c]R_4(t),$

$R_2(t) = S_2(t) + q_{23}(t)[c]R_3(t) + q_{23}^{(7)}(t)[c]R_3(t) + q_{24}(t)[c]R_4(t)$

$R_3(t) = q_{30}(t)[c]R_0(t) + q_{33}^{(6)}(t)[c]R_3(t),$

$R_4(t) = S_4(t) + (q_{43}(t)+ q_{43}^{(5)}(t))\ [c]R_3(t)$ (19-23)

Where

$S_1(t)= e^{-\lambda_1 t}\, e^{-\lambda_2 t},\ S_2(t) = e^{-\lambda_1 t}\ \overline{G}_2(t),\ S_4(t) = e^{-\lambda_1 t}\ \overline{G}_1(t)$ (24)

Taking Laplace Transform of eq. (19-23) and solving for $\widehat{R_0}(s)$

$\widehat{R_0}(s) = N_3(s) / D_2(s)$ (25)

where

$N_3(s) = (1 - \hat{q}_{33}^{(6)}(s))\ [\ \hat{q}_{01}(s)(\hat{S}_1(s) + \hat{q}_{14}(s)\,\hat{S}_4(s)+ \hat{q}_{02}(s)(\hat{S}_2(s) + \hat{q}_{24}(s)\,\hat{S}_4(s))]$ and $D_2(s)$ is already defined.

In the long run, $R_0 = \frac{N_3(0)}{D_2'(0)}$ (26)

where $N_3(0)= p_{30}\,[\ p_{01}\ (\hat{S}_1(0) + p_{14}\ \hat{S}_4(0)\ ) + p_{02}\ (\hat{S}_2(0) + p_{24}\ \hat{S}_4(0)\ )$ and $D_2'(0)$ is already defined.

The expected period of the system under Failure due to dense fog in (0, t] is

$\lambda_{rv}(t) = \int_0^{\infty} R_0\,(z)dz$ So that $\widehat{\lambda_{rv}}\ (s) = \frac{\hat{R}_0\,(s)}{s}$ (27)

The expected Busy period of the server for repair when failure is caused due to Failure due to Communication Misunderstanding in (0,t]

$B_0(t) = q_{01}(t)[c]B_1(t) + q_{02}(t)[c]B_2(t)$

$B_1(t) = q_{13}(t)[c]B_3(t) + q_{14}(t)[c]B_4(t),$

$B_2(t) = q_{23}(t)[c]\ B_3(t) + q_{23}^{(7)}(t)[c]B_3(t) + q_{24}(t)[c]\ B_4(t)$

$B_3(t) = T_3\,(t)+ q_{30}(t)[c]\ B_0(t) + q_{33}^{(6)}(t)[c]B_3(t)$

$B_4(t) = T_4\,(t)+ \{\ q_{43}(t) + q_{43}^{(5)}(t)\}\ [c]B_3(t)$

(28-32)

Where

$T_3\,(t) = e^{-\lambda_2 t}\,\overline{G}_1(t)$ $T_4\,(t) = e^{-\lambda_1 t}\,\overline{G}_1(t)$ (33)

Taking Laplace Transform of eq. (28-32) and solving for $\widehat{B_0}\ (s)$

$\widehat{B_0}\ (s) = N_4(s) / D_2(s)$ (34)

where

$N_4(s) = \widehat{T}_3(s)\ [\ \hat{q}_{01}(s)\{ \hat{q}_{13}(s)+ \hat{q}_{14}\ (s)\ (\hat{q}_{43}(s) + \hat{q}_{43}^{(5)}(s))\}+ \hat{q}_{02}(s)\{ \hat{q}_{23}(s)+ \hat{q}_{23}^{(7)}\ (s)+ \hat{q}_{24}(s)\ (\hat{q}_{43}(s)+ \hat{q}_{43}^{(5)}(s))\}]+ \widehat{T}_4(s)\ [\hat{q}_{01}(s)\,\hat{q}_{44}(s)(1 - \hat{q}_{33}^{(6)}\ (s)\ ) + (\hat{q}_{02}(s)\ \hat{q}_{24}\,(s)(1- \hat{q}_{33}^{(6)}(s)\ )]$

And $D_2(s)$ is already defined.

In steady state, $B_0 = \frac{N_4(0)}{D_2'(0)}$ (35)

where $N_4(0)= \widehat{T}_3(0)+ \widehat{T}_4(0)\ \{\ p_{30}\ (p_{01}p_{14} + p_{02}\ p_{24})\ \}$ and $D_2'(0)$ is already defined.

The expected busy period of the server for repair in (0, t] is

$\lambda_{ru}(t) = \int_0^{\infty} B_0\,(z)dz$ So that $\widehat{\lambda_{ru}}\ (s) = \frac{\hat{B}_0\,(s)}{s}$ (36)

The expected Busy period of the server for repair when failure caused due to Dense Fog in (o, t]

$P_0(t) = q_{01}(t)[c]P_1(t) + q_{02}(t)[c]P_2(t)$

$P_1(t) = q_{13}(t)[c]P_3(t) + q_{14}(t)[c]P_4(t),$

$P_2(t) = L_2\ (t)+ q_{23}(t)[c]P_3(t) + q_{23}^{(7)}(t)[c]P_3(t)+ q_{24}(t)[c]P_4(t)$

$P_3(t) = q_{30}(t)[c]P_0(t) + q_{33}^{(6)}(t)[c]P_3(t),$

$P_4(t) = (q_{43}(t)+ q_{43}^{(5)}(t))\ [c]P_3(t)$

(37-41)

Where $L_2\,(t) = e^{-\lambda_1 t}\,\overline{G}_2(t)$

Taking Laplace Transform of eq. (37-41) and solving for $\widehat{P_0}\ (s)$

$\widehat{P_0}\ (s) = N_5(s) / D_2(s)$ (43)

where $N_5(s) = \hat{q}_{02}(s\ )\ \hat{L}_2(s)\ (\ 1 - \hat{q}_{33}^{(6)}(s))$ and $D_2(s)$ is defined earlier.

In the long run, $P_0 = \frac{N_5(0)}{D_2'(0)}$ (44)

where $N_5(0)= p_{30}\ p_{02}\ \hat{L}_2(0)$ and $D_2'(0)$ is already defined.

The expected busy period of the server for repair of the unit when failure due to dense fog in (0, t] is

$\lambda_{rs}(t) = \int_0^{\infty} P_0\,(z)dz$ So that $\widehat{\lambda_{rs}}\ (s) = \frac{\hat{P}_0\,(s)}{s}$ (45)

The expected number of visits by the repairman for repairing the when faiure due to Failure due to Communication Misunderstanding in (0, t]

$H_0(t) = Q_{01}(t)[s]H_1(t) + Q_{02}(t)[s]H_2(t)$

$H_1(t) = Q_{13}(t)[s][1+H_3(t)] + Q_{14}(t)[s][1+H_4(t)],$

$H_2(t) = [Q_{23}(t) + Q_{23}^{(7)}(t)]\ [s][1+H_3(t)] + Q_{24}(t)[s][1+ H_4(t)]$

$H_3(t) = Q_{30}(t)[s]H_0(t) + Q_{33}^{(6)}(t)[s]H_3(t),$

$H_4(t) = (Q_{43}(t)+ Q_{43}^{(5)}(t))$ [s]$H_3(t)$ (46-50)

Taking Laplace Transform of eq. (46-50) and solving for $H_0^*(s)$

$H_0^*(s)$ = $N_6(s) / D_3(s)$ (51)

where

$N_6(s) = (1 - Q_{33}^{(6)*}(s))\{Q^*_{01}(s)(Q^*_{13}(s) + Q^*_{14}(s)) + Q^*_{02}(s)(Q^*_{24}(s) + Q^*_{23}(s)+Q^*_{23}{}^{(7)}(s))\}$

$D_3(s) = (1 - Q_{33}^{(6)*}(s)) - Q^*_{30}(s)[Q^*_{01}(s)\{Q^*_{13}(s) + Q^*_{14}(s)(Q_{43}^*(s) + Q^*_{43}{}^{(5)}(s))\} + Q^*_{02}(s)\{Q^*_{23}(s)+ Q^*_{23}{}^{(7)}(s)) + Q^*_{24}(s)(Q^*_{43}(s)) + Q^*_{43}{}^{(5)}(s))\}]$

In the long run, $H_0 = \frac{N_6(0)}{D_3'(0)}$ (52)

where $N_6(0)= p_{30}$ and $D'_3(0)$ is already defined.

The expected number of visits by the repairman for repairing when failure is caused due to Dense Fog in (0, t]

$V_0(t) = Q_{01}(t)[s]V_1(t) + Q_{02}(t)[s][1+V_2(t)]$

$V_1(t) = Q_{13}(t)[s]V_3(t) + Q_{14}(t)[s]V_4(t)$,

$V_2(t) = Q_{24}(t)[s][1+V_4(t)] +[Q_{23}(t) + Q_{23}^{(7)}(t)[s][1+V_3(t)]$

$V_3(t) = Q_{30}(t)[s]V_0(t) + Q_{33}^{(6)}(t)[s]V_3(t)$ (53-57)

Taking Laplace-Stieltjes transform of eq. (53-57) and solving for $V_0{}^*(s)$

$V_0{}^*(s)$ = $N_7(s) / D_4(s)$ (58)

where $N_7(s) = (1 - Q_{33}^{(6)*}(s))\{Q^*_{01}(s)(Q^*_{14}(s) + Q^*_{43}(s)) + Q^*_{02}(s)(Q^*_{24}(s)\, Q^*_{02}(s)(Q^*_{23}(s)+Q^*_{23}{}^{(7)}(s))\}$

and $D_4(s)$ is the same as $D_3(s)$

In the long run, $V_0 = \frac{N_7(0)}{D_4'(0)}$ (59)

where $N_7(0)= p_{30}\,[p_{01}\, p_{14}\, p_{43} + p_{02}]$ and $D'_3(0)$ is already defined.

COST BENEFIT ANALYSIS

The cost-benefit function of the system considering mean up-time, expected busy period of the system under Failure due to dense fog when the units stops automatically, expected busy period of the server for repair when failure due to Dense Fog, expected number of visits by the repairman when failure is caused due to Failure due to communication misunderstanding, expected number of visits by the repairman for Dense Fog.

The expected total cost-benefit incurred in (0, t] is

C (t) = Expected total revenue in (0, t]

- expected total repair cost for failure due to Dense Fog in (0,t] when the units automatically stop in (0,t]
- expected busy period of the system under Failure due to Communication Misunderstanding
- expected total repair cost for repairing the units when failure is caused due to Dense Fog in (0,t]
- expected number of visits by the repairman for repairing when failure caused due to Dense Fog in (0,t]
- expected number of visits by the repairman for repairing the units when failure is due to Communication Misunderstanding in (0,t]

The expected total cost per unit time in steady state is

$C = \lim_{t\to\infty}(C(t)/t) = \lim_{s\to 0}(s^2 C(s))$

$= K_1A_0 - K_2 R_0 - K_3B_0 - K_4 P_0 - K_5V_0 - K_6H_0$

Where

K_1: revenue per unit up-time,

K_2: cost per unit time for which the system failure due to Dense Fog when units automatically stop

K_3: cost per unit time for which the system is under unit repair failure due to Failure due to Communication Misunderstanding

K_4: cost per unit time for which the system is under Failure due to dense fog

K_5: cost per visit by the repairman for units repair when Failure due to communication misunderstanding,

K_6: cost per visit by the repairman for units repair when failure due to Dense Fog.

CONCLUSION

After studying the system, we have analyzed graphically that when the failure rate due to operation of the unit stops automatically, due to Dense Fog and, Failure due to Communication Misunderstanding rate increases, the MTSF and steady state availability decreases and the cost function decreased as the failure increases.

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Source of Support: None Declared
Conflict of Interest: None Declared