Research Article

Cost-benefit analysis of a two similar cold standby system with failure due to radiation damage causing cancer and failure due to ultraviolet (uv) radiation from the sun causing skin cancer

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Abstract

Radiation damage Radiation damage to cells in the body can happen after a person receives radiation therapy to treat cancer. It can also happen if a person is exposed to radiation through x-ray imaging, nuclear power, or fallout from nuclear weapons. If severe enough, radiation damage may cause cancer, birth defects, and other serious health problems. Doctors try to protect people undergoing radiation therapy for cancer by using low doses, being precise about targeting the radiation, and minimizing side effects. Usually side effects go away after the treatment stops. **What Causes Skin Cancer?** Skin cancer is the most prevalent form of all cancers in the U.S. and the number of cases continues to rise. It is the uncontrolled growth of abnormal skin cells. This rapid growth results in tumors, which are either benign (noncancerous) or malignant (cancerous). There are three main types of skin cancer: basal cell carcinoma, squamous cell carcinoma and melanoma. Basal cell and squamous cell cancers are less serious types and make up 95% of all skin cancers. Also referred to as non-melanoma skin cancers, they are highly curable when treated early. Melanoma, made up of abnormal skin pigment cells called melanocytes, is the most serious form of skin cancer and causes 75% of all skin cancer deaths. Left untreated, it can spread to other organs and is difficult to control. Ultraviolet (UV) radiation from the sun is the number-one cause of skin cancer, but UV light from tanning beds is just as harmful. Exposure to sunlight during the winter months puts you at the same risk as exposure during the summertime because UVA rays are present in daylight. Cumulative sun exposure causes mainly basal cell and squamous cell skin cancer, while episodes of severe sunburns, usually before age 18, can contribute to developing melanoma. Other less common causes are repeated X-ray exposure and occupational exposure to certain chemicals. We have taken units- failure due to radiation damage causing Cancer and failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer 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 due to radiation damage causing Cancer 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 due to Ultraviolet (UV) radiation from the sun causing skin Cancer in (0,t], the expected number of visits by the repairman for failure due to radiation damage causing Cancer in (0,t], the expected number of visits by the repairman for failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer in (0,t] and Cost-Benefit analysis using regenerative point technique. A special case using failure and repair distributions as exponential is derived and graphs have been drawn

Keyword: Cold Standby, failure due to radiation damage causing Cancer, failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer, MTSF, Availability, Busy period, Cost-Benefit Analysis

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These are common side effects when a person undergoes radiation treatment for cancer:

- Hair loss
- Stomach upset, nausea, vomiting, diarrhea
- Low white blood cells (leucopenia)
- Red and itchy skin at the site of the radiation
- Sore mouth or mouth ulcers (oral mucositis)

Radiation sickness or radiation emergency happens after exposure to a large amount of radiation. Acute radiation sickness occurs within 24 hours of exposure. Chronic radiation syndrome is a range of symptoms occurring over a period of time. These symptoms can happen immediately or months or years after exposure to radiation:

- Radiation syndrome: fatigue, weight loss, nausea, vomiting, diarrhea, sweating, fever, headache with bleeding and complications affecting the digestive system, nervous system, heart, and lungs
- Central nervous system diseases
- Kidney, liver, or gastrointestinal problems
- Poor growth in children
- Skin conditions
- Pericarditis (inflammation of the sac around the heart)
- Lung infections or conditions, respiratory failure
- Vision problems, including cataracts
- Problems with the reproductive organs

What Causes It?

Damage happens when radiation interacts with oxygen, causing certain molecules to form in the body. These molecules can damage or break strands of DNA in cells. The cells may die.

Who's Most At Risk?

People who have been exposed to radiation and who also have the following conditions or characteristics are at risk for developing radiation damage:

- High dose of radiation exposure
- Young age at time of exposure
- Use of chemotherapy, antibiotics
- Exposure to radiation before birth (while in the womb)

Who Is at Risk for Skin Cancer?

Although anyone can get skin cancer, the risk is greatest for people who have fair or freckled skin that burns easily, light eyes and blond or red hair. Darker skinned individuals are also susceptible to all types of skin cancer, although their risk is substantially lower. Aside from complexion, other risk factors include having a family history or personal history of skin cancer, having an outdoor job and living in a sunny climate. A history of severe sunburns and an abundance (greater than 30) of large and irregularly-shaped moles are risk factors unique to melanoma. What Are the Symptoms of Skin Cancer? The most common warning sign of skin cancer is a change on the skin, typically a new mole or skin lesion or a change in an existing mole.

- Basal cell carcinoma may appear as a small, smooth, pearly or waxy bump on the face, ears or neck, or as a flat pink, red or brown lesion on the trunk or arms and legs.

- Squamous cell carcinoma can appear as a firm, red nodule, or as a rough, scaly flat lesion that may bleed and become crusty. Both basal cell and squamous cell cancers mainly occur on areas of the skin frequently exposed to the sun, but can occur anywhere.
- Melanoma usually appears as a pigmented patch or bump but can also be red or white. It may resemble a normal mole, but usually has a more irregular appearance.

When looking for melanoma, think of the ABCDE rule that tells you the signs to watch for:

- Asymmetry - the shape of one half doesn't match the other
- Border - edges are ragged or blurred
- Color - uneven shades of brown, black, tan, red, white or blue
- Diameter - A significant change in size (greater than 6mm)- although any mole that begins enlarging should be brought to the attention of your dermatologist. Many melanomas are being diagnosed at much smaller diameters.
- Evolving - any new spot of mole changing in color, shape or size

In this paper, we have taken failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer which is non-instantaneous in nature. Here, we investigate a two identical cold standby –a system in which offline unit cannot fail. When there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer within specified limit, it operates as normal as before but if these are beyond the specified limit the operation of the unit is stopped to avoid excessive damage of the unit and as when there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer continues going on some characteristics of the unit change which we call failure of the unit. After failure due to radiation damage causing Cancer or failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer 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 radiation damage causing Cancer, failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer are exponential with rates $\lambda_{1,}$ λ_2 and λ_3 whereas the repairing rates for repairing the failed system due to radiation damage causing Cancer, due to Ultraviolet (UV) radiation from the sun causing skin Cancer are arbitrary with CDF G_1 (t) and G_2 (t) respectively.
2. When there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer within specified limit, it operates as normal as before but if these are beyond the specified limit the operation of the unit is avoided and as the failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer continues goes on some characteristics of the unit change which we call failure of the unit.
3. The failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer actually failed the units. The failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer 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, RDF, UVRSF

Operative, cold Standby, Stops the operation, the failure due to radiation damage causing Cancer, failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer respectively

Subscripts: nuvrs, uuvrs, rd, ur, wr, uR

No failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer, under failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer, the failure due to radiation damage causing Cancer, 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

$0(O_{nuvrs}, CS_{nuvrs})$

One unit is operative and the other unit is cold standby and there is no failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer in both the units.

$1(SO_{uuvrs}, O_{nuvrs})$

The operation of the first unit stops automatically due to failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer and cold standby unit starts operating with no failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer

2(SO_{uuvrs}, UVRSF $_{uvrs,, ur}$)

The operation of the first unit stops automatically due failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer and the other unit fails due to Ultraviolet (UV) radiation from the sun causing skin Cancer undergoes repair.

3(RDF $_{ur}$, O_{nuvrs})

The first unit fails due to radiation damage causing Cancer undergoes repair and the other unit continues to be operative with no failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer.

4(RDF $_{uR}$, SO_{uuvrs})

The one unit fails due to radiation damage causing Cancer continues to be under repair and the other unit also stops automatically when there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer

5(RDF $_{uR}$, RDF $_{wr}$)

The repair of the first unit is continued from state 4 and the other unit fails due to radiation damage causing Cancer is waiting for repair.

6(RDF $_{uR}$, SO_{uuvrs})

The repair of the first unit is continued from state 3 fails due to radiation damage causing Cancer and operation of other unit stops automatically when there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer

7(RDF_{wr}, $UVRSF_{uvrs, uR}$)

The repair of failed unit due to failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer is continued from state 2 and the first unit failed due to radiation damage causing Cancer is waiting for repair.

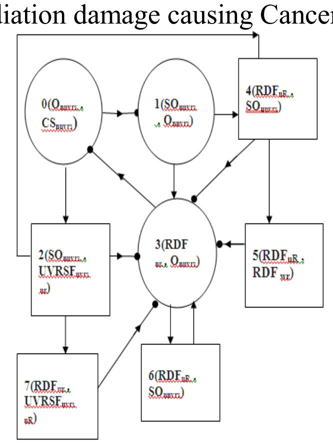

Figure 1: The State Transition Diagram

● 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 is

$\mu_0 = E(T) = \int_0^{\infty} P[T > t]dt$

$= -1/\lambda_1$

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, we get
$Q_0^*(s) = N_1(s) / D_1(s)$ (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.

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

$= (\mu_0 + p_{01}\, \mu_1 + p_{01}\, p_{13}\, \mu_3) / (1 - p_{01}\, p_{13}\, p_{30})$ (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
$A_0(t) = M_0(t) + q_{01}(t)[c]A_1(t) + q_{02}(t)[c]A_2(t)$
$A_1(t) = M_1(t) + q_{13}(t)[c]A_3(t) + q_{14}(t)[c]A_4(t)$,
$A_2(t) = \{q_{23}(t) + q_{23}^{(7)}(t)\}[c]A_3(t) + q_{33}^{(6)}(t)\,[c]A_3(t)$
$A_3(t) = M_3(t) + \{q_{30}(t) + q_{33}^{(6)}(t)\}[c]A_3(t)$
$A_4(t) = \{q_{43}(t) + q_{43}^{(5)}(t)[c]A_3(t)$ (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 $\widehat{\lambda_u}\,(s) = \frac{\widehat{A}_0\,(s)}{s} = \frac{N_2(S)}{SD_2(S)}$ (17)

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

$\lambda_d(t) = t - \lambda_u(t)$ 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 when there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer 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 Ultraviolet (UV) radiation from the sun causing skin Cancer in (0, t] is

$\lambda_{tsp}(t) = \int_0^{\infty} R_0\,(z)dz$ so that

$\widehat{\lambda_{tsp}}\,(s) = \frac{\widehat{R}_0\,(s)}{s}$ (27)

The expected Busy period of the server for repair when there is failure due to radiation damage causing Cancer 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

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

$\hat{q}_{33}^{(6)}(s)$)]

And $D_2(s)$ is already defined.

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

where $N_4(0) = \hat{T}_3(0) + \hat{T}_4(0)$ { 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

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

The expected Busy period of the server for repair when there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer 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 when failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer in (0, t] is

$\lambda_{cf}(t) = \int_0^{\infty} P_0(z)dz$

So that $\widehat{\lambda_{cf}}(s) = \frac{\hat{P}_0(s)}{s}$ (45)

The expected number of visits by the repairman for repairing the units when there is failure due to radiation damage causing Cancer 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 there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer 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 Ultraviolet (UV) radiation from the sun causing skin Cancer when the units stops automatically, expected busy period of the server for repair when there is failure due to radiation damage causing Cancer, expected total repair cost for repairing the units when there failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer, expected number of visits by the repairman when there is failure due to radiation damage causing Cancer, expected number of visits by the repairman for failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer. The expected total cost-benefit incurred in (0, t] is C (t) = Expected total revenue in (0, t]

- expected busy period of the system under failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer when the units automatically stop in (0,t]
- expected total repair cost when there is failure due to radiation damage causing Cancer in (0,t]
- expected total repair cost for repairing the units when there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer in (0,t]
- expected number of visits by the repairman for repairing when there is failure due to radiation damage causing Cancer in (0,t]
- expected number of visits by the repairman for repairing the units when there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer in (0,t]

The expected total cost per unit time in steady state is

$C = \lim_{t\to\infty}(C(t)/t)$
$= \lim_{s\to 0}(s^2 C(s))$
$= K_1A_0 - K_2\, R_0 - K_3B_0 - K_4\, P_0$
$- K_5\, H_0 - K_6\, V_0$

Where

K_1: Revenue per unit up-time,

K_2: Cost per unit time for which the system is under failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer when units automatically stop.

K_3: Cost per unit time for which the system is under unit repair when there is failure due to radiation damage causing Cancer

K_4: Cost per unit time for which the system failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer

K_5: Cost per visit by the repairman when there is failure due to radiation damage causing Cancer,

K_6: Cost per visit by the repairman when there is failure due to Ultraviolet (UV) radiation from the sun causing skin Cancer

CONCLUSION

After studying the system, we have analyzed graphically that when the **failure rate** due to operation of the unit stops automatically, due to radiation damage causing Cancer and due to Ultraviolet (UV) radiation from the sun causing skin Cancer increases, the MTSF and steady state availability decreases and the cost function decreased as the failure increases.

REFERENCES

1. Barlow, R.E. and Proschan, F., Mathematical theory of Reliability, 1965; John Wiley, New York.
2. Dhillon, B.S. and Natesen, J, Stochastic Anaysis of outdoor Power Systems in fluctuating environment, Microelectron. Reliab.. 1983; 23, 867-881.
3. Gnedanke, B.V., Belyayar, Yu.K. and Soloyer, A.D., Mathematical Methods of Relability Theory, 1969 ; Academic Press, New York.
4. Goel, L.R., Sharma,G.C. and Gupta, Rakesh Cost Analysis of a Two-Unit standby system with different weather conditions, Microelectron. Reliab., 1985; 25, 665-659.
5. Cao, Jinhua, Stochastic Behavior of a Man Machine System Operating under Changing Environment Subject to a Markov Process with two States, Microelectron. Reliab.1989, 28, pp. 373-378.

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