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Reliability And Sensitivity Analysis Of Linear Consecutive 2-Out-Of-4: F System

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***Abstract:** In the present paper author has been consider a system which is having a special kind of k-out-of-n redundancy namely linear consecutive 2-ot-of-4: F system. These types of system have wide application in many industrial systems especially in medical equipment. Many medical diagnose equipment (one of the example is X-ray machines) having the linear consecutive k-out-of-n: F/G system. Basically a linear consecutive k-out-of-n: G/F system is a system which work/failed if at least k consecutive components out of n components is working/failed. In the present paper one of the special cases of linear consecutive k-out-of-n: F system (by taking k=2, n=4) is investigated with the help of mathematical modelling and Markov process to find out its reliability characteristic. Critical units of the system are also obtained by sensitivity analysis.*

***Key-terms:** linear consecutive k-out-of-n: G/F system; Reliability characteristic; Sensitivity analysis; Markov process;*

1. Introduction

Redundancy will play a key role in every system for the improvement of its performance. In the history of reliability theory many redundancy [1-3] has been studied to get its effects on system performance indices. It can be employed in a system, according to the need, at two levels one is at components level and other is system level. Series redundancy, parallel redundancy, hot/cold/warm standby redundancy, k-out-of-n redundancy are some of the types of redundancy [4] which can be employed on any level. Many authors has been done valuable research regarding the uses, application and advantage k-out-of-n redundancy including [5-9] in different systems. The use of cold standby redundancy for optimizing the system reliability can be seen in [10]. In this work the author found imperfect component failure along with imperfect switching degradation by developing a new methodology.

Zuo [11] investigate about Birnbaum reliability of consecutive-k-out-of-n F and G systems. Also he has done a review on linear/circular consecutive k-out-of-n: F systems. The relationship between consecutive-k-out-of-n F and G system were investigated by developing the some good results also authors apply the results of one type system to another type system [12-15]. Huang et al. [16] proposed the definitions of consecutive k -out-of- n: F and G systems and identified the association between these two kind of special redundancies. Chiang and Niu [17] find out the exact reliability of a consecutive k-out-of-n: F system with the aid of recursive formula. In this work authors also provided the upper/lower bound of system's reliability. Bollinger and Salvia [18] evaluated the reliability for a consecutive k-out-of-n: F by developing a counting scheme.
Critically analyzing the above literature regarding the k-out-of-n and consecutive k-out-of-n system from reliability prospects, author founds that no one in the literature has been

investigated a linear consecutive k-out-of-n: F system by mathematical modelling and Markov process point of view for evaluating the reliability and sensitivity for the same. Consequently author has been decided to investigate a linear consecutive 2-out-of-4: F system (a special case of linear consecutive k-out-of-n: F system) by the aid of mathematical modelling and Markov process.

2. Systems description

The present paper investigates a specified case of linear consecutive k-out-of-n: F system by taking n=4 and k=2. The considered system is having four units and supposed to be failed if at least 2 successive units are fails. A mathematical model for the same is developed with the help of Markov process and solved by using Laplace transformation by taking constant failure rates. The different states, in which considered system can occur, are shown in the following state transition diagram (Figure 1).

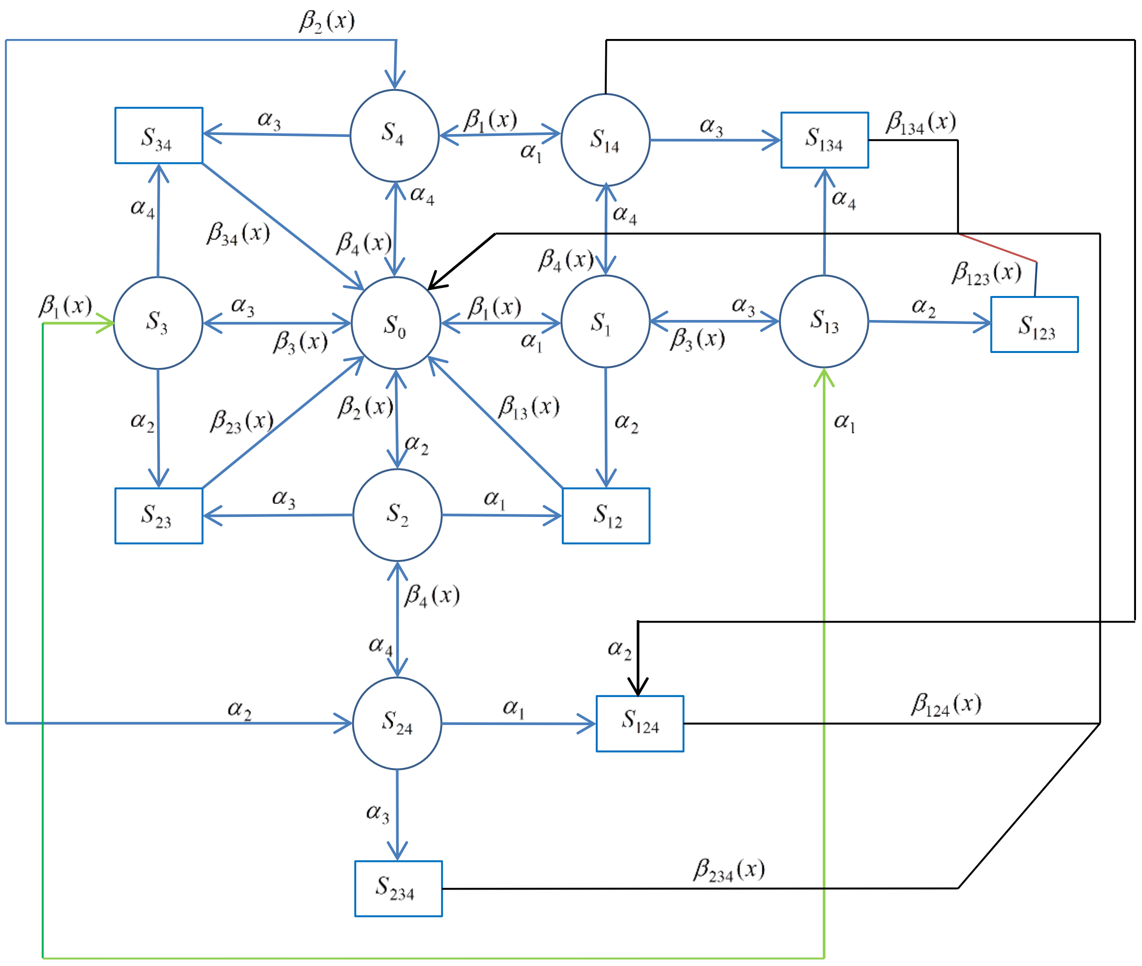

Figure 1 State Transition diagram

3. Assumptions

The mathematical formulation and calculation has been carried out by considering the following assumptions

- Initially the system is considered without any defect in its sub units.
- Simultaneous failure of the unit in the system is not considered.
- Mathematical modeling and state transition diagram is developed on the basis of Markov process.

4. Nomenclature

Table 1 gives the description about the various nomenclature/notation used in the paper.

t / s	Time unit/ Laplace Transformation variable.
$P_i(t)$; $i = 0,1,2,3,4,13,24$	System's probability being in state $S_i; i = 0,1,2,3,4,13,24$ at instant time t.
$P_i(x,t)$; $i = 12,23,34,134,$ $123,124,234$	System's probability being in state $S_i; i = 0,1,2,3,4,13,24$ at instant time t.
$\alpha_1 / \alpha_2 / \alpha_3 / \alpha_4$	The failure rate of first/second/third/fourth unit of the considered system respectively.
$\beta_1(x) / \beta_2(x) / \beta_3(x)$ $/ \beta_4(x)$	The repair rate of first/second/third/fourth unit of the considered system respectively.
$\beta_{12}(x) / \beta_{23}(x) /$ $\beta_{34}(x)$	Simultaneous repair rate of first-second/second-third/third-fourth unit of the considered system respectively.
$\beta_{123}(x) / \beta_{124}(x) /$ $\beta_{134}(x) / \beta_{234}(x)$	Simultaneous repair rate of first-second-third/first-second-fourth/first-third-fourth/second-third-fourth units of the considered system respectively.

Table 1 Nomenclature

5. State descriptions

The following Table 2 gives the description about the various states used in the present paper.

S_0	Working state: Considered system is working.
S_1	Working state: State in which first unit is failed.
S_2	Working state: State in which second unit is failed.
S_3	Working state: State in which third unit is failed.
S_4	Working state: State in which fourth unit is failed.
S_{14}	Working state: State in which first and fourth unit is failed.
S_{24}	Working state: State in which second and fourth unit is failed.
S_{13}	Working state: State in which first and third unit is failed.
S_{12}	Represent failed state which occurs from the failure of first and second unit.

S_{34}	Represent failed state which occurs from the failure of third and fourth unit.
S_{23}	Represent failed state which occurs from the failure of second and third unit.
S_{123}	Represent failed state which occurs from the failure of first, second and third unit.
S_{124}	Represent failed state which occurs from the failure of first, second and fourth unit.
S_{134}	Represent failed state which occurs from the failure of first, third and fourth unit.
S_{234}	Represent failed state which occurs from the failure of second, third and fourth unit.

Table 2 state descriptions

6. Formulation and solution of the Problem

The governing set intro-differential equation for the linear consecutive 2-out-of-4: F system will obtained from state diagram (Figure 1) in the time $(t, t+\Delta t)$ and $\Delta t \to 0$ as follow.

$$\left(\frac{\partial}{\partial t}+\sum_{i=1}^{4}\alpha_i\right)P_0(t)=\beta_1(x)P_1(t)+\beta_2(x)P_2(t)+\beta_3(x)P_3(t)+\beta_4(x)P_4(t)+\int_0^\infty \beta_{12}(x)P_{12}(x,t)\,dx$$
$$+\int_0^\infty \beta_{23}(x)P_{23}(x,t)\,dx+\int_0^\infty \beta_{34}(x)P_{34}(x,t)\,dx+\int_0^\infty \beta_{124}(x)P_{124}(x,t)\,dx+\int_0^\infty \beta_{234}(x)P_{234}(x,t)\,dx$$
$$+\int_0^\infty \beta_{123}(x)P_{123}(x,t)\,dx+\int_0^\infty \beta_{134}(x)P_{134}(x,t)\,dx$$
(1)

$$\left(\frac{\partial}{\partial t}+\beta_1(x)+\sum_{i=2}^{4}\alpha_i\right)P_1(t)=\beta_3(x)P_{13}(t)+\beta_4(x)P_{14}(t)+\alpha_1 P_0(t)$$
(2)

$$\left(\frac{\partial}{\partial t}+\beta_2(x)+\alpha_1+\alpha_3+\alpha_4\right)P_2(t)=\beta_4(x)P_{24}(t)+\alpha_2 P_0(t)$$
(3)

$$\left(\frac{\partial}{\partial t}+\beta_3(x)+\alpha_1+\alpha_2+\alpha_4\right)P_3(t)=\beta_1(x)P_{13}(t)+\alpha_3 P_0(t)$$
(4)

$$\left(\frac{\partial}{\partial t}+\beta_4(x)+\alpha_1+\alpha_2+\alpha_3\right)P_4(t)=\beta_2(x)P_{24}(t)+\alpha_4 P_0(t)$$
(5)

$$\left(\frac{\partial}{\partial t}+\beta_1(x)+\beta_3(x)+\alpha_2+\alpha_4\right)P_{13}(t)=\alpha_1 P_3(t)+\alpha_3 P_1(t)$$
(6)

$$\left(\frac{\partial}{\partial t}+\beta_1(x)+\beta_4(x)+\alpha_2+\alpha_3\right)P_{14}(t)=\alpha_1 P_4(t)+\alpha_4 P_1(t)$$
(7)

$$\left(\frac{\partial}{\partial t}+\beta_2(x)+\beta_4(x)+\alpha_1+\alpha_3\right)P_{13}(t)=\alpha_2 P_4(t)+\alpha_4 P_2(t)$$
(8)
$$\left(\frac{\partial}{\partial x}+\frac{\partial}{\partial t}+\beta_i(x)\right)P_i(t)=0$$
(9)
$where\ i=12,134,123,124,234,23,34$

Boundary conditions associated with the problem
$$P_{12}(0,t)=\alpha_2\ P_1(t)+\alpha_1\ P_2(t)$$
(10)
$$P_{134}(0,t)=\alpha_4\ P_{13}(t)+\alpha_3\ P_{14}(t)$$
(11)
$$P_{123}(0,t)=\alpha_2\ P_{13}(t)$$
(12)
$$P_{124}(0,t)=\alpha_1\ P_{24}(t)+\alpha_2\ P_{14}(t)$$
(13)
$$P_{234}(0,t)=\alpha_3\ P_{24}(t)$$
(14)
$$P_{23}(0,t)=\alpha_3\ P_2(t)+\alpha_2\ P_3(t)$$
(15)
$$P_{34}(0,t)=\alpha_3\ P_4(t)+\alpha_4\ P_3(t)$$
(16)

Initial condition $P_i(t)=\begin{cases}1\ ;\ \text{if}\ i=t=0\\ 0\ ;\ \text{otherwise}\end{cases}$

(17)

The set of equation (1)-(17) can be rewritten by using the Laplace transformation as follow.
$$\left(s+\sum_{i=1}^{4}\alpha_i\right)\overline{P}_0(s)=\beta_1(x)\overline{P}_1(s)+\beta_2(x)\overline{P}_2(s)+\beta_3(x)\overline{P}_3(s)+\beta_4(x)\overline{P}_4(s)+\int_0^\infty\beta_{12}(x)\overline{P}_{12}(x,s)\,dx$$
$$+\int_0^\infty\beta_{23}(x)\overline{P}_{23}(x,s)\,dx+\int_0^\infty\beta_{34}(x)\overline{P}_{34}(x,s)\,dx+\int_0^\infty\beta_{124}(x)\overline{P}_{124}(x,s)\,dx+\int_0^\infty\beta_{234}(x)\overline{P}_{234}(x,s)\,dx$$
$$+\int_0^\infty\beta_{123}(x)\overline{P}_{123}(x,s)\,dx+\int_0^\infty\beta_{134}(x)\overline{P}_{134}(x,s)\,dx$$
(18)
$$\left(s+\beta_1(x)+\sum_{i=2}^{4}\alpha_i\right)\overline{P}_1(s)=\beta_3(x)\overline{P}_{13}(s)+\beta_4(x)\overline{P}_{14}(s)+\alpha_1\ \overline{P}_0(s)$$
(19)
$$\left(s+\beta_2(x)+\alpha_1+\alpha_3+\alpha_4\right)\overline{P}_2(s)=\beta_4(x)\overline{P}_{24}(s)+\alpha_2\ \overline{P}_0(s)$$
(20)
$$\left(s+\beta_3(x)+\alpha_1+\alpha_2+\alpha_4\right)\overline{P}_3(s)=\beta_1(x)\overline{P}_{13}(s)+\alpha_3\ \overline{P}_0(s)$$
(21)

$$\left(s+\beta_4(x)+\alpha_1+\alpha_2+\alpha_3\right)\overline{P}_4(s)=\beta_2(x)\overline{P}_{24}(s)+\alpha_4\overline{P}_0(s)$$
(22)
$$\left(s+\beta_1(x)+\beta_3(x)+\alpha_2+\alpha_4\right)\overline{P}_{13}(s)=\alpha_1\overline{P}_3(s)+\alpha_3\overline{P}_1(s)$$
(23)
$$\left(s+\beta_1(x)+\beta_4(x)+\alpha_2+\alpha_3\right)\overline{P}_{14}(s)=\alpha_1\overline{P}_4(s)+\alpha_4\overline{P}_1(s)$$
(24)
$$\left(s+\beta_2(x)+\beta_4(x)+\alpha_1+\alpha_3\right)\overline{P}_{13}(s)=\alpha_2\overline{P}_4(s)+\alpha_4\overline{P}_2(s)$$
(25)
$$\left(\frac{\partial}{\partial x}+s+\beta_i(x)\right)\overline{P}_i(s)=0$$
(26)
$where\ i=12,134,123,124,234,23,34$

Boundary conditions associated with the problem
$$\overline{P}_{12}(0,s)=\alpha_2\overline{P}_1(s)+\alpha_1\overline{P}_2(s)$$
(27)
$$\overline{P}_{134}(0,s)=\alpha_4\overline{P}_{13}(s)+\alpha_3\overline{P}_{14}(s)$$
(28)
$$\overline{P}_{123}(0,s)=\alpha_2\overline{P}_{13}(s)$$
(29)
$$\overline{P}_{124}(0,s)=\alpha_1\overline{P}_{24}(s)+\alpha_2\overline{P}_{14}(s)$$
(30)
$$\overline{P}_{234}(0,s)=\alpha_3\overline{P}_{24}(s)$$
(31)
$$\overline{P}_{23}(0,s)=\alpha_3\overline{P}_2(s)+\alpha_2\overline{P}_3(s)$$
(32)
$$\overline{P}_{34}(0,s)=\alpha_3\overline{P}_4(s)+\alpha_4\overline{P}_3(s)\ (16)$$

Initial condition $P_i(s)=\begin{cases}1\ ; & \text{if } i=s=0\\ 0\ ; & \text{otherwise}\end{cases}$

(33)

The solution of the above set of equation (18)-(33) gives the value of various state probabilities of the considered system. Also it can be seen (Figure 1) that the reliability characteristic for the considered system can be obtained as following.

$$R(t)=\left[P_0(t)+P_1(t)+P_2(t)+P_3(t)+P_4(t)+P_{13}(t)+P_{24}(t)\right]_{All\ repairs\ tending\ to\ be\ zero.}$$
(34)

Where these state probabilities associated to the system reliability is obtained as

$$P_0(t)=\exp\left[-\left\{\sum_{i=1}^{4}\alpha_i\right\}t\right]$$
(35)

$$P_1(t)=\exp\left[-\left\{\sum_{i=2}^{4}\alpha_i\right\}t\right]-\exp\left[-\left\{\sum_{i=1}^{4}\alpha_i\right\}t\right]$$
(36)
$$P_2(t)=\exp\left[-\{\alpha_1+\alpha_3+\alpha_4\}t\right]-\exp\left[-\left\{\sum_{i=1}^{4}\alpha_i\right\}t\right]$$
(37)
$$P_3(t)=\exp\left[-\{\alpha_1+\alpha_2+\alpha_4\}t\right]-\exp\left[-\left\{\sum_{i=1}^{4}\alpha_i\right\}t\right]$$
(38)
$$P_4(t)=\exp\left[-\left\{\sum_{i=1}^{3}\alpha_i\right\}t\right]-\exp\left[-\left\{\sum_{i=1}^{4}\alpha_i\right\}t\right]$$
(39)
$$P_{13}(t)=\exp\left[-\{\alpha_2+\alpha_4\}t\right]-\exp\left[-\left\{\sum_{i=2}^{3}\alpha_i\right\}t\right]-\exp\left[-\{\alpha_1+\alpha_2+\alpha_4\}t\right]+\exp\left[-\left\{\sum_{i=1}^{4}\alpha_i\right\}t\right]$$
(40)
$$P_{24}(t)=\exp\left[-\{\alpha_1+\alpha_3\}t\right]-\exp\left[-\left\{\sum_{i=1}^{3}\alpha_i\right\}t\right]-\exp\left[-\{\alpha_1+\alpha_3+\alpha_4\}t\right]+\exp\left[-\left\{\sum_{i=1}^{4}\alpha_i\right\}t\right]$$
(41)

Therefor the reliability of the considered system will be obtained as (using equation (35)-(41) in equation (34)) given in equation (42).
$$R(t)=\begin{cases}\exp\left[-\{\alpha_1+\alpha_3\}t\right]+\exp\left[-\{\alpha_2+\alpha_3\}t\right]\\-\exp\left[-\{\alpha_1+\alpha_2+\alpha_3\}t\right]-\exp\left[-\{\alpha_2+\alpha_3+\alpha_4\}t\right]\end{cases}$$
(42)
The numerical value of the reliability of considered system will be obtained by substituting the values of associated failure rates in equation (42). Now here author will show the behavior of the reliability of the considered system w.r.t. different failures of the same.

7. Numerical Computation

7.1.Reliability

7.1.1. Reliability of the considered system w.r.t. the failure of first unit

The reliability of the considered system is given in equation (42). For the reliability w.r.t. failure rate of first unit here author put the value of the different failure rates as $\alpha_2=0.17,\alpha_3=0.25,\alpha_4=0.15$ and varying the failure rate of first unit i.e. α_1 in equation (42). Finally the behavior of reliability of the considered system w.r.t. time unit t and α_1 will obtain as given in Table 3 and corresponding Figure 2.

Time Unit (t)	Reliability		
	$\alpha_1=0.05$	$\alpha_1=0.10$	$\alpha_1=0.15$
0	1.0000000000	1.0000000000	1.0000000000
1	0.9594807690	0.9538323583	0.9484594239
2	0.8699541235	0.8549009446	0.8412802651
3	0.7629219553	0.7629219553	0.7402972567
4	0.6552210985	0.6282837441	0.6062293037

5	0.5551759298	0.5269152972	0.5049058942
6	0.4662878857	0.4388942001	0.4186004586
7	0.3894238430	0.3642625066	0.3465316126
8	0.3240949899	0.3018632817	0.2869609221
9	0.2691887895	0.2501087803	0.2379428292
10	0.2233753154	0.2073643431	0.1976531975

Table 3 Reliability w.r.t. α_1 vs. Time unit (t)

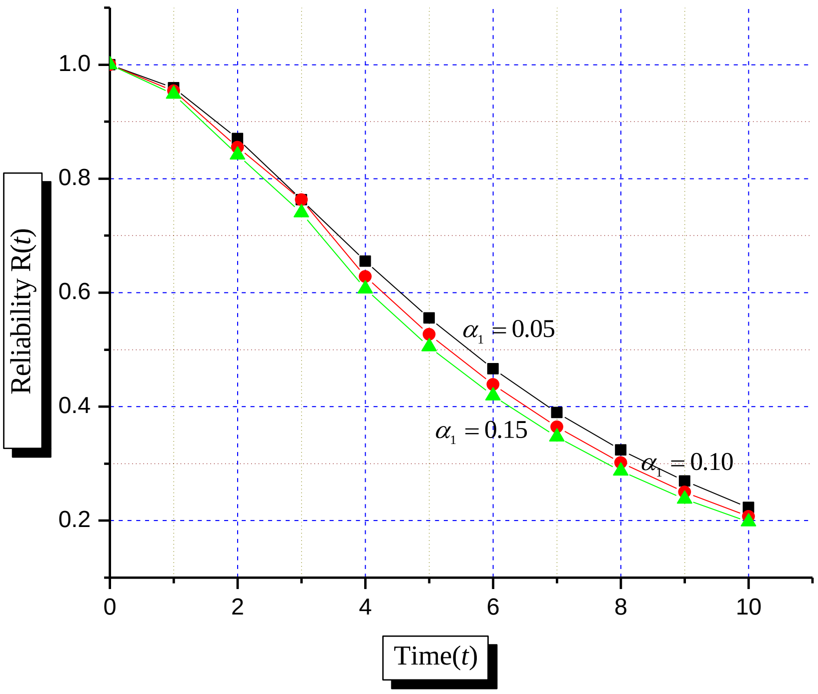

Figure 2 Reliability w.r.t. α_1 vs. Time unit (t)

7.1.2. Reliability of the considered system w.r.t. the failure of first second unit

In order to calculate the reliability of the considered system with respect to failure rate of second unit, author put the value of the different failure rates as $\alpha_1 = 0.10, \alpha_3 = 0.25, \alpha_4 = 0.15$ and varying the failure rate of second unit i.e. α_2 in equation (42). Finally the behavior of reliability of the considered system w.r.t. time unit t and α_2 will obtain as given in Table 4 and corresponding Figure 3.

Time Unit (t)	Reliability		
	$\alpha_2 = 0.12$	$\alpha_2 = 0.17$	$\alpha_2 = 0.22$
0	1.0000000000	1.0000000000	1.0000000000
1	0.9666062581	0.9538323583	0.9416814490
2	0.8925853295	0.8549009446	0.8208027031
3	0.8034707920	0.7402972567	0.6859232910
4	0.7127902499	0.6282837441	0.5590956689

5	0.6272164174	0.5269152972	0.4488007063
6	0.5496027416	0.4388942001	0.3568792954
7	0.4807502605	0.3642625066	0.2821749738
8	0.4204192082	0.3018632817	0.2223928675
9	0.3678952619	0.2501087803	0.1750048037
10	0.3222963182	0.2073643431	0.1376545763

Table 4 Reliability w.r.t. α_2 vs. Time unit (t)

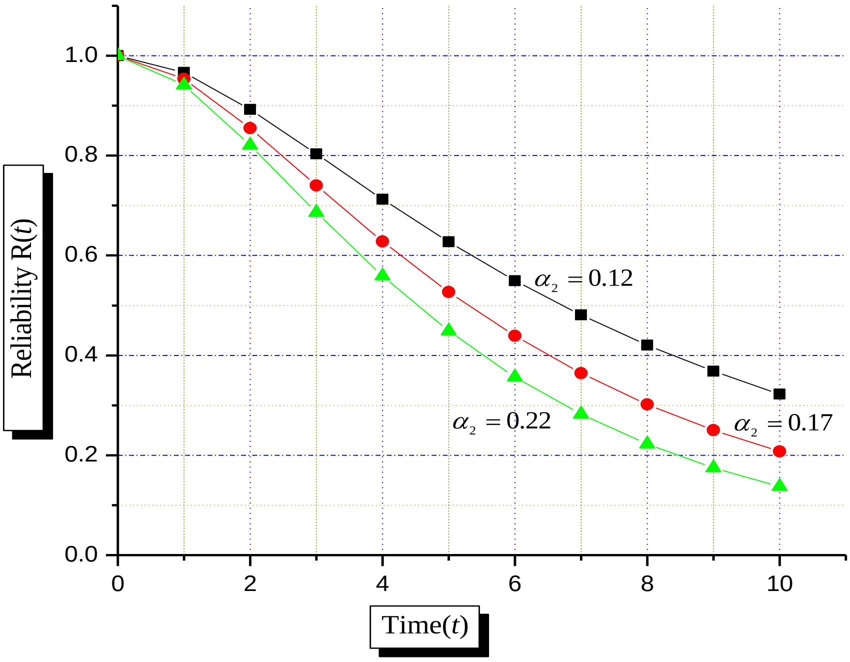

Figure 3 Reliability w.r.t. α_2 vs. Time unit (t)

7.1.3. Reliability of the considered system w.r.t. the failure of third unit

Reliability of the considered system with respect to failure rate of third unit will be calculated by taking $\alpha_1 = 0.10, \alpha_2 = 0.17, \alpha_4 = 0.15$ and varying α_3 in equation (42). The behavior of reliability of the considered system w.r.t. time unit t and α_3 will obtain as given in Table 5 and corresponding Figure 4.

Time Unit (t)	Reliability		
	$\alpha_3 = 0.20$	$\alpha_3 = 0.25$	$\alpha_3 = 0.30$
0	1.0000000000	1.0000000000	1.0000000000
1	0.9594807690	0.9538323583	0.9484594239
2	0.8699541235	0.8549009446	0.8412802651
3	0.7629219553	0.7402972567	0.7208239981
4	0.6552210985	0.6282837441	0.6062293037
5	0.5551759298	0.5269152972	0.5049058942
6	0.4662878857	0.4388942001	0.4186004586

7	0.3894238430	0.3642625066	0.3465316126
8	0.3240949899	0.3018632817	0.2869609221
9	0.2691887895	0.2501087803	0.2379428292
10	0.2233753154	0.2073643431	0.1976531975

Table 5 Reliability w.r.t. α_3 vs. Time unit (t)

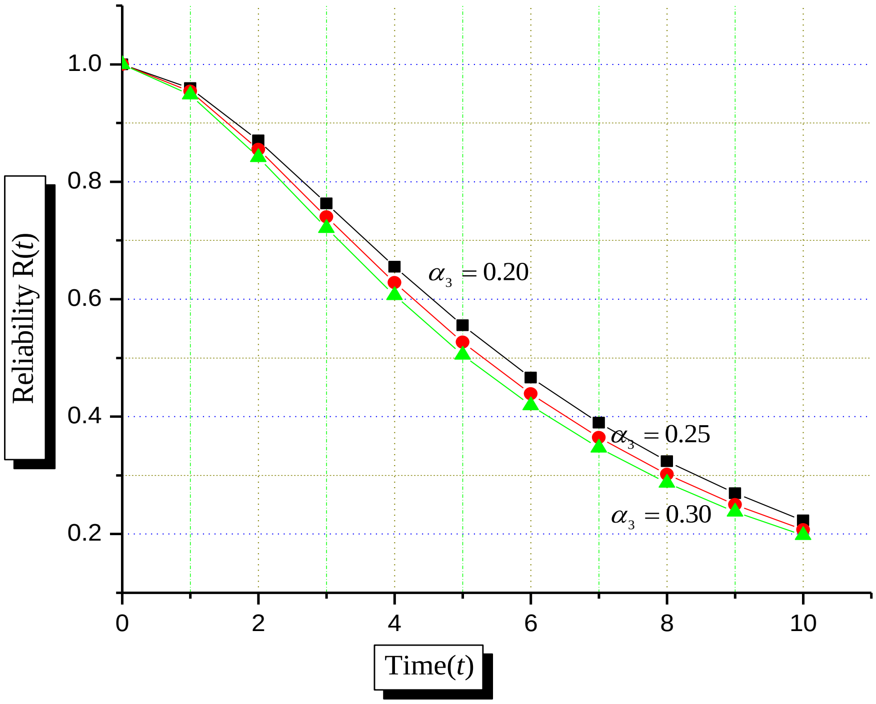

Figure 4 Reliability system w.r.t. α_3 vs. Time unit (t)

7.1.4. Reliability of the considered system w.r.t. the failure of fourth unit

Reliability of the considered system with respect to failure rate of fourth unit will be calculated by taking $\alpha_1 = 0.10, \alpha_2 = 0.17, \alpha_3 = 0.25$ and varying α_4 in equation (42). The behavior of reliability of the system w.r.t. time unit t and α_4 will obtain as given in Table 6 and corresponding Figure 5.

Time Unit (t)	Reliability		
	$\alpha_4 = 0.10$	$\alpha_4 = 0.15$	$\alpha_4 = 0.20$
0	1.0000000000	1.0000000000	1.0000000000
1	0.9538323583	0.9538323583	0.9538323583
2	0.8549009446	0.8549009446	0.8549009446
3	0.7402972567	0.7402972567	0.7402972567
4	0.6282837441	0.6282837441	0.6282837441
5	0.5269152972	0.5269152972	0.5269152972
6	0.4388942001	0.4388942001	0.4388942001

7	0.3642625066	0.3642625066	0.3642625066
8	0.3018632817	0.3018632817	0.3018632817
9	0.2501087803	0.2501087803	0.2501087803
10	0.2073643431	0.2073643431	0.2073643431

Table 6 Reliability w.r.t. α_4 vs. Time unit (t)

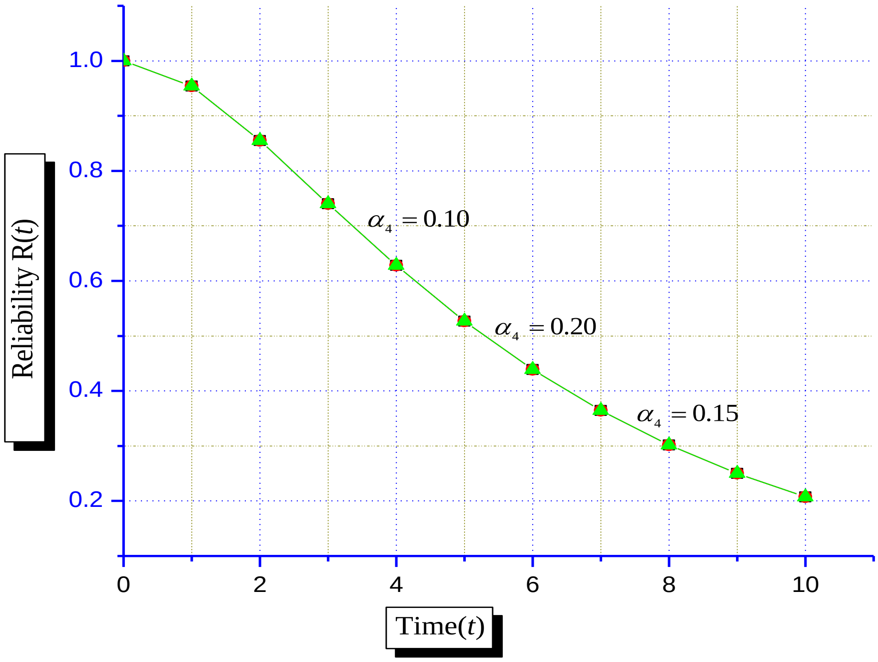

Figure 5 Reliability w.r.t. α_4 vs. Time unit (t)

7.2.Sensitivity of Reliability

One of the critical task for the management of a system is how to identify that which components affects system reliability most and which affect least, so that the maintenance strategy can be planned accordingly. Sensitivity analysis is one of the techniques which help the management to decide the same. Here in the present paper author tried to find out the critical components of the linear consecutive 2-out-of-4: F system which affects it reliability. It can be done by using reliability expression obtained in equation (42). Table 7 and Figure 6 give the sensitivity of the reliability of the considered system with respect to time unit t.

Time Unit (t)	Sensitivity for Reliability			
	$\frac{\partial R(t)}{\partial \alpha_1}$	$\frac{\partial R(t)}{\partial \alpha_2}$	$\frac{\partial R(t)}{\partial \alpha_3}$	$\frac{\partial R(t)}{\partial \alpha_4}$
0	0	0	0	0
1	-0.1101675417	-0.2491442686	-0.1101675417	-0.1866179968
2	-0.2862612436	-0.7166312820	-0.2862612436	-0.5601195992
3	-0.4194050334	-1.1710785220	-0.4194050334	-0.9505246565

4	-0.4866670068	-1.5267471210	-0.4866670068	-1.2809720660
5	-0.4975018265	-1.7657067690	-0.4975018265	-1.5247925180
6	-0.4697955593	-1.8986266300	-0.4697955593	-1.6808120000
7	-0.4202886977	-1.9457824410	-0.4202886977	-1.7594887480
8	-0.3616200376	-1.9284257530	-0.3616200376	-1.7754041440
9	-0.3021580168	-1.8653098810	-0.3021580168	-1.7434167830
10	-0.2468081900	-1.7716695970	-0.2468081900	-1.6768794730

Table 7 Sensitivity for System's reliability w.r.t. t

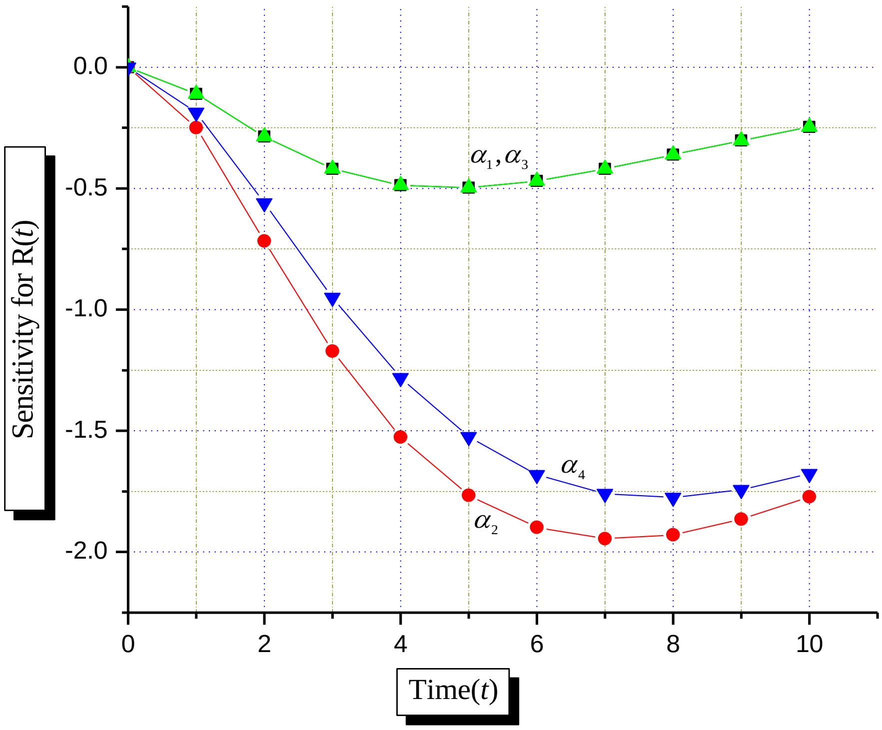

Figure 6 Sensitivity for System's reliability w.r.t. t

8. Result discussion and conclusion

An investigation of the reliability index of a linear consecutive 2-out-of-4: F system is carried out in this paper. The numerical value of the reliability for the same with respect to variation in the failure rates of different components is obtained. Also the reliability of the considered system w.r.t. failure of different unit's with a variation of ± 0.05 is shown in Figures 2-5. Figure 2 tells about the reliability of linear consecutive 2-out-of-4: F system with respect to the failure rate of first unit of the system. It reflects that the numerical value of system reliability w.r.t. first unit's failure at ten unit of time is 0.2233753154, 0.2073643431, 0.1976531975 when first unit failure is taken as 0.05, 0.10, 0.15 respectively. The numerical value of system reliability w.r.t. second unit failure at ten unit of time is 0.4204192082, 0.3018632817, 0.2223928675 when the failure of second unit is taken as 0.12, 0.17, 0.22 respectively (Figure 3). The numerical value of system reliability w.r.t. third unit failure at ten unit of time is 0.2233753154, 0.2073643431, 0.1976531975 when the failure of third unit is taken as 0.20, 0.25, 0.30 respectively (Figure 4). Also Figure 5 reflects the numerical value of considered reliability system w.r.t. fourth unit failure is 0.2073643431, 0.2073643431, 0.2073643431 when failure of fourth is taken as 0.10, 0.15, 0.20 respectively. One important observation from Figure 5 is that system reliability is having the same value with the variation in failure rate of unit four. Figure 6 shows the sensitivity of reliability of the considered system. It shown that the reliability of linear consecutive 2-out-of-4: F system is most sensitive w.r.t. the failure rate of second unit. Hence it can be concluded that the second unit affect the system reliability most. Also system reliability is equally sensitive w.r.t. the failure rate of first and third unit. In future more reliability characteristics e.g. availability, MTTF, MTTR etc. for linear consecutive k-out-of-n: F/G system can be evaluated by using the same techniques.

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