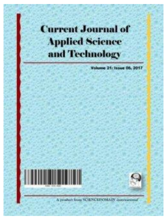

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Reliability Analysis of Ten Unit Bridge Network Connected in Series with Critical and Non-critical Human Errors

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This paper represents about a complex system can produce a non –series parallel structure. The most simple non-series parallel structure is a bridge configuration. In this paper, we discuss the Reliability analysis of ten unit's Bridge network with critical& non-critical human errors. People will always make mistakes when interacting with system design and development processes. Fortunately, human errors can be anticipated, and protective measures taken against their occurrence. This requires the application of human factors in process. It can yield major benefits in risk reduction while construction of complex systems and improved operability for system development processes. When dealing with reliability of complex system, it needs to explore difficulties with human errors early in design with the aim of improving design. Hence complex system development will be erroneous process through reliability technique when compare with other usability and walkthrough techniques. Also, human errors can be eradicated by using experienced people as well by standardizing the process and procedures of system design and development. This concept expresses the using of newly developed approach to perform system reliability analysis.

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1. INTRODUCTION

Humans play a crucial role in the design, development and operational phases incorporated in engineering systems. Among them, Reliability evaluation of systems without taking into consideration the human element does not provide a realistic picture. Hence, there is a mandatory requirement for incorporating the occurrence of human errors in system reliability evaluation [1,2].

A human error is defined as the failure to perform a prescribed task or the performance of a prohibited action which could lead to disruption of scheduled operations and result in damage to property and equipment. Nextly, depending upon the severity of human error consequences, human errors can be classified into two categories, namely, critical and non critical [3,1,2,4]. For our requirement the occurrence of a critical human error causes the entire system to fail, whereas the occurrence of a non-critical human error results in a single unit failure.

In this chapter, we discuss the reliability analysis of bridge network with critical and non-critical human errors. A newly developed approach is used to perform system reliability analysis. This approach is a modified version of the block diagram approach and is demonstrated in model I. model I represents the ten unit bridge network [5,6,7,8].

2. ASSUMPTIONS

The following assumptions are associated with analysis given below: [1-2].

1. A unit can fail either due to a hardware failure or due to a non-critical human error.
2. The occurrence of a critical human error can result in total system failure but the occurrence of a non-critical human error can cause the failure of a single unit only.
3. Each unit failure is independent of others.

3. NOTATIONS

The following symbols are associated with Model I [3,1,2,4,5]:

F_j	Hardware failure probability of j the unit, for j = 1, 2,…..10
f_j	j the unit failure probability with respect to non-critical human errors, For j = 1, 2,……10
f_c	Critical human error occurrence probability associated with the system.
R_{Hj}	Hardware reliability of the j the unit
R_{NCj}	Reliability of the j the unit with respect to non-critical human errors
R_j	Reliability of the j the unit with respect to hardware failures and non-critical human errors
R_C	System reliability with respect to critical human errors
$R_{H, NC}$	System reliability with respect to R_b Bridge system reliability with respect to hardware failure, critical and non-critical human errors
R_b	Bridge system reliability with respect to hardware failure, critical and non-critical human errors
s	Laplace transform variable
t	time

4. ANALYSIS OF BRIDGE NETWORK

This model represents a ten unit bridge network with critical and non-critical human errors as shown in Fig. 1.

In this figure, each real unit is represented by a rectangle. The failure probability of each unit is divided into two components, namely, hardware failure probability and non-critical human error probability [1,2]. These failure probabilities are represented by blocks connected in series as shown in each rectangle in Fig. 1. A hypothetical unit representing critical human errors is connected in series with the bridge network. The total system can fail due to the failure of this hypothetical unit [6,7,8,9,10].

The time-independent reliability analyses are developed for the following two cases [1,2,11,12]:

4.1 Case 1: Non-identical Units

The hardware reliability of j the unit is given by

$$R_{Hj} = 1 - F_j, \text{ for } j = 1, 2, \ldots.-10 \qquad (1)$$

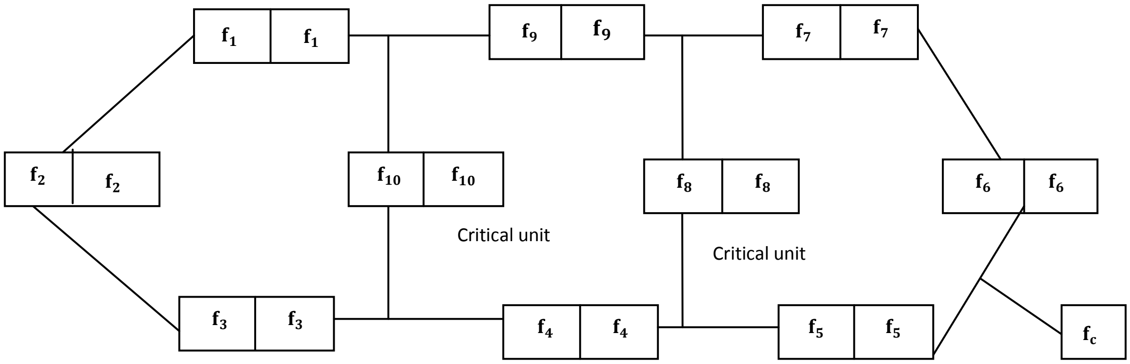

Fig. 1. Block diagram for bridge network

The reliability of the unit with respect to non-critical human errors is

$$R_{NCj} = 1 - f_j,\ \text{for } j = 1,2,\ldots\ldots.10 \qquad (2)$$

The reliability of the j th unit with respect to hardware failures and non-critical human errors is

$$R_J = R_{HJ}\, RNCJ,\ \text{for } j = 1, 2,\ldots..10 \qquad (3)$$

The bride network's reliability with respect to hardware failures and non-critical human errors is:

$$R_{H,NC} = 9\, R_1R_2R_3R_4R_5R_6R_7R_8R_9R_{10} - 4R_1R_2R_3R_4R_5R_6R_7R_8R_9R_{10} - 4R_1R_2R_3R_4R_5R_6R_7R_8R_9 - R_1R_2R_3R_4R_5R_6R_7R_9R_{10} + R_1 R_2 R_3 R_4 R_5 R_6 R_7 R_8 R_9 R_{10} + R_1 R_3 R_4 R_5 R_6 R_7 R_9 R_{10} - 4\, R_1 R_3 R_4 R_5 R_6 R_7 R_8 R_9 + R_1 R_2 R_3 R_4 R_5 R_6 R_7 R_9 - {}_1R\ {}_2R\ {}_3R\ {}_4R\ {}_6R\ {}_7R\ {}_9R\ R_{10} - R_1 R_2 R_3 R_4 R_5 R_6 R_7 R_8 + R_1 R_2 R_4 R_5 R_6 R_7 R_9 R_{10} + R_2 R_3 R_4 R_6 R_7 R_8 R_9 R_{10} + (2\, R_1 R_4 R_5 R_6 R_7 R_9 R_{10}) - R_1 R_2 R_3 R_4 R_5 R_8 R_9 + 2\, R_1 R_3 R_4 R_5 R_6 R_7 R_9 - R_1 R_3 R_4 R_5 R_8 R_9 R_{10} + 2R_1 R_3 R_4 R_6 R_7 R_8 R_9) + 4R_1 R_5 R_6 R_7 R_8 R_9 + 2\, R_1 R_4 R_5 R_8 R_9 R_{10} - R_2 R_3 R_6 R_7 R_9 R_{10} + 2R_1 R_3 R_4 R_5 R_8 R_9 - R_3 R_4 R_6 R_7 R_8 - 4R_2 R_5 R_8 R_9 - 2R_1 R_6 R_7 R_9 \qquad (4)$$

The reliability of the bridge network with respect to critical human errors only is

$$R_C = 1 - f_c \qquad (5)$$

Finally, we get the Reliability of the Bridge Network is

$$R_b = R_c\, .\, R_{H,\,NC} \qquad (6)$$

4.2 CASE 2: Identical Units

By setting $R_j = R$ (i.e., $F_j = F$ and $f_j = f$), for j = 1,2,……6,7--10 then the reliability of the Bridge Network is

$$R_b = R_c\,(9R^{10} - 7R^9 - 3R^8 - 4R^7 + 7R^6 - R^5 - 6R^4) \qquad (7)$$

Where $R = R_{H.}\ R_{NC}$, $R_H = 1 - F$ and $R_{NC} = 1 - f$

The plots of equation (7) are shown in Fig. 2. for the specified values of F, f and f_c. These plots clearly show the impact of varying critical human error probability f_c and non-critical human error probability f on bridge system reliability. It is evident from these plots that the system reliability decreases with increasing values of 'f' and f_c [11,12,13,14].

Time dependent analysis for the following two cases is developed:

Case A: Exponentially distributed failure times:

For exponentially distributed hardware failure, critical and non-critical human error times the time dependent equations for $R_{c,}$ R, $R_{H,}$ R_{NC} are as follows:

$$R_H\,(t) = e^{-\lambda_{H}1}\ : \qquad (8)$$

Where λ_H is the constant hardware failure rate of a unit

$$R_{NC}\,(t) = e^{-\lambda_{NC}t}; \qquad (9)$$

Where λ_{NC} is the constant non-critical human error rate associated with a unit.

$$R(t) = e^{-xt} \quad ; \qquad (10)$$

Where $x = \lambda_H + \lambda_{NC}$

$$R_C(t) = e^{-\lambda_c t}; \qquad (11)$$

where λ_c is the constant critical human error rate associated with the system.

Using equations (7) – (11), we get the reliability of ten identical unit bridge networks as follows:

$$R_b(t) = 9e^{-(bx+\lambda_c)t} - 7e^{-(9x+\lambda_c)t} - 3e^{-(8x+\lambda_c)t} - 4e^{-(7x+\lambda_c)t} + 7e^{-(6x+\lambda_c)t} - e^{-(5x+\lambda_c)t} - 6e^{-(4x+\lambda_c)t} \qquad (12)$$

5. DISCUSSION

Bridge system Reliability Versus critical human error probability for different values is plotted from these graph system reliability decreases with human error probability and time more rapidly. Failure rate of critical human errors are directly impacting on single unit and unit failures are leading the reduction of system reliability over a period of time. The life of the units is low as the errors evolved due to humans and failure times of human errors are distributed exponentially. Bridge system reliability can be improved by reducing human error failure rate.

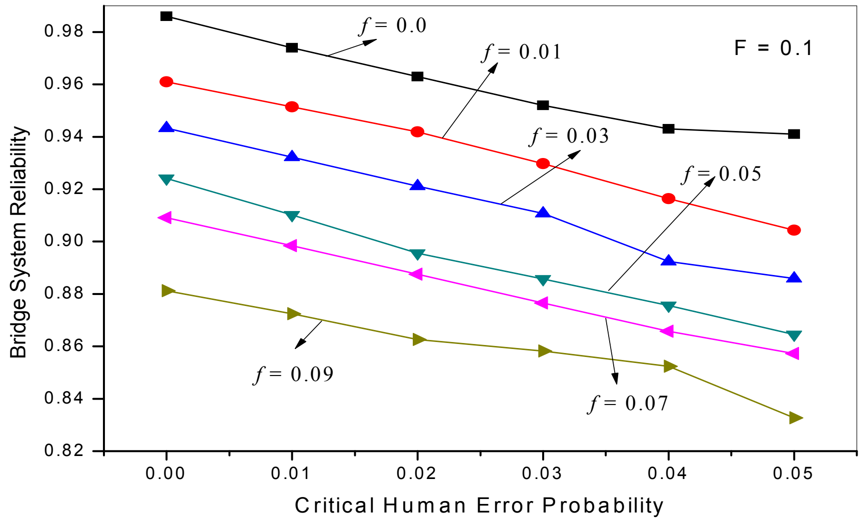

Fig. 2. Critical human error probability vs bridge system

Table 1. Reliability of the bridge network

f_c	Reliability of the bridge network						
	f=0.0	***f=0.01***	***f=0.03***	***f=0.05***	***f= 0.07***	***f=0.09***	***f=1.00***
0.0	0.986	0.9610	0.9433	0.9241	0.9091	0.8812	0.7640
0.01	0.974	0.9514	0.9322	0.9102	0.8984	0.8724	0.7342
0.02	0.963	0.9419	0.9211	0.8592	0.8875	0.8626	0.7423
0.03	0.952	0.9297	0.9107	0.8487	0.8765	0.8582	0.7526
0.04	0.943	0.9164	0.8924	0.8376	0.8657	0.8524	0.7624
0.05	0.941	0.9043	0.8859	0.8246	0.8572	0.8327	0.7562

Table 2. Reliability of the bridge network

S. no.	Time (t)	Reliability of the bridge network				
		$\lambda_c = 0.0$	$\lambda_c = 0.05$	$\lambda_c = 0.1$	$\lambda_c = 0.15$	$\lambda_c = 0.2$
1	0	1	1	1	1	1
2	2	0.6272	0.6589	0.6067	0.5476	0.4240
3	4	0.2865	0.2936	0.2585	0.2198	0.2062
4	6	0.0999	0.0675	0.0526	0.0415	0.0334
5	8	0.0341	0.0262	0.0208	0.0082	0.0084
6	10	0.0083	0.0055	0.0064	0.0026	0.008

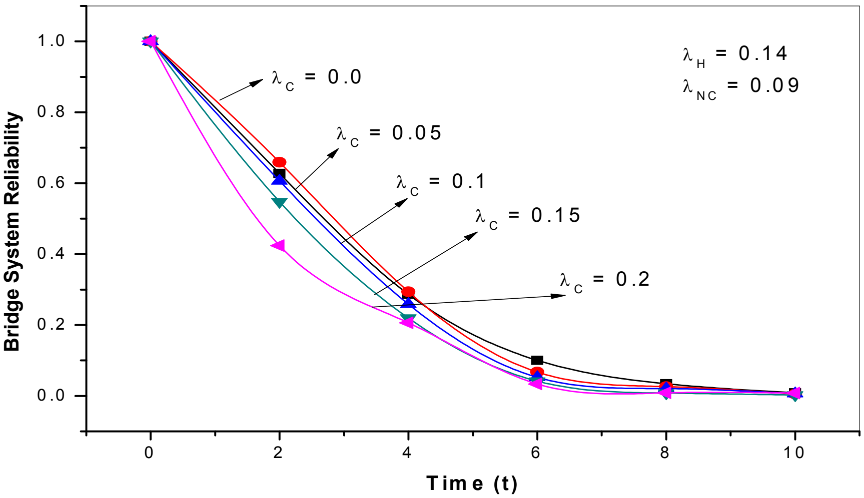

Fig. 3. Time vs reliability

6. CONCLUSION

In this paper, The Reliability Vs Critical human error probability curves and the Reliability Vs Time curves are plotted through exponential model. Here, critical human errors are considered as unit failures to analyze bridge system reliability. Hence, by performing the reliability analysis of ten-unit bridge network connected in series with critical and non-critical human errors, the results evolved from the first graph shows the Bridge System's Reliability decreases slowly while the Critical human error probability increases, and from second graph, the Bridge system Reliability decreases as the time period increases instantaneously. The demonstrations show that the exponential approach can be a very powerful tool to model random human errors of bridge network systems development.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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