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Performance Evaluation and Availability Analysis of a Harvesting System using Fuzzy Reliability Approach

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Abstract: ***Conventional reliability of a system consider the binary state assumption of the probability theory, i.e., either success or failed. But this assumption is unrealistic for large complex systems like harvesting systems due to lack of sufficient probabilistic information. The uncertainty of each individual component enhances the uncertainty of the whole system. In this paper, the concept of fuzzy reliability has been used for the analysis of fuzzy availability of a harvesting system. The effect of coverage factor, failure and repair rate of subsystems on system fuzzy availability has been analysed. Mathematical formulation of problem with help of mnemonic rule and Chapman-Kolmogorov differential equations has been done. The governing differential equations are solved by Runge–Kutta method of order four using MATLAB (Ode 45 function).***

Index Terms: Harvesting System, Markov Process, Fuzzy Availability, Runge-Kutta Method.

INTRODUCTION

From the inception of civilization, human being is engaged in agricultural activities for survival. In the last few decades of 20th century with the development of science and technology use of machinery rapidly increased in agriculture for cultivation, irrigation and harvesting. Before that, most of the manpower always remain engaged in these activities and big amount of crop destroyed in fields due to natural calamities. Technology solve these problems up to a considerable level. Now, harvesting systems like combines are used for harvesting and the use of these save manpower, crops and also economical beneficial. Though, these systems are used extensively but it is mandatory to operate these systems with care and high reliability. Because, these systems are very complex combination of various subsystems. The failure of one subsystem causes the failure of the whole system and failure results as huge economical lose. Though, it is observed that such complex system does not fail directly from the operative state but fail in a gradual manner. So, use of conventional reliability approach, i.e. either fail of operative, for performance evaluation of these systems seems inappropriate.

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In such situations, fuzzy reliability methodology seems useful for reliability evaluation. Zadeh (1965) presented this methodology first time by showing its
applications in scientific environment.
It helps to study the system at all of its possible states from operative to failed state. Singer (1990) suggested a new methodology for finding reliability measures using fault tree and fuzzy set approach. All the repair and failure time variables were considered as triangular fuzzy numbers. Cai and Wen (1990) discussed street-lighting lamps replacement in a fuzzy viewpoint. Cai et al. (1991) studied a gracefully degraded computing system under fuzzy set approach. Kumar et al. (1992) obtained the availability of the crystallization system using the concept of common-cause failure. Cai et al. (1993) suggested fuzzy state as a basis of fuzzy reliability. Cai (1996) defined the fuzzy sets as a mathematical tool to investigate the real world systems fuzziness. Let $x \in X$ be an element of a conventional set then fuzzy set has been defined as a ordered pair of the element and the corresponding membership function over the interval [0, 1]. The membership function is defined as the ratio of available comments and total number of components in the system. Chongshan (2009) derived expression for fuzzy availability of a repairable consecutive-2- out-of-3: F System. Kumar et al. (2009) obtained fuzzy reliability and fuzzy availability of the serial process in butter-oil processing plant. Kumar and Kumar (2011) defined fuzzy availability of the system as the expression $A(t) = \sum_{i=1}^{k} \mu_S(S_i) P_i(t)$, where k denotes the operative states and the concept of coverage factor in terms of probability of successful reconfiguration operation of a fault-tolerant system. It lies between 0 to 1 and if it's value is less than 1called imperfect coverage. In the studies referred above, numerical results obtained by using complex mathematical calculations. To overcome this problem a new approach has been developed in which Runge–Kutta method of order four was used for finding the numerical solution of the developed mathematical model. Aggarwal et al. (2014) studied the availability and performance of a butter oil production system. Aggarwal et al. (2016) formulated a mathematical model and obtained the results for reliability of the serial processes in feeding system of harvesting system. Kumar and Saini (2017) developed a mathematical model for a sugar plant using fuzzy reliability fuzzy approach and obtain the solution using Runge–Kutta method of order four. Till now, no study has been carried out for the reliability evaluation of harvesting systems.

In the present study, an effort has been made to obtain various performance measures of harvesting system using numerical technique and for this analysis required data for estimation of various failure and repair rates are collected from a harvesting system manufacturing industry.

System Description:

Harvesting System is a complex system designed by a combination of various subsystems. It mainly comprises of four subsystems; human, tractor, combine and wagon assembled in a series configuration.

The failure of any single subsystem resulted the complete failure of the whole system. The systematic flow diagram of the harvesting system has been shown in figure-1.

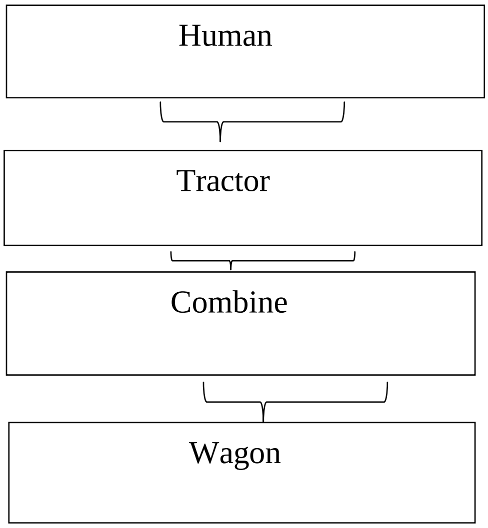

Fig. 1: Reliability Block Diagram

Notations

○ Operative State

◇ Operative with reduced capacity

□ Failed State

Subsystem A (Human): It consists of one unit. It's failure causes the complete failure of the system.

Subsystem B (Tractor): It consists of one unit. It's failure causes the complete failure of the system. It may be remained operative in partially failed state.

Subsystem C (Combine): It consists of one unit. It's failure causes the complete failure of the system. It may be remained operative in partially failed state.

Subsystem D (Wagon): It consists of one unit. It's failure causes the complete failure of the system. A standby unit is provided in spare.

α_1 & μ_1 : Failure and repair rates of subsystem A.

α_2 & μ_2 : Failure and repair rates of subsystem B.

α_3 & μ_3 : Failure and repair rates of subsystem C.

α_4 & μ_4 : Failure and repair rates of subsystem D.

α_5 : Failure rate of subsystem $\overline{B}$

α_6 : Failure rate of subsystem $\overline{C}$

α_7 : Failure rate of standby subsystem D_1

c: It denotes the coverage factor. It may assume any value on the interval [0, 1]. If the unit successfully reconfigured it assigned c coverage factor otherwise its value is 1-c.

a, b, c , d: Denotes the failed state of the subsystem A, B, C , D.

Assumptions

- Two units cannot fails simultaneously.
- The time related random variables are independent to each other.
- Repairs are perfect.
- The repair rate of subsystems B & $\overline{B}$ is considered same.
- The repair rate of subsystems C & $\overline{C}$ is considered same.
- Repair rate of unit D & D_1 is considered same.

System States

The system may be any one of the following states:

$S_1(A,B,C,D)$; $S_2(a,B,C,D)$, $S_3(A,\overline{B},C,D)$; $S_4(A,B,\overline{C},D)$; $S_5(A,B,C,D_1)$; $S_6(a,\overline{B},C,D)$; $S_7(A,b,C,D)$; $S_8(A,\overline{B},\overline{C},D)$; $S_9(A,\overline{B},C,D_1)$; $S_{10}(a,B,\overline{C},D)$; $S_{11}(A,B,c,D)$; $S_{12}(A,B,\overline{C},D_1)$; $S_{13}(a,B,C,D_1)$; $S_{14}(A,B,C,d)$; $S_{15}(a,\overline{B},\overline{C},D)$; $S_{16}(A,b,\overline{C},D)$; $S_{17}(A,\overline{B},c,D)$; $S_{18}(A,\overline{B},\overline{C},D_1)$; $S_{19}(a,\overline{B},C,D_1)$; $S_{20}(A,b,C,D_1)$; $S_{21}(A,\overline{B},C,d)$; $S_{22}(A,B,\overline{C},d)$; $S_{23}(a,B,\overline{C},D_1)$; $S_{24}(A,B,c,D_1)$; $S_{25}(a,\overline{B},\overline{C},D_1)$; $S_{26}(A,b,\overline{C},D_1)$; $S_{27}(A,\overline{B},c,D_1)$; $S_{28}(A,\overline{B},\overline{C},d)$

Mathematical Modelling:

The mathematical modeling of harvesting system is carried out by using Markov birth-death process and the Chapman-Kolmogorov equations are derived. The equations for fuzzy availability are as follows:

$$\frac{dP_1(t)}{dt} + \begin{bmatrix} (1-c)\alpha_1 + c\alpha_2 \\ +c\alpha_3 + c\alpha_4 \end{bmatrix} P_1(t) = \mu_1 P_2(t) + \mu_2 P_3(t)$$
$$+\mu_3 P_4(t) + \mu_4 P_5(t) + \mu_2 P_7(t) + \mu_3 P_{11}(t) \quad (1)$$

$$\frac{dP_2(t)}{dt} + \mu_1 P_2(t) = (1-c)\alpha_1 P_1(t) \quad (2)$$

$$\frac{dP_3(t)}{dt} + \left[(1-c)\alpha_1 + \mu_2 + (1-c)\alpha_5 + c\alpha_3 + c\alpha_4\right] P_3(t)$$
$$= c\alpha_2 P_1(t) + \mu_1 P_6(t) + \mu_4 P_9(t) \quad (3)$$

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$$\frac{dP_4(t)}{dt}+\begin{bmatrix}\mu_3+c\alpha_4+\mu_5+(1-c)\alpha_6\\+(1-c)\alpha_1+c\alpha_2\end{bmatrix}P_4(t)= c\alpha_3P_1(t)+\mu_1P_{10}(t)+\mu_2P_8(t)+\mu_4P_{12}(t) \quad (4)$$

$$\frac{dP_5(t)}{dt}+\begin{bmatrix}c\alpha_3+\mu_4+(1-c)\alpha_7\\+(1-c)\alpha_1+c\alpha_2\end{bmatrix}P_5(t)=c\alpha_4P_1(t)+\mu_1P_{13}(t) +\mu_2P_9(t)+\mu_5P_{14}(t)+\mu_3P_{12}(t) \quad (5)$$

$$\frac{dP_6(t)}{dt}+\mu_1P_6(t)=(1-c)\alpha_1P_3(t) \quad (6)$$

$$\frac{dP_7(t)}{dt}+\mu_2P_7(t)=(1-c)\alpha_5P_3(t) \quad (7)$$

$$\frac{dP_8(t)}{dt}+\begin{bmatrix}c\alpha_4+\mu_2+(1-c)\alpha_5\\+(1-c)\alpha_1+(1-c)\alpha_6\end{bmatrix}P_8(t)=c\alpha_3P_3(t)+c\alpha_2P_4(t) +\mu_1P_{15}(t)+\mu_2P_{16}(t)+\mu_3P_{17}(t)+\mu_4P_{13}(t) \quad (8)$$

$$\frac{dP_9(t)}{dt}+\begin{bmatrix}c\alpha_3+\mu_4+(1-c)\alpha_5\\+\mu_2+(1-c)\alpha_1+(1-c)\alpha_7\end{bmatrix}P_9(t)=c\alpha_2P_5(t) +c\alpha_4P_3(t)+\mu_1P_{19}(t)+\mu_2P_{20}(t)+\mu_5P_{21}(t) \quad (9)$$

$$\frac{dP_{10}(t)}{dt}+\mu_1P_{10}(t)=(1-c)\alpha_1P_4(t) \quad (10)$$

$$\frac{dP_{11}(t)}{dt}+\mu_4P_{11}(t)=(1-c)\alpha_4P_4(t) \quad (11)$$

$$\frac{dP_{12}(t)}{dt}+\begin{bmatrix}c\alpha_2+\mu_4+(1-c)\alpha_6+\mu_3\\+(1-c)\alpha_1+(1-c)\alpha_7\end{bmatrix}P_{12}(t)=c\alpha_3P_5(t) +c\alpha_4P_4(t)+\mu_1P_{23}(t)+\mu_3P_{24}(t)+\mu_5P_{22}(t) \quad (12)$$

$$\frac{dP_{13}(t)}{dt}+\mu_1P_{13}(t)=(1-c)\alpha_1P_5(t) \quad (13)$$

$$\frac{dP_{14}(t)}{dt}+\mu_5P_{14}(t)=(1-c)\alpha_7P_5(t) \quad (14)$$

$$\frac{dP_{15}(t)}{dt}+\mu_1P_{15}(t)=(1-c)\alpha_1P_8(t) \quad (15)$$

$$\frac{dP_{16}(t)}{dt}+\mu_2P_{16}(t)=(1-c)\alpha_5P_8(t) \quad (16)$$

$$\frac{dP_{17}(t)}{dt}+\mu_3P_{17}(t)=(1-c)\alpha_6P_8(t) \quad (17)$$

$$\frac{dP_{18}(t)}{dt}+\begin{bmatrix}(1-c)\alpha_6+\mu_4+(1-c)\alpha_5\\+(1-c)\alpha_1+(1-c)\alpha_7\end{bmatrix}P_{18}(t)=c\alpha_2P_{12}(t) +c\alpha_3P_9(t)+c\alpha_4P_8(t)+\mu_1P_{25}(t)+\mu_2P_{26}(t)+\mu_5P_{28}(t)+\mu_3P_{27}(t) \quad (18)$$

$$\frac{dP_{19}(t)}{dt}+\mu_1P_{19}(t)=(1-c)\alpha_1P_9(t) \quad (19)$$

$$\frac{dP_{20}(t)}{dt}+\mu_2P_{20}(t)=(1-c)\alpha_5P_9(t) \quad (20)$$

$$\frac{dP_{21}(t)}{dt}+\mu_5P_{21}(t)=(1-c)\alpha_7P_9(t) \quad (21)$$

$$\frac{dP_{22}(t)}{dt}+\mu_5P_{22}(t)=(1-c)\alpha_7P_{12}(t) \quad (22)$$

$$\frac{dP_{24}(t)}{dt}+\mu_3P_{24}(t)=(1-c)\alpha_6P_{12}(t) \quad (23)$$

$$\frac{dP_{24}(t)}{dt}+\mu_3P_{24}(t)=(1-c)\alpha_6P_{12}(t) \quad (24)$$

$$\frac{dP_{25}(t)}{dt}+\mu_1P_{25}(t)=(1-c)\alpha_1P_{18}(t) \quad (25)$$

$$\frac{dP_{26}(t)}{dt}+\mu_2P_{26}(t)=(1-c)\alpha_5P_{18}(t) \quad (26)$$

$$\frac{dP_{27}(t)}{dt}+\mu_3P_{27}(t)=(1-c)\alpha_6P_{18}(t) \quad (27)$$

$$\frac{dP_{28}(t)}{dt}+\mu_4P_{28}(t)=(1-c)\alpha_7P_{18}(t) \quad (28)$$

$$FA=P_1(t)+\frac{4}{5}P_3(t)+\frac{4}{5}P_4(t)+\frac{4}{5}P_5(t)+\frac{4}{5}P_8(t)+\frac{4}{5}P_9(t) +\frac{4}{5}P_{12}(t)+\frac{4}{5}P_{18}(t) \quad (29)$$

$$FB=\frac{1}{5}P_2(t)+\frac{1}{5}P_6(t)+\frac{1}{5}P_7(t)+\frac{1}{5}P_{10}(t)+\frac{1}{5}P_{11}(t)+\frac{1}{5}P_{13}(t) +\frac{1}{5}P_{14}(t)+\frac{1}{5}P_{15}(t)+\frac{1}{5}P_{16}(t)+\frac{1}{5}P_{17}(t)+\frac{1}{5}P_{19}(t)+\frac{1}{5}P_{20}(t) +\frac{1}{5}P_{21}(t)+\frac{1}{5}P_{22}(t)+\frac{1}{5}P_{23}(t)+\frac{1}{5}P_{24}(t)+\frac{1}{5}P_{25}(t)+\frac{1}{5}P_{26}(t) +\frac{1}{5}P_{27}(t)+\frac{1}{5}P_{28}(t) \quad (30)$$

$$FP=K_0FA-K_1FB \quad (31)$$

Initial Condition

$$P_j(0)=\begin{cases}1 & if\ \ j=1\\0 & if\ \ j\neq 1\end{cases} \quad (32)$$

Performance Analysis

This section is devoted to the performance evaluation of the harvesting systems by solving mathematical equations [1-28] along with initial condition [29] for fixed set of observations $\alpha_1=0.0003,\ \alpha_2=0.0002, \alpha_3=0.0021,\ \alpha_4=0.0035,$ $\alpha_5=0.009, \alpha_6=0.007, \alpha_7=0.008$ and $\mu_1=1.95,\ \mu_2=1.82, \mu_3=1.7,\ \mu_4=1.92, \mu_5=1.82$. The effect of various repair and failure parameters on availability and profit function has been analysed by taking variation in the values of parameters along with coverage factor and time.

Table-1: Effect of failure and repair rates α_1 & μ_1 on the fuzzy availability and profit of the harvesting system

Coverage Factor	Time (days)	Fuzzy Availability			Profit Analysis		
		Set-I	$\alpha_1 = 0.0003$ to $\alpha_1 = 0.1$	$\beta_1 = 1.95$ to $\beta_1 = 2.4$	Set-I	$\alpha_1 = 0.0003$ to $\alpha_1 = 0.1$	$\beta_1 = 1.95$ to $\beta_1 = 2.4$
C=1	20	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	40	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	60	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	80	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	100	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
C=0.8	20	0.9963	0.98922	0.996873	49811.93	49450.83	49841.17
	40	0.9963	0.98922	0.996873	49811.93	49450.83	49841.17
	60	0.9963	0.98922	0.996873	49811.93	49450.83	49841.17
	80	0.9963	0.98922	0.996873	49811.93	49450.83	49841.17
	100	0.9963	0.98922	0.996873	49811.93	49450.83	49841.17
C=0.6	20	0.9963	0.98922	0.99455	49811.93	49450.83	49722.51
	40	0.993409	0.979432	0.99455	49664.35	48951.48	49722.51
	60	0.993409	0.979432	0.99455	49664.35	48951.48	49722.51
	80	0.993409	0.979432	0.99455	49664.35	48951.48	49722.51
	100	0.993409	0.979432	0.99455	49664.35	48951.48	49722.51
C=0	20	0.984867	0.984867	0.984867	49227.92	49227.92	49227.92
	40	0.984856	0.984856	0.984856	49227.67	49227.67	49227.67
	60	0.984851	0.984851	0.984851	49227.41	49227.41	49227.41
	80	0.984851	0.984851	0.984851	49227.33	49227.33	49227.33
	100	0.984851	0.984851	0.984851	49227.29	49227.29	49227.29

Table-2: Effect of failure and repair rates α_2 & μ_2 on the fuzzy availability and profit of the harvesting system

Coverage Factor	Time (days)	Fuzzy Availability			Profit Analysis		
		Set-I	$\alpha_2 = 0.0002$ to $\alpha_2 = 0.08$	$\beta_2 = 1.82$ to $\beta_2 = 2.7$	Set-I	$\alpha_2 = 0.0002$ to $\alpha_2 = 0.08$	$\beta_2 = 1.82$ to $\beta_2 = 2.7$
C=1	20	0.99921	0.988685	0.999219	49960.48	49434.25	49960.48
	40	0.99921	0.988685	0.999219	49960.48	49434.25	49960.48
	60	0.99921	0.988685	0.999219	49960.48	49434.25	49960.48
	80	0.99921	0.988685	0.999219	49960.48	49434.25	49960.48
	100	0.99921	0.988685	0.999219	49960.48	49434.25	49960.48
C=0.8	20	0.9963	0.987814	0.996307	49811.93	49387.6	49811.93
	40	0.9963	0.987814	0.996307	49811.93	49387.6	49811.93
	60	0.9963	0.987814	0.996307	49811.93	49387.6	49811.93
	80	0.9963	0.987814	0.996307	49811.93	49387.6	49811.93
	100	0.9963	0.987814	0.996307	49811.93	49387.6	49811.93
C=0.6	20	0.993409	0.986994	0.993415	49664.35	49343.54	49664.35
	40	0.993409	0.986994	0.993415	49664.35	49343.54	49664.35

	60	0.993409	0.986994	0.993415	49664.35	49343.54	49664.35
	80	0.993409	0.986994	0.993415	49664.35	49343.54	49664.35
	100	0.993409	0.986994	0.993415	49664.35	49343.54	49664.35
C=0	20	0.984867	0.984867	0.984867	49227.92	49227.92	49227.92
	40	0.984856	0.984856	0.984856	49227.67	49227.67	49227.67
	60	0.984851	0.984851	0.984851	49227.41	49227.41	49227.41
	80	0.984851	0.984851	0.984851	49227.33	49227.33	49227.33
	100	0.984851	0.984851	0.984851	49227.29	49227.29	49227.29

Table-3: Effect of failure and repair rates α_3 & μ_3 on the fuzzy availability and profit of the harvesting system

Coverage Factor	**Time (days)**	**Fuzzy Availability**			**Profit Analysis**		
		Set-I	$\alpha_3 = 0.0021$ to $\alpha_3 = 0.9$	$\beta_3 = 1.7$ to $\beta_3 = 2.8$	**Set-I**	$\alpha_3 = 0.0021$ to $\alpha_3 = 0.9$	$\beta_3 = 1.7$ to $\beta_3 = 2.8$
C=1	20	0.99921	0.913126	0.99933	49960.48	45656.32	49966.52
	40	0.99921	0.913126	0.999331	49960.48	45656.32	49966.53
	60	0.99921	0.913126	0.999331	49960.48	45656.32	49966.53
	80	0.99921	0.913126	0.999331	49960.48	45656.32	49966.53
	100	0.99921	0.913126	0.999331	49960.48	45656.32	49966.53
C=0.8	20	0.9963	0.922312	0.996397	49811.93	46112.31	49816.77
	40	0.9963	0.922312	0.996397	49811.93	46112.3	49816.77
	60	0.9963	0.922312	0.996397	49811.93	46112.3	49816.78
	80	0.9963	0.922312	0.996397	49811.93	46112.3	49816.77
	100	0.9963	0.922312	0.996397	49811.93	46112.3	49816.78
C=0.6	20	0.993409	0.933462	0.993482	49664.35	46666.58	49667.99
	40	0.993409	0.933462	0.993482	49664.35	46666.58	49667.99
	60	0.993409	0.933462	0.993482	49664.35	46666.58	49667.98
	80	0.993409	0.933462	0.993482	49664.35	46666.58	49667.99
	100	0.984867	0.984867	0.984867	49227.92	49227.92	49227.92
C=0	20	0.984856	0.984856	0.984856	49227.67	49227.67	49227.67
	40	0.984851	0.984851	0.984851	49227.41	49227.41	49227.41
	60	0.984851	0.984851	0.984851	49227.33	49227.33	49227.33
	80	0.984851	0.984851	0.984851	49227.29	49227.29	49227.29
	100	0.984867	0.984867	0.984867	49227.92	49227.92	49227.92

Table-4: Effect of failure and repair rates α_4 & μ_4 on the fuzzy availability and profit of the harvesting system

Coverage Factor	**Time (days)**	**Fuzzy Availability**			**Profit Analysis**		
		Set-I	$\alpha_4 = 0.0035$ to $\alpha_4 = 0.7$	$\beta_4 = 1.92$ to $\beta_4 = 2.5$	**Set-I**	$\alpha_4 = 0.0035$ to $\alpha_4 = 0.7$	$\beta_4 = 1.92$ to $\beta_4 = 2.5$
C=1	20	0.99921	0.932952	0.999315	49960.48	46647.62	49965.75
	40	0.99921	0.932952	0.999315	49960.48	46647.62	49965.75
	60	0.99921	0.932952	0.999315	49960.48	46647.62	49965.75
	80	0.99921	0.932952	0.999315	49960.48	46647.62	49965.75

	100	0.99921	0.932952	0.999315	49960.48	46647.62	49965.75
C=0.8	20	0.9963	0.940264	0.996385	49811.93	47009.97	49816.16
	40	0.9963	0.940264	0.996385	49811.93	47009.97	49816.16
	60	0.9963	0.940264	0.996385	49811.93	47009.97	49816.16
	80	0.9963	0.940264	0.996385	49811.93	47009.97	49816.16
	100	0.9963	0.940264	0.996385	49811.93	47009.97	49816.16
C=0.6	20	0.993409	0.948836	0.993473	49664.35	47435.38	49667.52
	40	0.993409	0.948836	0.993473	49664.35	47435.38	49667.53
	60	0.993409	0.948836	0.993473	49664.35	47435.38	49667.53
	80	0.993409	0.948836	0.993473	49664.35	47435.38	49667.53
	100	0.993409	0.948836	0.993473	49664.35	47435.38	49667.53
C=0	20	0.984867	0.984867	0.984867	49227.92	49227.92	49227.92
	40	0.984856	0.984856	0.984856	49227.67	49227.67	49227.67
	60	0.984851	0.984851	0.984851	49227.41	49227.41	49227.41
	80	0.984851	0.984851	0.984851	49227.33	49227.33	49227.33
	100	0.984851	0.984851	0.984851	49227.29	49227.29	49227.29

Table-5: Effect of failure and repair rates α_5 & μ_5 on the fuzzy availability and profit of the harvesting system

Coverage Factor	**Time (days)**	**Fuzzy Availability**			**Profit Analysis**		
		Set-I	$\alpha_5 = 0.009$ to $\alpha_5 = 0.09$	$\beta_5 = 1.82$ to $\beta_5 = 2.6$	**Set-I**	$\alpha_5 = 0.009$ to $\alpha_5 = 0.09$	$\beta_5 = 1.82$ to $\beta_5 = 2.6$
C=1	20	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	40	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	60	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	80	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	100	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
C=0.8	20	0.9963	0.996299	0.9963	49811.93	49811.9	49811.93
	40	0.9963	0.996299	0.9963	49811.93	49811.9	49811.93
	60	0.9963	0.996299	0.9963	49811.93	49811.9	49811.93
	80	0.9963	0.996299	0.9963	49811.93	49811.9	49811.93
	100	0.9963	0.996299	0.9963	49811.93	49811.9	49811.93
C=0.6	20	0.993409	0.993408	0.993409	49664.35	49664.3	49664.35
	40	0.993409	0.993408	0.993409	49664.35	49664.3	49664.35
	60	0.993409	0.993408	0.993409	49664.35	49664.3	49664.35
	80	0.993409	0.993408	0.993409	49664.35	49664.3	49664.35
	100	0.993409	0.993408	0.993409	49664.35	49664.3	49664.35
C=0	20	0.984867	0.984867	0.984867	49227.92	49227.92	49227.92
	40	0.984856	0.984856	0.984856	49227.67	49227.67	49227.67
	60	0.984851	0.984851	0.984851	49227.41	49227.41	49227.41
	80	0.984851	0.984851	0.984851	49227.33	49227.33	49227.33
	100	0.984851	0.984851	0.984851	49227.29	49227.29	49227.29

Table-6: Effect of failure rates α_6 & α_7 on the fuzzy availability and profit of the harvesting system

Coverage Factor	Time (days)	Fuzzy Availability			Profit Analysis		
		Set-I	$\alpha_6 = 0.007$ to $\alpha_6 = 0.8$	$\alpha_7 = 0.008$ to $\alpha_7 = 0.91$	Set-I	$\alpha_6 = 0.007$ to $\alpha_6 = 0.8$	$\alpha_7 = 0.008$ to $\alpha_7 = 0.91$
C=1	20	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	40	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	60	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	80	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
	100	0.99921	0.99921	0.99921	49960.48	49960.48	49960.48
C=0.8	20	0.9963	0.996237	0.996164	49808.72	49808.72	49805
	40	0.9963	0.996237	0.996164	49808.72	49808.72	49805
	60	0.9963	0.996237	0.996164	49808.71	49808.71	49805
	80	0.9963	0.996237	0.996164	49808.72	49808.72	49805
	100	0.9963	0.996237	0.996164	49808.72	49808.72	49805
C=0.6	20	0.993409	0.993323	0.993207	49659.94	49659.94	49654.01
	40	0.993409	0.993324	0.993207	49659.94	49659.94	49654.01
	60	0.993409	0.993323	0.993207	49659.94	49659.94	49654.01
	80	0.993409	0.993323	0.993207	49659.94	49659.94	49654.01
	100	0.993409	0.993323	0.993207	49659.94	49659.94	49654.01
C=0	20	0.984867	0.984867	0.984867	49227.92	49227.92	49227.92
	40	0.984856	0.984856	0.984856	49227.67	49227.67	49227.67
	60	0.984851	0.984851	0.984851	49227.41	49227.41	49227.41
	80	0.984851	0.984851	0.984851	49227.33	49227.33	49227.33
	100	0.984851	0.984851	0.984851	49227.29	49227.29	49227.29

CONCLUSION

In the present study, performance evaluation of a harvesting system has been carried out using fuzzy reliability approach. The results derived here are useful for harvesting system manufacturers. It is revealed from numerical results shown in tables [1-6] that coverage factor plays a prominent role in the availability and profit of the system. These measures decrease rapidly if value of fault coverage factor decreases. It is simultaneously observed that availability and profit decreases with increase of various failure rates and time while there is enough enhancement in the value of these measures by increase various repair rates. Finally, it is conclude that by improving the process of fault coverage, by making provision of standby units, adopting proper maintenance policies the fuzzy availability and profit can be improved.

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