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Research Article

RAMD analysis of mixed standby serial manufacturing system

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ABSTRACT

This study aimed to increase textile manufacturing system dependability, reliability, maintainability, availability, and metrics like MTBF and MTTF by boosting RAMD. The textile system under investigation is a serial system consisting of five subsystems, which are; subsystem A is weaving section, subsystem B is the dry clean section, subsystem C is the cross cut section, subsystem D is the side seam section and subsystem E is the cleaning section. Each of the subsystem consist of main unit, warm standby unit and cold standby unit. For design and prediction, the Markovian birth-death method is employed to assemble the system governing the differential difference equation from the state-to-state transition diagram. The rates of repair and failure of each subsystem are exponentially distributed and statistically independent. For several subsystems of the system, the findings for RAMD, all of which are crucial to system performance, have been acquired and shown in figures and tables. Furthermore, the results of this study reveal that the highest system performance and dependability may be achieved when the overall system failure rate is low. The findings of this research are thought to be valuable for analyzing performance and determining the best system design and feasible maintenance strategies that may be used in the future to improve system performance, strength, effectiveness, production output as well as revenue mobilization.

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INTRODUCTION

RAMD is a logistical technique for assessing the strength, effectiveness, and performance of equipment at various levels. It ensures system safety and operation problems and identifies which of the system's units, components, or subsystems require adequate maintenance. RAMD (reliability, availability, maintainability, and dependability) management is critical to a company's success. These four measures of system strength, effectiveness, and performance can be used to forecast system speed, product quality, and volume production output.

Researchers have used a variety of approaches to assess reliability measures in the literature. RAMD analysis was used by [1] to generate a mathematical model for assessing the effectiveness of serial mechanisms in a sugar plant's refining system. [2] proposed a reliability and availability assessment of the skim industry powder business. The

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Markovian process is used to evaluate measures such as maintainability, reliability, dependability, and availability in determining its capability and reliability. [3] concentrate on increasing the profit of engineering systems with serial subsystems by improving system performance indicators like availability and reliability. [4] investigate the reciprocating unit's system availability, maintainability, and dependability in the oil and gas industries in order to improve the unit's operating performance. [5] uses particle swamp optimization and fuzzy techniques to assess industrial reliability, maintainability, and availability. [6] investigated the efficiency of the forming industry by assessing system maintainability, dependability, and availability. [7] developed Markov models for RAM performance estimation of circulation system of water. [8] discuss the RAM evaluation of Load Haul Dumpers.

Available studies either neglects or overlooks the importance of warm and cold standby in strengthening system reliability, availability, mean time to failure, and MTBF. Most previous studies focused solely on system availability and effectiveness evaluation, paying little attention to the influence of warm and cold standby units on reliability, availability, mean time to failure, and generated revenue. More advanced designs with mixed standby units should indeed be established to reduce the likelihood of a complete breakdown, expenditures, overall reliability, availability, mean time to failure, and revenue generated (profit).

The aforementioned literature review presented in Table 1 above reveals that the RAMD evaluation of some industrial and manufacturing system having mixture of warm and cold standby units when failure and repair rates as Lindley and Exponentiated Weibull distributed has not been explored so far. Motivated by the aforementioned studies in Table 1 above, the objective of this work is to perform RAMD analysis of textile system with mixed standby unit when failure rates follows Lindley and Exponentiated Weibull distribution. As a result, this study considers a textile manufacturing system that consists of five distinct subsystems equipped as a series-parallel system, each consisting of a combination of primary units, warm standby units, and cold standby units. The system's effectiveness is investigated via first order differential difference equations. Availability as one of the performance measures of system strength and effectiveness have been computed for each configuration. The present work will perform RAMD analysis of textile system with mixed standby unit when failure rates follows Lindley and Exponentiated Weibull distribution.

The following are the paper's contributions:

✓ To formulated novel models of RAMD analysis of textile manufacturing system considering models; main,

Table 1. Some related research on availability, maintainability, reliability and dependability of some complex systems

Reference	System	Standby used	Exponential distribution	Lindley distribution	Exponentiated Weibull distribution	Reliability	Availability	Maintainability	Dependability
[9]	Sewage treatment plant	N/A	yes	no	no	yes	yes	yes	yes
[10]	Series-parallel	Cold	yes	no	no	yes	yes	yes	yes
[11]	Cement	Cold	yes	no	no	yes	yes	yes	no
[12]	Steam turbine power plant	N/A	yes	no	no	yes	yes	yes	No
[13]	Water treatment plant	N/A	yes	no	no	yes	yes	yes	Yes
[14]	Tube-well	N/A	yes	no	no	yes	yes	yes	Yes
[15]	Sugar Plant	N/A	yes	no	no	yes	yes	yes	yes
[16]	microprocessor	N/A	yes	no	no	yes	yes	yes	yes
[17]	sugar manufacturing plant	N/A	no	no	no	yes	no	yes	no
[18]	hot standby database systems	N/A	yes	no	no	yes	yes	yes	no
[19]	Automotive manufacturing	N/A	yes	no	no	yes	yes	yes	yes
[20]	power generating unit of sewage treatment plant	N/A	yes	no	no	yes	no	yes	no
Proposed study	Textile confection plant	mixed	yes	yes	yes	yes	yes	yes	yes

warm and cold standby units. Warm standby unit reduce energy use and recovery period because a standby unit is partly energized and subjected to maximum stress while the primary unit is up and running and completely powered and functional after the primary unit stops working.

- ✓ Developing the explicit expressions for the availability, reliability, mean time between failure, maintainability, mean time to failure and dependability for each subsystem.
- ✓ To see the performance of the system through ramd models under exponential, Lindley and exponentiated Weibull distributions.

The following is how this paper is structured. The framework for this study is described in Section 2. Section 3 discusses the methods and materials used. Section 4 is dedicated to the modelling approach. Section 5 presents the simulation studies and consequences discussion, and Section 6 concludes the paper.

DESCRIPTION OF THE SYSTEM AND NOTATIONS

Description of The System

The textile system under investigation is a serial system consisting of five subsystems, which are; weaving section, dry clean section, cross cut section, side seam section and cleaning section. Each of the subsystem consist of main unit, warm standby unit and cold standby unit as shown in Table 2. Warm standby unit are introduced in enhancing the performance of the system. Warm standby units have the capacity to reduce energy use and recovery period because a standby unit is partly energized and subjected to maximum stress while the primary unit is up and running and completely powered and functional after the primary unit stops working. When one of the primary units fails, the warm standby resumes to work with minimal service interruption. Sequel to this, system with warm or mixed standby units have gained the attention of different researchers. To cite few, [21] analysed the cost benefit of warm standby retrial systems with imperfect coverage. Analysis of reliability and availability of a redundant k-out-of-n warm standby system in the presence of common cause failure has been presented in [22]. Evaluation of reliability and performance of power system having warm standby unit is given in [23]. [24] focus on profit optimization of a warm standby non identical system in normal and abnormal environment. [25] analysed reliability of warm standby serial system with switching mechanism and uncertain lifetimes. [26] presented reliability simulation of warm standby two component system having switching and back switching failures. [27] focus on economic analysis of warm standby system attended by single server. [28] analysed the profit of warm standby system attended by single server with priority. [29] analysed the performance of warm standby machine repair problem with servers' vacation, impatient and controlling F-policy.

The system can be in perfect or initial state when new. At the failure of one of the primary unit, a warm standby unit will shift to take over the failed unit while the cold standby unit will take the position of warm standby unit. This failure is called the partial failure. When all the primary and warm standby failed, the system is down. This called complete failure.

Subsystem A (Weaving)

Any machine that weaves yarn into fabric is referred to as a weaving machine. They are used to render upholstery fabric, silk, and ornate carpets. They come in shuttle, circular, and narrow fabric options.

Subsystem B (Dry Clean): A dry cleaning machine is any sanitizing device that uses a solvent other than water to tidy clothing and textiles. Although liquid is still used in dry cleaning, clothes are submerged in a water-free liquid solvent and other detergent, which is the most commonly used solvent.

Subsystem C (Cross Cut): A cross cutter machine is an equipment that cuts both hard and soft wood.

Subsystem D (Side Seam): A seam is a method of joining a number of pieces of garment, typically with thread to form stitches. Seams can be hand-stitched or machine-stitched. A seam is a line that connects pieces of fabric and other materials in a garment.

Subsystem E (Cleaning): Cleaning is the mechanical removal of loosely bound fibers, such as brushing, sueding, or grinding. Cleaning processes that are solvent-free are workable alternatives to the traditional solvent-based regular cleaning. They reduce waste generation and remove potential risks caused by the use and application of toxic, ozone-depleting, and frequently flammable solvents. Sanding, grinding, polishing, brushing / sueding, cropping, and shearing are examples of cleaning operations.

Table 2. System Configuration

Machine/Subsystem	Primary Unit	Warm Standby Unit	Cold Standby Unit	Total
Weaving (A)	4	1	1	6
Dry Clean (B)	5	2	1	8
Cross Cut (C)	2	2	2	6
Side Seam (D)	3	2	1	6
Cleaning (E)	4	2	1	7

Notations

q: time variable

λ_1 / λ_2 / λ_3 / λ_4 / λ_5: main unit failure rate in weaving subsystem, dry clean subsystem, cross cot subsystem, side seam subsystem and cleaning subsystem.

α_1 / α_2 / α_3 / α_4 / α_5: warm standby unit failure rate in weaving subsystem, dry clean subsystem, cross cot subsystem, side seam subsystem and cleaning subsystem.

μ_1 / μ_2 / μ_3 / μ_4 / μ_5: warm standby unit failure rate in weaving subsystem, dry clean subsystem, cross cot subsystem, side seam subsystem and cleaning subsystem.

$\vartheta_k(q)$: probability that the system is in state S_k at time q.

MATERIALS AND METHODS

Reliability Models

The chance that a system/machine will be up and running throughout a period of time q is defined as reliability. Thus, reliability $R(q) = P_r\{Q > q\}$, where Q is the time when the system is down and not running with $R(q) \geq 0$, $R(q) = 1$. (For a full description, see Ebeling (2000)). Thus,

$$R(q) = \int_q^\infty f(q_0)\, dq_0 \tag{1}$$

and

$$R(q) = e^{-mq} \tag{2}$$

$$R(q) = \left(\frac{1+m+mq}{1+m}\right)e^{-mq} \tag{3}$$

$$R(t) = 1 - \left(1 - e^{-(\lambda t)^\gamma}\right)^\alpha \tag{4}$$

for exponentially, Lindley and exponentiated Weibull distributed rate of failure respectively.

$$A(q) = lim A(Q) = \frac{MTBF}{MTBF+MTTR}\,. \tag{5}$$

Maintainability

$$M(q) = P(Q \leq q) = 1 - e^{\left(\frac{-q}{MTTR}\right)} = 1 - e^{-\mu q}. \tag{6}$$

where μ is the constant system's repair rate.

Dependability

Dependability is a metric given by

$$D_{min} = 1 - \left(\frac{1}{h-1}\right)\left(e^{-log(h)/h-1} - e^{-hlog(h)/h-1}\right)\,. \tag{7}$$

where

$$h = \frac{\mu}{\theta} = \frac{MTBF}{MTTR}. \tag{8}$$

Mean Time Between Failure

The average time between the failures is known as MTBF. It's usually expressed in hours. As the MTBF increases, so does the system's reliability. The MTBF is given by

$$MTBF = \int_0^\infty R(q)\, dq = \int_0^\infty e^{-mq}\, dq = \frac{1}{m}. \tag{9}$$

Mean Time to Repair

The reciprocal of the system repair rate is specified as MTTR given by

$$MTTR = \mu^{-1} \tag{10}$$

where μ is the system's repair rate.

FORMULATION OF MATHEMATICAL MODELS FOR RAMD

In this section, Chapman Kolmogorov differential equations for each subsystem have been constructed using the Markov birth-death process for mathematical modeling of textile manufacturing system. Table 3 displays various subsystem failure and repair rates. Table 4 below gives the description of the state of each subsystem.

Table 4. Transition rate table for Subsystem A

	S_0	S_1	S_2	S_3
S_0	0	$4\lambda_1 + \alpha_1$	0	0
S_1	μ_1	0	$4\lambda_1 + \alpha_1$	0
S_2	0	$2\mu_1$	0	$4\lambda_1$
S_3	0	0	$3\mu_1$	0

Table 3. Failure and repair rate

Machine/Subsystem	Failure rate (λ) Operational Units	Failure rate (α) Warm standby Units	Repair rate (μ)
Weaving (A)	0.015	0.015	0.35
Dry Clean (B)	0.025	0.016	0.20
Cross Cut (C)	0.010	0.014	0.15
Side Seam (D)	0.035	0.017	0.40
Cleaning (E)	0.050	0.013	0.55

RAMD Analysis for Subsystem A (Weaving unit)

This section consists of four primary operation unit (main unit), one warm standby unit and one cold standby unit. When one of the primary units failed, the warm standby unit switch to operation as primary unit and the cold standby unit switch to the position of warm standby unit. Through Table 4 below, the Chapman-Kolmogrov differential difference equations (11)-(14) are derived using Markovian birth-death process.

Where S_0 is the perfect state, S_1, S_2 are partial failure states and S_3 is the complete failure state.

$$\frac{d}{dq}\vartheta_0(q) = -(4\lambda_1 + \alpha_1)\vartheta_0(q) + \mu_1\vartheta_1(q) \tag{11}$$

$$\frac{d}{dq}\vartheta_1(q) = -(4\lambda_1 + \alpha_1 + \mu_1)\vartheta_1(q) + (4\lambda_1 + \alpha_1)\vartheta_0(q) + 2\mu_1\vartheta_2(q) \tag{12}$$

$$\frac{d}{dq}\vartheta_2(q) = -(4\lambda_1 + 2\mu_1)\vartheta_1(q) + (4\lambda_1 + \alpha_1)\vartheta_1(q) + 3\mu_1\vartheta_3(q) \tag{13}$$

$$\frac{d}{dq}\vartheta_3(q) = -3\vartheta_3(q) + 4\lambda_1\vartheta_2(q) \tag{14}$$

The normalizing condition for this problem is

$$\vartheta_0(q) + \vartheta_1(q) + \vartheta_2(q) + \vartheta_3(q) = 1 \tag{15}$$

Availability of subsystem A is

$$A_{S1} = \vartheta_0(q) + \vartheta_1(q) + \vartheta_2(q) \tag{16}$$

Setting (11) to (14) to zero as $q \to \infty$ in steady state, availability of subsystem A in (16) is now

$$A_{S1}(\infty) = \frac{1 + m_1 + \frac{m_1^2}{2}}{1 + m_1 + \frac{m_1^2}{2} + \frac{2\lambda_1 m_1^2}{3\mu_1}} \tag{17}$$

Where $m_1 = \left(\frac{4\lambda_1 + \alpha_1}{\mu_1}\right)$

The Corresponding reliability, maintainability, dependability and MTBF, MTTR for main and warm standby unit of subsystem A are

$$R_{S1}(q) = \exp^{-\lambda_1 q} \tag{18}$$

$$R_{S1}(q) = \exp^{-\alpha_1 q} \tag{19}$$

$$M_{S1} = 1 - \exp^{-\mu_1 q} \tag{20}$$

Mean time between failure (MTBF= $\lambda_1^{-1} = 66.6667\,h$ for main unit

Mean time between failure (MTBF)= $\alpha_1^{-1} = 66.6667\,h$ for warm standby unit

Mean time to repair (MTTR)= $\mu_1^{-1} = 2.8571\,h$

Dependability ratio d= $\frac{\mu_1}{\lambda_1} = 23.3345$ for main unit

Dependability ratio d= $\frac{\mu_1}{\alpha_1} = 23.3345$ for warm standby unit

$$D_{\min}(s_1) = 1 - \left(\frac{1}{d-1}\right)\left(\exp^{-\frac{\ln d}{d-1}} - \exp^{\frac{d \ln d}{d-1}}\right) = 0.9595$$

for main and warm standby unit

RAMD Analysis for Subsystem B (Dry Clean section)

This section consist of five primary unit, two warm standby and one cold standby unit. Similar to the method described in section 4.1 above, from Table 5 the differential difference equations in (21)-(25) are derived using Markovian birth-death process.

Where S_0 is the perfect state, S_1, S_2, S_3 are partial failure states and S_4 is the complete failure state

Table 5. Transition rate table for Subsystem B

	S_0	S_1	S_2	S_3	S_4
S_0	0	$5\lambda_2 + 2\alpha_2$	0	0	0
S_1	μ_2	0	$5\lambda_2 + 2\alpha_2$	0	0
S_2	0	$2\mu_2$	0	$5\lambda_2 + \alpha_2$	0
S_3	0	0	$3\mu_2$	0	$5\lambda_2$
S_4	0	0	0	$4\mu_2$	0

$$\frac{d}{dq}\vartheta_0(q) = -(5\lambda_2 + \alpha_2)\vartheta_0(q) + \mu_2\vartheta_1(q) \tag{21}$$

$$\frac{d}{dq}\vartheta_1(q) = -(5\lambda_2 + 2\alpha_2 + \mu_2)\vartheta_1(q) + (5\lambda_2 + 2\alpha_2)\vartheta_0(q) + 2\mu_2\vartheta_2(q) \tag{22}$$

$$\frac{d}{dq}\vartheta_2(q) = -(5\lambda_2 + \alpha_2 + 2\mu_2)\vartheta_2(q) + (5\lambda_2 + 2\alpha_2)\vartheta_1(q) + 3\mu_2\vartheta_3(q) \tag{23}$$

$$\frac{d}{dq}\vartheta_3(q) = -(5\lambda_2 + 3\mu_2)\vartheta_3(q) + (5\lambda_2 + \alpha_2)\vartheta_2(q) + 4\mu_2\vartheta_4(q) \tag{24}$$

$$\frac{d}{dq}\vartheta_4(q) = -4\mu_2\vartheta_4(q) + 5\lambda_2\vartheta_3(q) \tag{25}$$

Table 6. Transition rate table for Subsystem C

	S_0	S_1	S_2	S_3	S_4	S_5
S_0	0	$2\lambda_3 + 2\alpha_3$	0	0	0	0
S_1	μ_3	0	$2\lambda_3 + 2\alpha_3$	0	0	0
S_2	0	$2\mu_3$	0	$2\lambda_3 + 2\alpha_3$	0	0
S_3	0	0	$3\mu_3$	0	$2\lambda_3 + \alpha_3$	0
S_4	0	0	0	$4\mu_3$	0	$2\lambda_3$
S_5	0	0	0	0	$5\mu_3$	0

The normalizing condition for this problem is

$$\vartheta_0(q)+\vartheta_1(q)+\vartheta_2(q)+\vartheta_3(q)+\vartheta_4(q)=1 \tag{26}$$

Availability of subsystem B is

$$A_{S2}=\vartheta_0(q)+\vartheta_1(q)+\vartheta_2(q)+\vartheta_3(q) \tag{27}$$

Setting (21) to (25) to zero as $q ® $ in steady state, availability of subsystem B in (27) is now

$$A_{S2}=\frac{1+m_2+\frac{m_2^2}{2}+\frac{(5\lambda_2+\alpha_2)m_2^2}{6\mu_2}}{1+m_2+\frac{m_2^2}{2}+\frac{(5\lambda_2+\alpha_2)m_2^2}{6\mu_2}+\frac{5\lambda_2(5\lambda_2+\alpha_2)m_2^2}{24\mu_2^2}} \tag{28}$$

Where $m_2=\left(\frac{5\lambda_2+2\alpha_2}{\mu_2}\right)$

The Corresponding reliability, maintainability, dependability and MTBF, MTTR for main and warm standby unit of subsystem B are

$$R_{S2}(q)=\exp^{-\lambda_2 q} \tag{29}$$

$$R_{S2}(q)=\exp^{-\alpha_2 q} \tag{30}$$

$$M_{S2}=1-\exp^{-\mu_2 q} \tag{31}$$

Mean time between failure (MTBF)= $\lambda_2^{-1}=40\,h$ for main unit

Mean time between failure (MTBF)= $\alpha_2^{-1}=62.5\,h$ for warm standby unit

Mean time to repair (MTTR)= $\mu_2^{-1}=5h$

Dependability ratio d= $\frac{\mu_2}{\lambda_2}=8$ for main unit

$$D_{\min}(s_2)=1-\left(\frac{1}{d-1}\right)\left(\exp^{-\frac{\ln d}{d-1}}-\exp^{\frac{d\ln d}{d-1}}\right)=0.8877$$

for main unit

Dependability ratio d= $\frac{\mu_2}{\alpha_2}=12.5$ for warm standby unit

$$D_{\min}(s_2)=1-\left(\frac{1}{d-1}\right)\left(\exp^{-\frac{\ln d}{d-1}}-\exp^{\frac{d\ln d}{d-1}}\right)=0.9357$$

for main and warm standby unit

RAMD Analysis for Subsystem C (Cross Cut Unit)

The cross-cut section consists of two primary operation unit, two warm standby unit and two cold standby unit. Using the method described in section 4.1 above, the Chapman-Kolmogrov differential difference equations (32)-(37) are derived using Markovian birth-death process from Table 6 below:

Where S_0 is the perfect state, S_1, S_2, S_3, S_4 are partial failure states and S_5 is the complete failure state

$$\frac{d}{dq}\vartheta_0(q)=-(2\lambda_3+2\alpha_3)\vartheta_0(q)+\mu_3\vartheta_1(q) \tag{32}$$

$$\frac{d}{dq}\vartheta_1(q)=-(2\lambda_3+2\alpha_3+\mu_3)\vartheta_1(q)+(2\lambda_3+2\alpha_3)\vartheta_0(q)+2\mu_3\vartheta_2(q) \tag{33}$$

$$\frac{d}{dq}\vartheta_2(q)=-(2\lambda_3+2\alpha_3+2\mu_3)\vartheta_2(q)+(2\lambda_3+2\alpha_3)\vartheta_1(q)+3\mu_3\vartheta_3(q) \tag{34}$$

$$\frac{d}{dq}\vartheta_3(q)=-(2\lambda_3+\alpha_3+3\mu_3)\vartheta_3(q)+(2\lambda_3+2\alpha_3)\vartheta_2(q)+4\mu_3\vartheta_4(q) \tag{35}$$

$$\frac{d}{dq}\vartheta_4(q)=-(2\mu_3+4\mu_3)\vartheta_4(q)+(2\lambda_3+\alpha_3)\vartheta_3(q)+5\mu_3\vartheta_5(q) \tag{36}$$

$$\frac{d}{dq}\vartheta_5(q)=-5\mu_3\vartheta_5(q)+2\lambda_3\vartheta_4(q) \tag{37}$$

The normalizing condition for this problem is

$$\vartheta_0(t)+\vartheta_1(t)+\vartheta_2(t)+\vartheta_3(t)+\vartheta_4(t)+\vartheta_5(t)=1 \tag{38}$$

Availability of subsystem C is

$$A_{S3} = \vartheta_0(t) + \vartheta_1(t) + \vartheta_2(t) + \vartheta_3(t) + \vartheta_4(t) \tag{39}$$

Setting (32) to (37) to zero as $q \to \infty$ in steady state, availability of subsystem C in (39) is now

$$A_{S3} = \frac{1 + \frac{m_3}{\mu_3} + \frac{m_3^2}{2\mu_3^2}\vartheta + \frac{m_3^3}{6\mu_3^3} + \frac{(2\lambda_3 + \alpha_3)m_3^3}{24\mu_3^4}}{1 + \frac{m_3}{\mu_3} + \frac{m_3^2}{2\mu_3^2} + \frac{m_3^3}{6\mu_3^3} + \frac{(2\lambda_3 + \alpha_3)m_3^3}{24\mu_3^4} + \frac{2\lambda_3(2\lambda_3 + \alpha_3)m_3^3}{120\mu_3^5}} \tag{40}$$

Where $m_3 = (2\lambda_3 + 2\alpha_3)$

The Corresponding reliability, maintainability, dependability and MTBF, MTTR for main and warm standby unit of subsystem C are

$$R_{S3}(q) = \exp^{-\lambda_3 q} \tag{41}$$

$$R_{S3}(q) = \exp^{-\alpha_3 q} \tag{42}$$

$$M_{S3} = 1 - \exp^{-\mu_3 q} \tag{43}$$

Mean time between failure (MTBF)= $\lambda_3^{-1} = 100\,h$ for main unit

Mean time between failure (MTBF)= $\alpha_3^{-1} = 71.4286\,h$ for warm standby unit

Mean time to repair (MTTR)= $\mu_3^{-1} = 5h$

Dependability ratio d=$\frac{\mu_3}{\lambda_3} = 14.9999$ for main unit

$$D_{\min}(s_3) = 1 - \left(\frac{1}{d-1}\right)\left(\exp^{-\frac{\ln d}{d-1}} - \exp^{\frac{d \ln d}{d-1}}\right) = 0.9451$$

for main unit

Dependability ratio d=$\frac{\mu_3}{\alpha_3} = 14.2857$ for warm standby unit

$$D_{\min}(s_3) = 1 - \left(\frac{1}{d-1}\right)\left(\exp^{-\frac{\ln d}{d-1}} - \exp^{\frac{d \ln d}{d-1}}\right) = 0.9427$$

for main and warm standby unit

RAMD Analysis for Subsystem D (Side Seam)

The side seam section consists of three primary operation unit, two warm standby unit and one cold standby unit. Using the method described in section 4.1 above, the Chapman-Kolmogrov differential difference equations (44)-(48) are derived using Markovian birth-death process from Table 7 below.

Where S_0 is the perfect state, S_1, S_2, S_3 are partial failure states and S_4 is the complete failure state

Table 7. Transition rate table for Subsystem D

	S_0	S_1	S_2	S_3	S_4
S_0	0	$3\lambda_4 + 2\alpha_4$	0	0	0
S_1	μ_4	0	$3\lambda_4 + 2\alpha_4$	0	0
S_2	0	$2\mu_4$	0	$3\lambda_4 + \alpha_4$	0
S_3	0	0	$3\mu_4$	0	$3\lambda_4$
S_4	0	0	0	$4\mu_4$	0

$$\frac{d}{dq}\vartheta_0(q) = -(3\lambda_4 + 2\alpha_4)\vartheta_0(q) + \mu_4\vartheta_1(q) \tag{44}$$

$$\frac{d}{dq}\vartheta_1(q) = -(3\lambda_4 + 2\alpha_4 + \mu_4)\vartheta_1(q) + (3\lambda_4 + 2\alpha_4)\vartheta_0(q) + 2\mu_4\vartheta_2(q) \tag{45}$$

$$\frac{d}{dq}\vartheta_2(q) = -(3\lambda_4 + \alpha_4 + 2\mu_4)\vartheta_2(q) + (3\lambda_4 + 2\alpha_4)\vartheta_1(q) + 3\mu_4\vartheta_3(q) \tag{46}$$

$$\frac{d}{dq}\vartheta_3(q) = -(3\lambda_4 + 3\mu_4)\vartheta_3(q) + (3\lambda_4 + \alpha_4)\vartheta_2(q) + 4\mu_4\vartheta_4(q) \tag{47}$$

$$\frac{d}{dq}\vartheta_4(q) = -4\mu_4\vartheta_4(q) + 3\lambda_4\vartheta_3(q) \tag{48}$$

The normalizing condition for this problem is

$$\vartheta_0(q) + \vartheta_1(q) + \vartheta_2(q) + \vartheta_3(q) + \vartheta_4(q) = 1 \tag{49}$$

Availability of subsystem D is

$$A_{S4} = \vartheta_0(q) + \vartheta_1(q) + \vartheta_2(q) + \vartheta_3(q) \tag{50}$$

Setting (44) to (48) to zero as $q \to \infty$ in steady state, availability of subsystem D in (50) is now

$$A_{S4} = \frac{1 + \frac{(2\lambda_2 + 2\alpha_2)}{\mu_2} + \frac{m_4^2}{2\mu_2^2} + \frac{(3\lambda_4 + \alpha_4)m_4^2}{6\mu_2^3}}{1 + \frac{(2\lambda_2 + 2\alpha_2)}{\mu_2} + \frac{m_4^2}{2\mu_2^2} + \frac{(3\lambda_4 + \alpha_4)m_4^2}{6\mu_2^3} + \frac{3\lambda_4(3\lambda_4 + \alpha_4)m_4^2}{24\mu_2^4}} \tag{51}$$

$$m_4 = (3\lambda_4 + 2\alpha_4)$$

The Corresponding reliability, maintainability, dependability and MTBF, MTTR for main and warm standby unit of subsystem D are

$$R_{S4}(q) = \exp^{-\lambda_4 q} \tag{52}$$

$$R_{S4}(q) = \exp^{-\alpha_4 q} \tag{53}$$

$$M_{S4} = 1 - \exp^{-\mu_4 q} \tag{54}$$

Mean time between failure (MTBF)= $\lambda_4^{-1} = 28.5714\,h$ for main unit

Mean time between failure (MTBF)= $\alpha_4^{-1} = 58.8235\,h$ for warm standby unit

Mean time to repair (MTTR)= $\mu_4^{-1} = 2.5h$

Dependability ratio d= $\frac{\mu_4}{\lambda_4} = 11.4286$ for main unit

$$D_{\min}\left(s_4\right) = 1 - \left(\frac{1}{d-1}\right)\left(\exp^{-\frac{\ln d}{d-1}} - \exp^{\frac{d\ln d}{d-1}}\right) = 0.9307$$

for main unit

Dependability ratio d= $\frac{\mu_4}{\alpha_4} = 23.5294$ for warm standby unit

$$D_{\min}\left(s_4\right) = 1 - \left(\frac{1}{d-1}\right)\left(\exp^{-\frac{\ln d}{d-1}} - \exp^{\frac{d\ln d}{d-1}}\right) = 0.9630$$

for main and warm standby unit

RAMD Analysis for Subsystem E (Cleaning)

The cleaning section consists of four primary operation unit, two warm standby unit and one cold standby unit. Using the method described in section 4.1 above, the Chapman-Kolmogrov differential difference equations (55)-(59) are derived using Markovian birth-death process from Table 8 below.

Table 8. Transition rate table for Subsystem E

	S_0	S_1	S_2	S_3	S_4
S_0	0	$4\lambda_5 + 2\alpha_5$	0	0	0
S_1	μ_5	0	$4\lambda_5 + 2\alpha_5$	0	0
S_2	0	$2\mu_5$	0	$4\lambda_5 + \alpha_5$	0
S_3	0	0	$3\mu_5$	0	$4\lambda_5$
S_4	0	0	0	$4\mu_5$	0

Where S_0 is the perfect state, S_1, S_2, S_3 are partial failure states and S_4 is the complete failure state

$$\frac{d}{dq}\vartheta_0\left(q\right) = -\left(4\lambda_5 + 2\alpha_5\right)\vartheta_0\left(q\right) + \mu_5\vartheta_1\left(q\right) \tag{55}$$

$$\frac{d}{dq}\vartheta_1\left(q\right) = -\left(4\lambda_5 + 2\alpha_5 + \mu_5\right)\vartheta_1\left(q\right) + \left(4\lambda_5 + 2\alpha_5\right)\vartheta_0\left(q\right) + 2\mu_5\vartheta_2\left(q\right) \tag{56}$$

$$\frac{d}{dq}\vartheta_2\left(q\right) = -\left(4\lambda_5 + \alpha_5 + 2\mu_5\right)\vartheta_2\left(q\right) + \left(4\lambda_5 + 2\alpha_5\right)\vartheta_1\left(q\right) + 3\mu_5\vartheta_3\left(q\right) \tag{57}$$

$$\frac{d}{dq}\vartheta_3\left(q\right) = -\left(4\lambda_5 + 3\mu_5\right)\vartheta_3\left(q\right) + \left(4\lambda_5 + \alpha_5\right)\vartheta_2\left(q\right) + 4\mu_5\vartheta_4\left(q\right) \tag{58}$$

$$\frac{d}{dq}\vartheta_4\left(q\right) = -4\mu_5\vartheta_4\left(q\right) + 4\lambda_5\vartheta_3\left(q\right) \tag{59}$$

The normalizing condition for this problem is

$$\vartheta_0\left(q\right) + \vartheta_1\left(q\right) + \vartheta_2\left(q\right) + \vartheta_3\left(q\right) + \vartheta_4\left(q\right) = 1 \tag{60}$$

Availability of subsystem E is

$$A_{S5} = \vartheta_0\left(q\right) + \vartheta_1\left(q\right) + \vartheta_2\left(q\right) + \vartheta_3\left(q\right) \tag{61}$$

Setting (55) to (59) to zero as $q ® $ in steady state, availability of subsystem E in (61) is now

$$A_{S5} = \frac{1 + \frac{m_5}{\mu_5} + \frac{m_5^2}{2\mu_5^2} + \frac{\left(4\lambda_5 + \alpha_5\right)m_5^2}{6\mu_5^3}}{1 + \frac{m_5}{\mu_5} + \frac{m_5^2}{2\mu_5^2} + \frac{\left(4\lambda_5 + \alpha_5\right)m_5^2}{6\mu_5^3} + \frac{\lambda_5\left(4\lambda_5 + \alpha_5\right)m_5^2}{24\mu_5^4}} \tag{62}$$

$$m_5 = \left(4\lambda_5 + 2\alpha_5\right)$$

The Corresponding reliability, maintainability, dependability and MTBF, MTTR for main and warm standby unit of subsystem D are

$$R_{S4}\left(q\right) = \exp^{-\lambda_5 q} \tag{62}$$

$$R_{S4}\left(q\right) = \exp^{-\alpha_5 q} \tag{63}$$

$$M_{S5} = 1 - \exp^{-\mu_5 q} \tag{64}$$

Mean time between failure (MTBF)= $\lambda_5^{-1} = 20\,h$ for main unit

Mean time between failure (MTBF)= $\alpha_5^{-1} = 76.9230\,h$ for warm standby unit

Mean time to repair (MTTR)= $\mu_5^{-1} = 1.8182h$

Dependability ratio d= $\frac{\mu_5}{\lambda_5} = 10.9285$ for main unit

$$D_{\min}\left(s_5\right) = 1 - \left(\frac{1}{d-1}\right)\left(\exp^{-\frac{\ln d}{d-1}} - \exp^{\frac{d\ln d}{d-1}}\right) = 0.9285$$

for main unit

Dependability ratio d= $\frac{\mu_5}{\alpha_5} = 42.3072$ for warm standby uni

$$D_{\min}\left(s_5\right) = 1 - \left(\frac{1}{d-1}\right)\left(\exp^{-\frac{\ln d}{d-1}} - \exp^{\frac{d\ln d}{d-1}}\right) = 0.9784$$

for main and warm standby unit

NUMERICAL SIMULATIONS AND DISCUSSION

Numerical simulations of reliability, availability, maintainability, and dependability are discussed in this section.

Reliability Using Exponential Distribution

Reliability Using Lindley Distribution

Reliability Using Exponentiated Weibull Distribution

This section discusses the numerical simulations in order to obtain understanding of how the strength, efficacy, and performance of the model under review are evaluated at various levels. Here, we employ the exponential, Lindley, and exponentiated Weibull distributions as three alternative distributions to first choose the optimum distribution that will improve system reliability. On the basis of this, the performance of the model is evaluated.

Table 9 and Figure 1 displayed the results of availability of individual subsystems and the entire system with respect to failure rates. From the table and figure, it is noted that availability of individual subsystems and the entire system decreases with increase in failure rate. It is clear from the table and figure that the availability of the system is lower than the availability of the individual subsystems. This can

Table 9. Variation in Availability of system due to with respect to availability of individual subsystem

Failure rate	Availability					System
	Subsystem A	Subsystem B	Subsystem C	Subsystem D	Subsystem E	
0.00	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
0.02	1.0000	1.0000	0.9998	1.0000	1.0000	0.9998
0.04	0.9999	0.9999	0.9994	1.0000	0.9999	0.9991
0.06	0.9998	0.9998	0.9989	1.0000	0.9999	0.9984
0.08	0.9997	0.9996	0.9982	0.9999	0.9998	0.9972

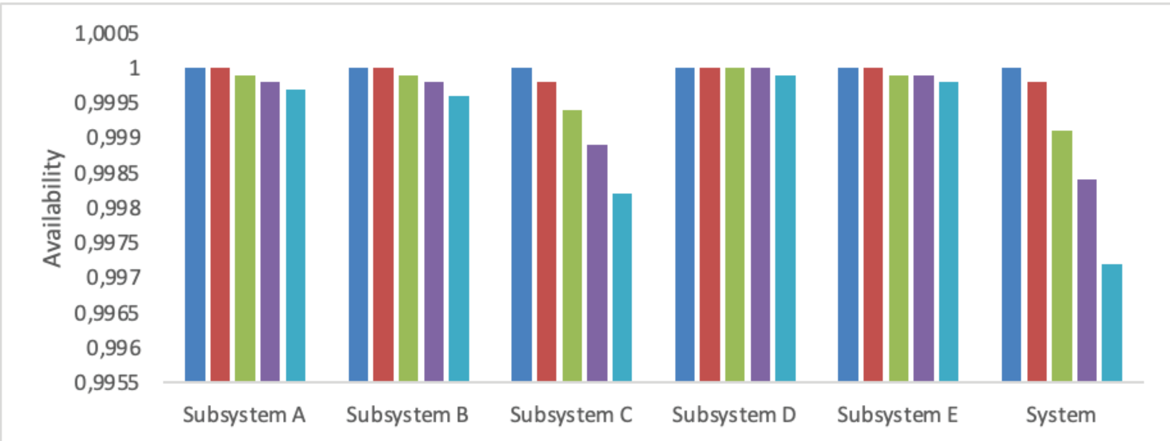

Figure 1. Availability of the system and individual subsystems.

Table 10. Variation in reliability of system due to changes in Exponential failure rate of subsystems for main unit

Time	Reliability of Subsystem A $\lambda_1 = 0.015$	Reliability of Subsystem B $\lambda_2 = 0.025$	Reliability of Subsystem C $\lambda_3 = 0.010$	Reliability of Subsystem D $\lambda_4 = 0.035$	Reliability of Subsystem E $\lambda_5 = 0.050$	System Reliability
0	1.000000000	1.000000000	1.000000000	1.000000000	1.000000000	1.00000000
20	0.74081822	0.60653066	0.81873075	0.49658530	0.36787944	0.06720551
40	0.54881164	0.36787944	0.67032005	0.24659696	0.13533528	0.00451658
60	0.40656966	0.22313016	0.54881164	0.12245642	0.04978706	0.00030353
80	0.30119421	0.13533528	0.44932896	0.06081006	0.01831563	0.00002039
100	0.22313016	0.082084999	0.36787944	0.03019738	0.00673794	0.00000137

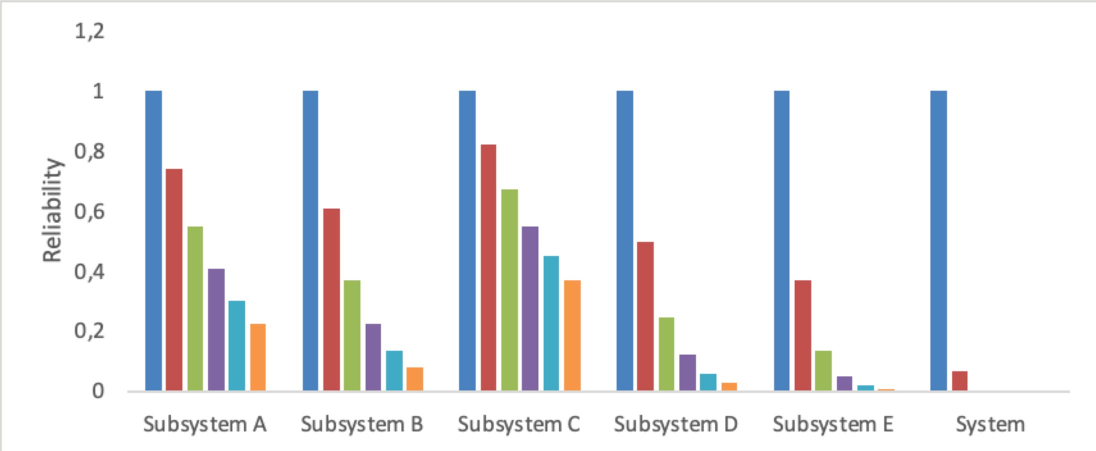

Figure 2. Variation in reliability of system due to changes in Exponential failure rate of subsystems for main unit.

Table 11. Variation in reliability of system due to changes in Exponential failure rate of subsystems for warm standby unit

Time	Reliability of Subsystem A $\alpha_1 = 0.015$	Reliability of Subsystem B $\alpha_2 = 0.016$	Reliability of Subsystem C $\alpha_3 = 0.014$	Reliability of Subsystem D $\alpha_4 = 0.017$	Reliability of Subsystem E $\alpha_5 = 0.013$	System Reliability
0	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000
20	0.74081822	0.72614903	0.75578374	0.7117703	0.77105158	0.22313016
40	0.54881163	0.52729242	0.57120906	0.50661699	0.59452054	0.04978706
60	0.40656965	0.38289288	0.43171052	0.36059494	0.45840601	0.01110899
80	0.30119421	0.27803730	0.32627979	0.25666077	0.35345468	0.00247875
100	0.22313016	0.2018965	0.24659696	0.18268352	0.27253179	0.00055308

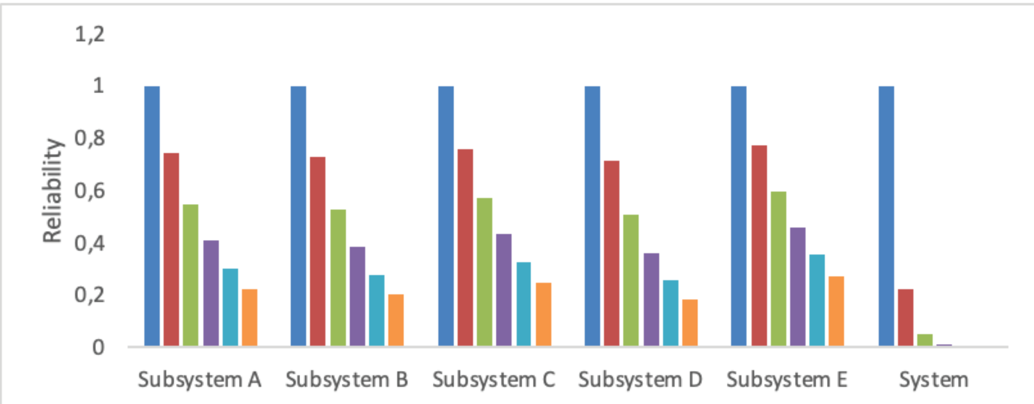

Figure 3. Variation in reliability of system due to changes in Exponential failure rate of subsystems for warm standby unit.

lead to decrease in production which will in turn culminated in less revenue mobilization. To avert this problem adequate preventive maintenance before such as regular inspection, oiling, greasing etc should be invoke to avoid system failure. From the table and figure, it is worthwhile to notice that subsystem C has the least availability. Therefore, maintenance priority should be set aside to subsystem C in order to improve its availability.

Table 10 and Figure 2 and table 11 and Figure 3 presents the results of reliability of the individual subsystems and the system when the failure rate of the main and warm standby unit follows exponential distribution. The table and figure show that reliability decreases drastically with passage of

Table 12. Variation in reliability of system due to changes in Lindley failure rate of subsystems for main unit

Time	Reliability of Subsystem A $\lambda_1 = 0.015$	Reliability of Subsystem B $\lambda_2 = 0.025$	Reliability of Subsystem C $\lambda_3 = 0.010$	Reliability of Subsystem D $\lambda_4 = 0.035$	Reliability of Subsystem E $\lambda_5 = 0.050$	System Reliability
0	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.0000000
20	0.95977927	0.90239927	0.98085565	0.83244010	0.71824081	0.14697050
40	0.87323231	0.72678621	0.93579333	0.58015807	0.39311677	0.00590089
60	0.76707478	0.54966210	0.87483835	0.37091875	0.19203583	0.00014415
80	0.65728589	0.39940413	0.80523309	0.22532037	0.08808950	0.00000267
100	0.55287917	0.28229231	0.73211651	0.13231414	0.03882340	0.0000004

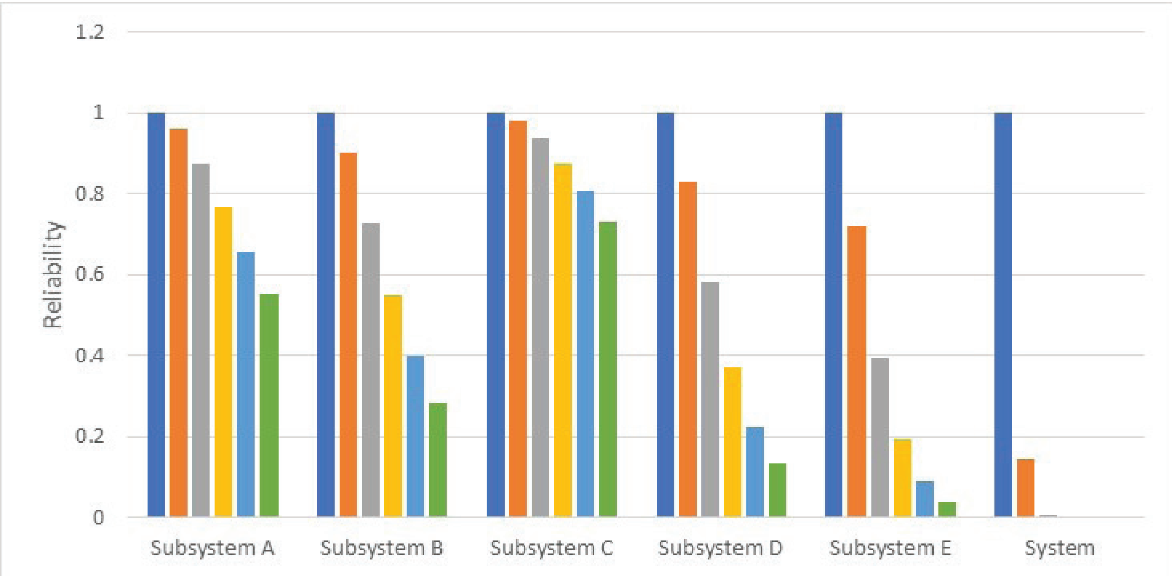

Figure 4. Variation in reliability of system due to changes in Lindley failure rate of subsystems for main unit.

Table 13. Variation in reliability of system due to changes in Lindley failure rate of subsystems for Warm standby Unit

Time	Reliability of Subsystem A $\alpha_1 = 0.015$	Reliability of Subsystem B $\alpha_2 = 0.016$	Reliability of Subsystem C $\alpha_3 = 0.014$	Reliability of Subsystem D $\alpha_4 = 0.017$	Reliability of Subsystem E $\alpha_5 = 0.013$	System Reliability
0	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000
20	0.95977927	0.95485739	0.96448142	0.94972696	0.96895228	0.50827697
40	0.87323231	0.85944513	0.88666969	0.84535795	0.89970384	0.03210535
60	0.76707478	0.74468143	0.78934054	0.72225358	0.81137411	0.00096330
80	0.65728589	0.62832051	0.68666773	0.59988462	0.71633017	0.00002017
100	0.55287917	0.51984379	0.58706614	0.48805421	0.62227644	0.0000004

time from 0 to 100. From the table and figure it can be seen that reliability of the system is less than the reliability of each subsystem. Subsystem E has the least reliability among the subsystems from the Table 10 and Figure 2 when the failure rate of the main unit obeys exponential distribution while subsystem D has the least reliability from Table 11 and Figure 3 when the failure rate of the warm standby unit obeys exponential distribution.

From Table 12 and Figure 4 and Table 13 and Figure 5 for reliability analysis of the individual subsystems and the system when the failure rate of the main and warm standby unit obeys Lindley distribution. It is observed from the

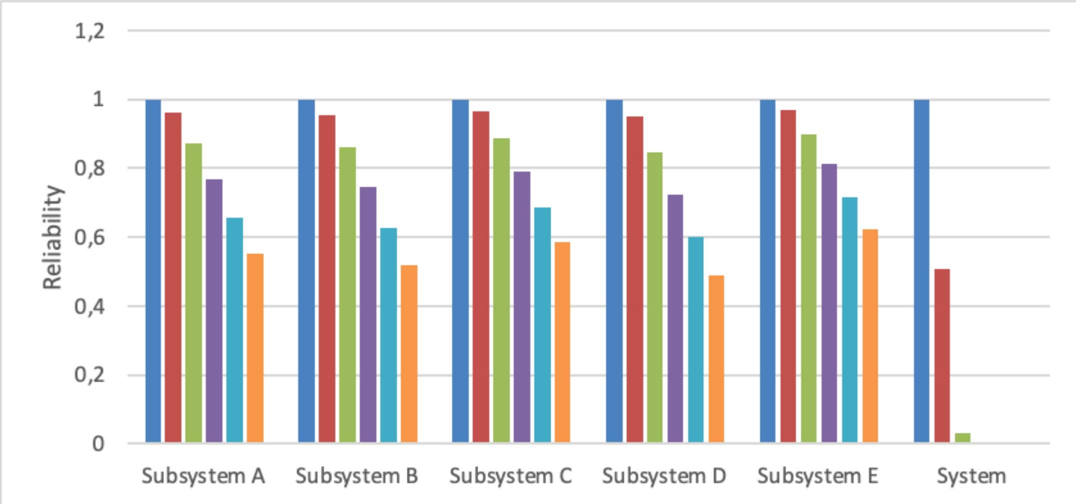

Figure 5. Variation in reliability of system due to changes in Lindley failure rate of subsystems for warm standby unit.

Table 14. Variation in reliability of system due to changes in Exponentiated Weibull failure rate of subsystems for main unit

Time	Reliability of Subsystem A $\lambda_1 = 0.015$	Reliability of Subsystem B $\lambda_2 = 0.025$	Reliability of Subsystem C $\lambda_3 = 0.010$	Reliability of Subsystem D $\lambda_4 = 0.035$	Reliability of Subsystem E $\lambda_5 = 0.050$	System Reliability
0	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.0000000
20	0.99660863	0.99094408	0.89131112	0.982932729	0.93282480	0.83679084
40	0.98721301	0.96714146	0.69676141	0.94035841	0.79642906	0.55758066
60	0.97286409	0.93282480	0.51167047	0.88238311	0.64784043	0.32632241
80	0.95447233	0.89131112	0.36303083	0.81613833	0.51167047	0.17562407
100	0.93282480	0.84518187	0.25235492	0.74657364	0.39647325	0.08918513

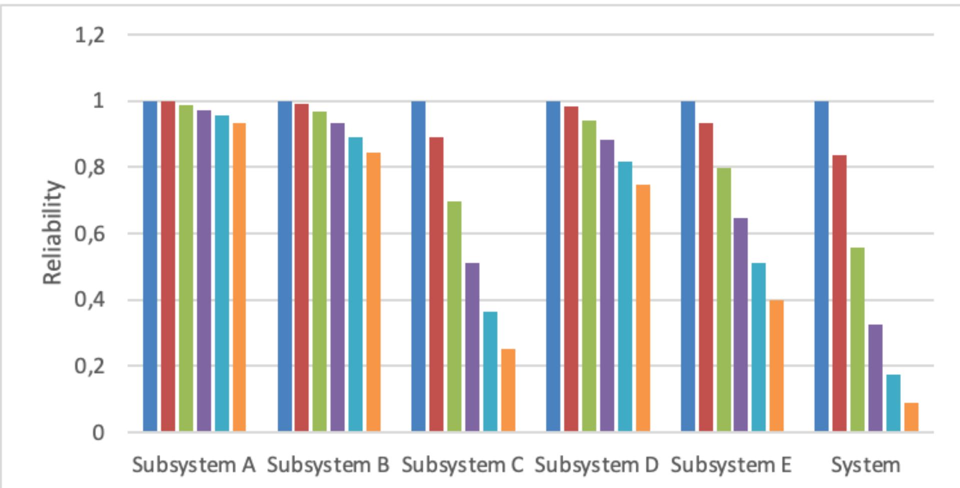

Figure 6. Variation in reliability of system due to changes in Exponentiated Weibull failure rate of subsystems for main unit.

Table 15. Variation in reliability of system due to changes in Exponentiated Weibull failure rate of subsystems for warm standby unit

Time	Reliability of Subsystem A $\alpha_1 = 0.015$	Reliability of Subsystem B $\alpha_2 = 0.016$	Reliability of Subsystem C $\alpha_3 = 0.014$	Reliability of Subsystem D $\alpha_4 = 0.017$	Reliability of Subsystem E $\alpha_5 = 0.013$	System Reliability
0	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000	1.00000000
20	0.99660863	0.99615661	0.99703401	0.99567831	0.99743243	0.98302549
40	0.98721301	0.98556478	0.98877338	0.98383100	0.99024355	0.93724977
60	0.97286409	0.96948230	0.97608456	0.96594586	0.97913685	0.87071433
80	0.95447233	0.94898814	0.95972558	0.94328660	0.96473380	0.79108357
100	0.93282480	0.92500565	0.94035841	0.91692365	0.94758262	0.70499843

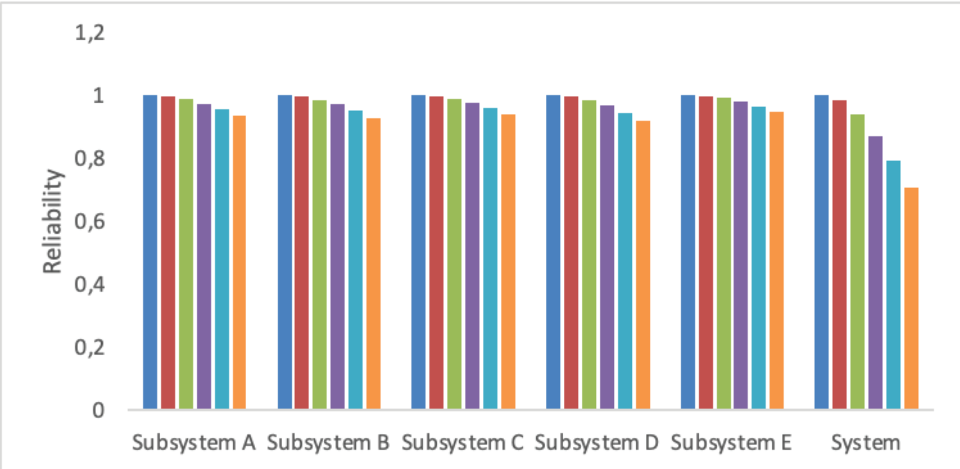

Figure 7. Variation in reliability of system due to changes in Exponentiated Weibull failure rate of subsystems for warm standby unit.

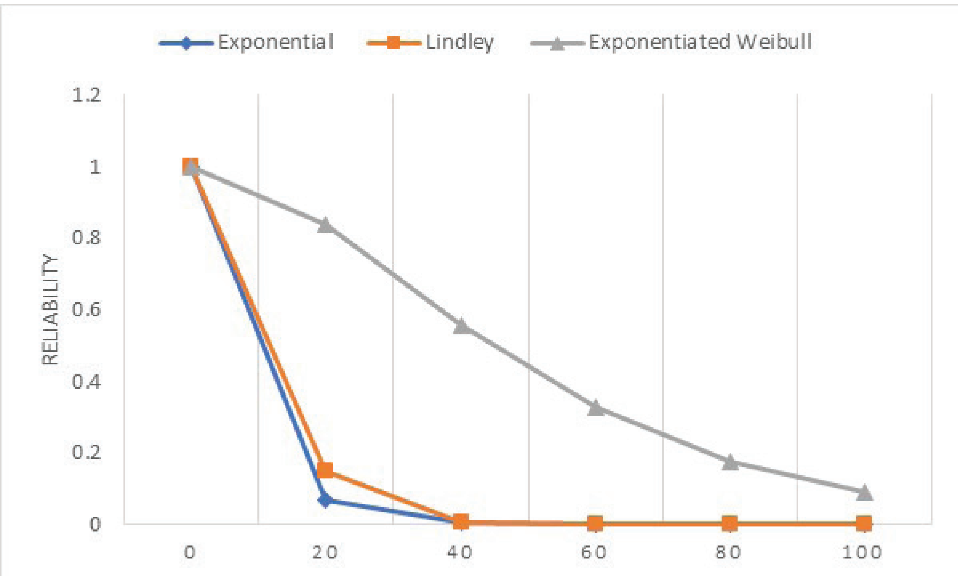

Figure 8. Reliability for main unit failure against time for different distributions.

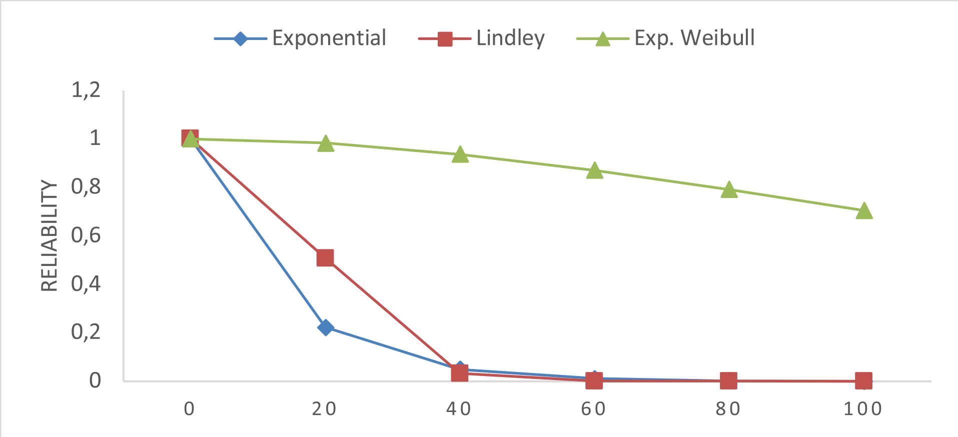

Figure 9. Reliability for warm standby unit failure against time for different distributions.

Table 16. Variation in maintainability of system due to with respect to of individual subsystem

Time	Maintainability of Subsystem A $\mu_1 = 0.35$	Maintainability of Subsystem B $\mu_2 = 0.20$	Maintainability of Subsystem C $\mu_3 = 0.15$	Maintainability of Subsystem D $\mu_4 = 0.40$	Maintainability of Subsystem E $\mu_5 = 0.55$	System Maintainability
0	0. 000000000	0. 000000000	0. 000000000	0. 000000000	0. 000000000	0. 000000000
20	0.9990881180	0.9816843611	0.9502129316	0.9996645374	0.9999832983	0.9316303655
40	0.9999991685	0.9996645374	0.9975212478	0.9999998875	0.9999999997	0.9971856751
60	0.9999999992	0.9999938558	0.9998765902	1.000000000	1.000000000	0.9998704460
80	1.000000000	0.9999998875	0.9999938558	1.000000000	1.000000000	0.9999937433
100	1.000000000	0.9999999979	0.9999996941	1.000000000	1.000000000	0.9999996920

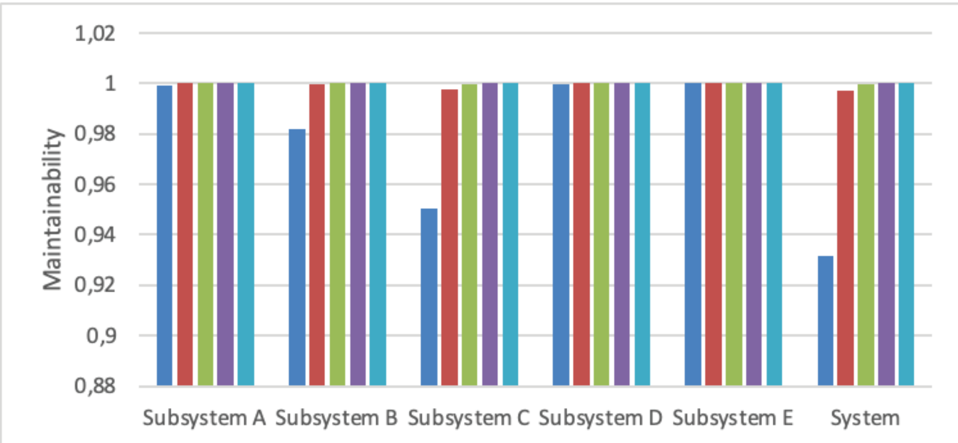

Figure 10. Variation in maintainability of system and subsystems.

tables and figures that reliability decreases slightly with passage of time from 0 to 100 in which reliability of the system is less than the reliability of each subsystem. It is evident from the tables and figures that subsystem E has the least reliability among the subsystems when the failure rate of the main obeys Lindley distribution and subsystem D for warm standby unit obeys Lindley distribution.

On other hand, when the failure follows exponentiated Weibull distribution for both main and warm standby unit From Table 14 and Figure 6 and Table 15 and Figure 7 for reliability analysis of the individual subsystems and the

Table 17. Ramd indices

Indices	Subsystem A	Subsystem B	Subsystem C	Subsystem D	Subsystem E
Reliability Main	$\exp^{-0.015q}$	$\exp^{-0.025q}$	$\exp^{-0.010q}$	$\exp^{-0.035q}$	$\exp^{-0.050q}$
Reliability Warm	$\exp^{-0.015q}$	$\exp^{-0.016q}$	$\exp^{-0.014q}$	$\exp^{-0.017q}$	$\exp^{-0.013q}$
Reliability Main	$\frac{1.015+0.015q}{1.015}e^{-0.015q}$	$\frac{1.025+0.025q}{1.025}e^{-0.025q}$	$\frac{1.010+0.010q}{1.010}e^{-0.010q}$	$\frac{1.035+0.035q}{1.035}e^{-0.035q}$	$\frac{1.050+0.050q}{1.050}e^{-0.050q}$
Reliability Warm	$\frac{1.015+0.015q}{1.015}e^{-0.015q}$	$\frac{1.016+0.016q}{1.016}e^{-0.016q}$	$\frac{1.014+0.014q}{1.014}e^{-0.014q}$	$\frac{1.017+0.017q}{1.017}e^{-0.017q}$	$\frac{1.013+0.013q}{1.013}e^{-0.013q}$
Maintainability	$1-\exp^{-0.35q}$	$1-\exp^{-0.20q}$	$1-\exp^{-0.15q}$	$1-\exp^{-0.40q}$	$1-\exp^{-0.55q}$
Reliability Main	$1-\left(1-e^{-(0.015q)^{0.2}}\right)^2$	$1-\left(1-e^{-(0.025q)^{0.2}}\right)^2$	$1-\left(1-e^{-(0.010q)^{0.2}}\right)^2$	$1-\left(1-e^{-(0.035q)^{0.2}}\right)^2$	$1-\left(1-e^{-(0.050q)^{0.2}}\right)^2$
Reliability Warm	$1-\left(1-e^{-(0.015q)^{0.2}}\right)^2$	$1-\left(1-e^{-(0.016q)^{0.2}}\right)^2$	$1-\left(1-e^{-(0.014q)^{0.2}}\right)^2$	$1-\left(1-e^{-(0.017q)^{0.2}}\right)^2$	$1-\left(1-e^{-(0.013q)^{0.2}}\right)^2$
Availability	0.9996	0.9995	0.9978	0.9999	0.9997
Dependability Main	0.9595	0.8877	0.9451	0.9307	0.9784
Dependability Warm	0.9595	0.9357	0.9427	0.9630	0.9784
MTTR	2.8571	5	5	2.5	1.8182
MTBF Main	66.6667	40	100	28.5714	20
MTBF Warm	66.6667	62.5	71.4286	58.8235	76.9230
Dependability ratio Main	23.3345	8	14.9999	11.4286	10.9285
Dependability ratio Warm	2345.33	12.5	14.2857	23.5294	42.3072

system it is clear that reliability decreases slightly with passage of time from 0 to 100 in which reliability of the system is less than the reliability of each subsystem. It is evident from the tables and figures that subsystem C for main unit has the least reliability among the subsystems and subsystem D is the least when the failure rate of warm standby unit obeys exponentiated Weibull distribution.

Exponentiated Weibull distribution, in contrast, has a higher system reliability than the other two distributions for both main unit and warm standby units. This is seen in Figure 8 and 9, Table 14 and Figure 6 and Table 15 and Figure 7. The variation in system reliability caused by variations in the exponentiated Weibull failure rate of subsystems for main units is depicted in table 13 and figure 6. From this table 13 and its corresponding figure 6, we can see that the system reliability's equivalent values for main unit at time $t = 40$ are $Rel._{subsystem\ A}$= 0.98721301, $Rel._{subsystem\ B}$ = 0.96714146, $Rel._{subsystem\ C}$ = 0.69676141, $Rel._{subsystem\ D}$ = 0.94035841, and $Rel._{subsystem\ D}$ = 0.79642906. In time t = 40, there is $Main._{system}$ = 0.32632241 chance of successfully completing maintenance and repairs, and $Main._{subsystem\ A}$ = 0.99999916, $Main._{subsystem\ B}$ = 0.99966453, $Main._{subsystem\ C}$ = 0.99752124, $Main._{subsystem\ D}$ = 0.99999988 and $Main._{subsystem\ E}$ = 0.999999999. The system is 0.33632241 times reliable at t = 60 due to a form decline. This is brought on by the low reliability value of subsystem C. This demonstrates that subsystem C is the main unit's key subsystem. The value of availability is another indicator of how important subsystem C is to the main unit..

Table 9-15 and Figure 1-7 show the variation in system reliability caused by changes in the exponential, Lindley and exponentiated Weibull failure rate of the main and warm standby unit's subsystems. Subsystems with the lowest reliability value among the other subsystems need adequate attention of the management for proper maintenance in order to avoid system breakdown and subsequent loss of production and revenue as the tables and figures make sufficient evident. This demonstrates that critical subsystems are the most important and delicate part of the system and needs careful consideration.

CONCLUSION

In this study, the metrics of RAMD for both weaving, dry clean, cross cut, side seam and cleaning section of the textile are analyzed to assess the performance of the textile manufacturing system. Expressions associated with metrics for weaving, dry clean, cross cut, side seam and cleaning section have been derived and numerical experiments are performed. The assumed values for failure and repair rates for each subsystem are given in table 1. Table 16 lists all RAMD measurements, while tables 3 and 4 capture the variation in reliability and maintainability over time, respectively. Tables 9, 10, 11, 13 and 14 indicate the impact of different failure rates on subsystems and system reliability and figures 2-7 that side seam is the most important and delicate component of the system. The models/results described in this work, if modified, will allow management to stop poor reliability assessments and decision-making, which will cause high expenditures. Moreover, the accepted framework for the model under consideration's inspection and maintenance could be proposed and incorporated to satisfy the client and lower failure rates. These are the findings of the current investigation. This work can be enlarged to include both offline and online routine maintenance at both partial and total failure states. This study will be carried out in the future.

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