Reliability Distribution of Industrial System Through Stochastic Process

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Abstract-The main focus of the researcher is to study the reliability distribution of industrial systems using the stochastic process. This topic is concerned with the study of how industrial systems behave over time using mathematical models that incorporate randomness and uncertainty. By analysing the reliability distribution of these systems through stochastic processes, engineers can identify potential failure points and develop strategies to improve overall performance and efficiency. The reliability distribution of an industrial system can be analysed through a stochastic process, which allows for the prediction of failure rates and maintenance schedules. This analysis can lead to more efficient and cost-effective operation of the system. In this study, the researcher analysed the probability plot for reliability data through various distributions such as the normal distribution, gamma distribution, weibull distribution, and exponential distribution. The result of the study was prepared using Minitab software. The result of the study shows that the normal distribution of reliability fits best in comparison to the gamma, weibull, and exponential distributions.
Keywords-Reliability distribution, industrial system, stochastic process.

1. INTRODUCTION

The introduction of stochastic models in the analysis of industrial systems has proven to be an effective tool for predicting system reliability and identifying potential failure points. By incorporating probabilistic variables into the analysis, engineers and managers can make informed decisions about maintenance schedules, system upgrades, and other strategies to improve overall system performance. As technology continues to advance and data collection methods become more sophisticated, the use of stochastic models is likely to become even more widespread in the field of industrial engineering. The world is expanding quickly and heading towards a "smart world" where technology controls everything. The cost and complexity of industrial processes have greatly increased with the advancement of technology in the twenty-first century. Hence, it has become crucial to run industrial systems with the least amount of downtime possible in order to achieve optimal productivity, boost revenue, and prevent losses. Hence, dependability modelling and analysis of complex industrial systems is a need that cannot be avoided.

Many studies have been done on the subject of dependability modelling, analysis, and complex industrial systems under various operating situations and hypotheses. So first read a review on the modelling and analysis of complex industrial systems' reliability, in which different reliability indices were presented in relation to various system parameters and various failure and repair rate distribution types used by various authors were discussed. Taking into account different failure distributions analysed failure data, and goodness of fit testing.

It was discovered that the exponential distribution was the foundation for the consequences of stochastic processes for system performance, and additional behaviour analysis of the process industry was conducted based on steady-state availability analysis and reliability analysis. In order to determine if the findings obtained genuinely have an exponential distribution, we develop a stochastic model for an industrial process in this study. Several of the foundational ideas are covered in the part after this one before we move on.

2. LITERATURE REVIEW

Weiwei Bao and Fansen Kong (2016)

In order to assess the assembly system's capacity and fulfil the order, the author of this research uses a stochastic flow network to study the assembly manufacturing system's dependability. The graph-based model is efficient, however the study topic is the generic serial manufacturing system based on processing equipment, disregarding a crucial and unique manufacturing system called the assembly manufacturing system. It is distinguished by its non-serial structure, random working time, cycle time as the primary assessment metric. The author creates the assembly manufacturing system reliability assessment model and determines the real cycle of the assembly manufacturing system to satisfy the order requirement, or the system dependability. The findings provide industrial businesses practical assistance for production planning and decision-making.

H. Badria et al. (2016)

Value-based Supply Chain Management (VbSCM) is now seen as a source of competitive advantages and is found to be an effective contributor to sustainability by businesses with long-term strategic goals. All value drivers (i.e., sales, supply chain expenses, xed assets, and working capital) are significantly impacted by the supply chain network architecture in this situation. In order to construct a value-based supply chain network where choices about physical output (raw materials and finished goods) and financial output are combined, this research offers a stochastic mixed integer linear programming model. The suggested model optimises the value of the firm based on the economic value-added idea by making certain strategic and tactical choices affecting the value drivers. It is developed for a four-echelon, multi-commodity, multi-period supply chain. In addition, a scenario generating approach based on Nataf transformation is used to construct a scenario-based two-stage stochastic programming model. A computational study is also done to show how well the suggested strategy works.

Nilesh Pancholi and Dr. M.G.Bhatt (2016)

Several applications in maintenance engineering are interested in the performance dependability of continuous process industries. There seems to have been very little study on how to increase the performance dependability of process industries by improving maintenance procedures via failure analysis. The purpose of this study is to comprehend the state of the process industries and to assess performance dependability in light of failure analysis-based maintenance plan improvement. Understanding component lifespans and related failures will aid in effectively reengineering new technologies in order to achieve an operational advantage. This report presents a thorough literature evaluation of the dependability and maintenance challenges scenario. The literature study is separated into reliability analysis, process industry maintenance plans, and maintenance optimisation.

Abdulaziz T. Almaktoom (2017)

Dynamic reliability measures and controls, as well as inventory management systems, are nevertheless difficult to implement at every level, particularly when operational circumstances and temporal variations are taken into account. A system for managing inventory must remain effective over time while adjusting to the ambiguity of inventory flow. Unexpected delays in inventory transfer might compromise the system's overall dependability and resilience. This article describes a technique for calculating an inventory management system's dependability. Also, a brand-new, reliability-based robust design optimisation model has been created to efficiently allocate and plan time while taking inventory movement unpredictability into account. Purchase, shipping, receiving, tracking, warehousing, storage, and turnover are some of the procedures involved. To show the model's effectiveness, a case study of a furniture firm in Saudi Arabia is provided.

Rasoul Jamshidi (2019)

A number of variables, including physical and mental exhaustion, competence, and the amount of time available in the production processes, have an impact on the performance of human resources. In general, the aforementioned characteristics have an impact on human dependability, which alters the dependability of production processes. The stochastic nature of fatigue means that it might vary depending on the sort of work being done, the length of the task, and the surroundings. To measure fatigue and manage its impact on dependability, several models have been put forward. Nevertheless, most of these models treated fatigue as a deterministic variable even though it is an unpredictable element. In order to improve dependability, we provide a stochastic model for human weariness in this study. We use the Chance Constraint (CC) to take into account the fatigue uncertainty, and several techniques are applied to transform the model into a deterministic one. The suggested model takes into account human and machine tiredness as two significant determinants of the dependability of production systems. The suggested model has been used to simulate a real-world scenario, and the findings demonstrate that it can more accurately assess the dependability of production systems.

Yessica Andrea Mercado et al. (2021)

This research assesses the possible advantages of employing a multi skilled workforce utilising a k-chaining strategy with k 2, taking into account an unpredictable demand. We first propose a deterministic mixed-integer linear programming model for the service sector and, in particular, for the retail industry that determines how many employees should be multi skilled, in which and how many departments they should be trained, and how their weekly working hours will be assigned. Finally, in order to explicitly account for the unpredictable manpower need, the deterministic model is rebuilt using a two-stage stochastic optimisation (TSSO) model. Real and simulated data from a Chilean retail shop are used to evaluate the technique in a case study. Also, we contrast the outcomes of the TSSO and myopic techniques (i.e., zero and total multiskilling). The case study is designed to address two important issues: how much multiskilling should be added, and how should it be added. Findings demonstrate that for all degrees of demand variability taken into account, TSSO method solutions always report maximum dependability. Also, it was shown that a k-chaining policy with k 2 is more cost-effective than a 2-chaining strategy for high levels of demand fluctuation. Lastly, two truncation types in the probability density function related to the manpower demand were taken into consideration in order to assess the amount of conservatism in the answers supplied by the TSSO technique. Findings reveal that the levels of necessary multiskilling are greater if the pdf is just truncated at zero (more cautious truncation) than when the pdf is truncated at the 5th and 95th percentiles.

Nabila Al Balushi (2021)

The literature on dependability analysis of sophisticated industrial systems is reviewed in this essay. Throughout the last three decades, a variety of industrial systems have been examined under various operating scenarios and presumptions. The systems were analysed primarily for the purpose of determining reliability indices such mean time to failure, availability analysis, failure frequency, mean downtime, projected busy times for the repairmen, and their corresponding cost-benefit analyses. Focusing on system performance over a lengthy period of time has been the key goal during these years; essentially, case studies on industrial system performance are being done. This study makes an effort to compile the necessary research and provide some helpful suggestions for interdisciplinary diversification for better system performance outcomes.

S.K. Tiwari et al. (2022)

Every manufacturing industry's maintenance strategy will have a direct impact on overall productivity and profitability. It should reduce operational expenses while maximising system availability. In order to decrease maintenance downtime and costs, this article tries to design a preventive maintenance (PM) model based on delay-time analysis. A multi-objective genetic algorithm (MOGA) is used to optimise the created maintenance model in order to establish the ideal maintenance frequency. To further confirm the coherence of the suggested model, sensitivity analysis is carried out. Finally, the model's applicability is evaluated by applying it to a foundry unit. This results in a significant decrease in total maintenance downtime and expense of nearly 71.69%.

Maureen Nalubowa S. et al. (2022)

Multi-objective optimisations are common models for manufacturing challenges when goals are seen as competing with one another. In practical applications, maximising a particular solution for one goal may provide undesirable outcomes for the other goals. The functioning of the system is impacted by the uncertainty that many manufacturing organisations work under. The performance and decision-making of the production system are often impacted by the difficulty of stochastic product demand. Each manufacturer must solve manufacturing lot-sizing issues correctly since doing so enables the business to compete in the market. In this research, a manufacturing lot size optimisation model was developed using Markov chains and stochastic goal programming. By specifying the target restrictions, deviation factors, priority, and objective function, the overachievement or underachievement of the manufacturing lot size was ascertained. States of a Markov chain were used to represent the various demand states for the stochastic demand product. The optimisation model was then solved, calculating the amount of product to be made in a certain quarter of the year as demand varies from one state to the next using MATLAB TM's applied mathematics solver.

3. RELIABILITY DISTRIBUTION

It represents the Time to Failure as a statistical distribution, which is often defined by a certain pattern, using a Reliability Distribution Analysis. The aforementioned distribution types may be used. The timing of failure for a component is an example of a random event for which the result is unpredictable. Probability distributions are used to represent such occurrences. It is uncertain when that component will fail prior to putting a demand on it. A probability distribution models the distribution of the chance of failure at various periods. Random variables will be identified in this book by a capital letter, such as T for time. Researcher use little letter, such as t for time, to indicate when the random variable takes on a value. For instance, we would find P (T≤t) if we wanted to know the likelihood that the component would fail before time t. There are two types of random variables: discrete and continuous. The random variable in a discrete distribution has a specific or countable range of potential values, such as the number of demands before failure. The random variable in a continuous distribution is not restricted to certain potential values, unlike the time-to-failure distribution.

Probability $R(t) = P(T>t),\ t\geq 0$

Where T- Random variable

-Time

Failure probability distribution function

$$F(t) = 1 - R(t) = P(T\leq t)$$

Probability density function

$$F(t) = \int_{-\infty}^{T} f(t)\,dt$$

(i) Normal Distribution

A distribution in which continuous random variable has the probability density function is of the following form.

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}}\, e^{\frac{-(t-\mu)^2}{2\sigma^2}}$$

Where μ and $\boldsymbol{\sigma}$ are arbitrary constant

(ii) Gamma distribution

A distribution in which continuous random variable has the probability density function is of the following form.

$$f(t) = c\, t^{a-1}\, e^{-bt},\ t \geq 0$$

Where a, b and c are constant

(iii) Weibull distribution

A distribution in which continuous random variable has the probability density function is of the following form.

$$f(t) = a\, t^{b}\, e^{\frac{-(a t^{b+1})}{(b+1)}},\ t \geq 0$$

Where a and b are constant

(iv) Exponential distribution

A distribution in which continuous random variable has the probability density function is of the following form.

$$f(t) = \begin{cases} \lambda e^{-\lambda t}, & 0 < t < \infty \\ 0, & t < 0 \end{cases}$$

4. INDUSTRIAL PROCESS AND RELIABILITY DISTRIBUTION

An industry is chosen for reliability distribution and to know about the failure. The industrial procedure is divided into five sub systems.

The sub system name with number of machines, their failure and mean time failure explained as below.

Sub System	Number of machines	Failure condition	Mean time failure MTBF
A. Storage Room	5	Never Fails	100000
B. Mixture	3	Failed when 2 machines fail	20000
C. Slasher	5	Failed when 3 machines fail	16000
D. Loom	300	Failed when 30 machines fail	50000
E. Machine for Fabric Inspection	3	Failed when all 3 machines fail	80000

Table 1: Industrial Process with Failures

The reliability for stochastic model R_1 (t) $=1-\sum_{i=1}^{4} P_i(t) = 0$

The value of transient probabilities is obtained by using following equations.

$$P_o'(t) + \sum_{i=1}^{4} \lambda i P_0(t) = 0,$$
$$P_i'(t) = \lambda_i P_0(t)$$

Wher e i=1, 2, 3, 4

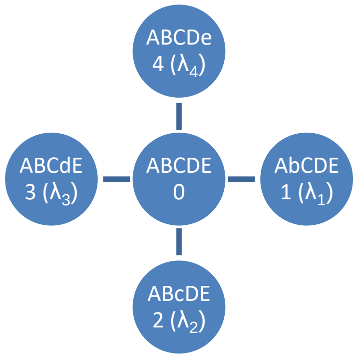
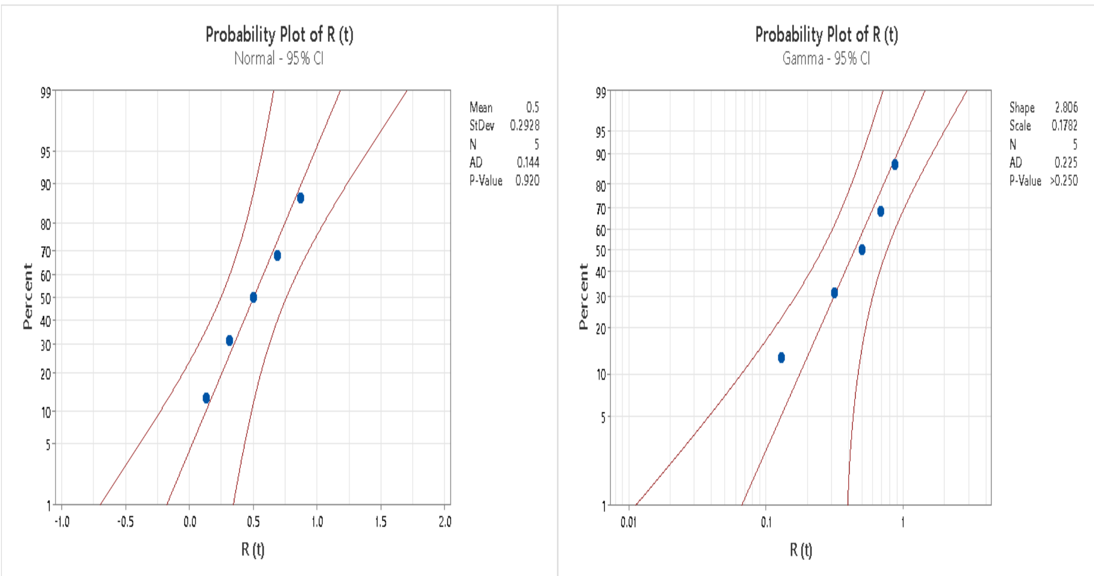


Figure 1: Space diagram of Industrial Process

The above figure describes the sub system of industry in which A, B, C, D and E are the operating conditions and a, b, c, d and e describes the failed state of the model.



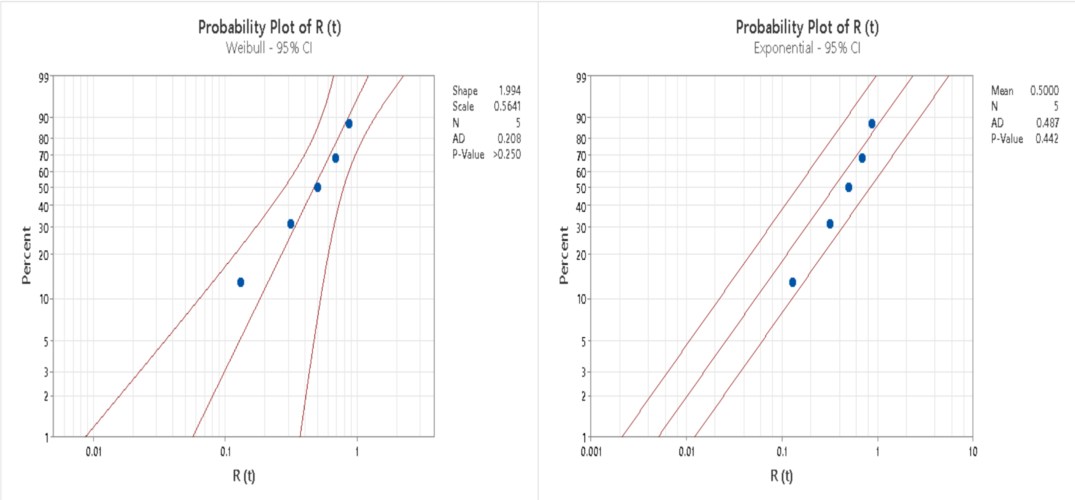


Figure 2: Probability Curve for Normal, Gamma, Weibull and Exponential Distribution

5. RESULT

The reliability of the model checked using the above equations. The probability distribution can be explained and plots by using Minitab software. In probability curve left line shows the lower bounds for confidence intervals, right line shows upper bounds for confidence intervals and middle line shows most fitted probability distribution. When value of P is more than its given value them distribution is best fit. In the above figure 2 it is cleared that normal distribution of probability is best fit. So the conclusion of this study is that for reliability of an industry normal distribution is the fit. So this represents the best distribution for maintenance of an industrial process.

6. CONCLUSION

The reliability distribution of an industrial system can be effectively analysed through stochastic processes, which provide a probabilistic framework for modelling and predicting system failures. This approach can help industries optimize maintenance schedules and improve overall system performance.

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