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A comprehensive review on economic reliability test plan for various life time distributions

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Abstract
The present review critically examines Economic Reliability test plans, with particular attention to the statistical distributions commonly applied in assessing product reliability. It traces the historical development of reliability testing methods and highlights the key contributions of researchers who have shaped the field. Recent advancements are also discussed, including the introduction of new acceptance sampling strategies based on truncated life tests for a variety of distributions. By comparing different methodologies and their practical applications, this review evaluates both their effectiveness and their economic implications. The findings aim to provide researchers and industry professionals with a consolidated understanding of the current state of economic reliability test plans, while also identifying potential directions for future research.

Keywords: Acceptance sampling plan, life test, termination time, producer's risk, minimum sample size

1. Introduction

In an era where product reliability is crucial for maintaining competitive advantage, economic reliability test plans have emerged as essential tools for ensuring both quality and cost-effectiveness. These test plans enable businesses to optimize resource allocation while achieving desired reliability levels, thereby enhancing customer satisfaction and reducing costs.

The development of Economic reliability test plans has been influenced by various statistical methodologies, each contributing to more precise and efficient reliability assessments. From their historical origins to recent advancements, these test plans have evolved to incorporate new acceptance sampling plans, especially those based on truncated life tests for different statistical distributions. Reliability testing fundamentally about understanding and mitigating the risk of product failure. The cost implications of such failures can be significant, making economic considerations a key aspect of reliability test planning. By integrating cost benefit analyses with reliability assessments, economic reliability test plans provide a comprehensive framework for decision-making. This includes determining the optimal balance between the costs of testing and costs associated with potential product failures.

Historically, the field of reliability life testing has seen substantial contributions from researchers who have developed various models and methodologies. Among these are acceptance sampling plans that allow for efficient decision-making under uncertain conditions. These plans have been adapted to various distributions. Sobel and Tischendrof (1959) [2] developed reliability test plans for exponential distribution. Goode and Kao (1961) [3] constructed sampling plans for Weibull distribution. Gupta and Groll (1961) [4] constructed sampling plans for Gamma distribution. Sampling plans similar to those of Gupta and Groll (1961) [4] were developed by Kantam and Rosaiah (1998) for half-logistic distribution. Kantam *et al*. (2001) developed a detailed study on life tests based on Log-logistic distribution. Recently, Jayalakshmi and Vijilamery (2022) [10] developed acceptance sampling plan for truncated life test based on percentiles using Gompertz Frechet distribution. Jayalakshmi and Aleesha (2024) [11] using Exponentiated Generalized Inverse Rayleigh distribution.

Advancements in the field have introduced innovative approaches to economic reliability test plans. These include the development of new acceptance sampling plans based on truncated life tests, which provide more reliability assessments by focusing on the early stages of product life. Such methodologies are particularly useful in industries where early failure detection is critical to maintaining product quality and customer satisfaction.

Statistical Quality Control (SQC) plays a pivotal role in the development and implementation of economic reliability test plans. SQC involves using statistical methods to monitor and control production processes, ensuring that products meet specified quality standards. Techniques such as control charts and process capability analysis are integral to SQC an provide a quantitative basis for making informed decisions in reliability testing.

This review paper aims to synthesize the vast body of literature on economic reliability test plans, providing a comprehensive analysis of different approaches and their practical applications. By examining the effectiveness and economic implications of these test plans, this paper seeks to offer valuable insights for researches and industry professions alike. Through a thorough exploration of historical developments, current methodologies, and future trends, this review will highlight the critical role of economic reliability test plans and statistical quality control in modern industry.

2. Economic Reliability Test Plan

A methodology designed to balance the costs of reliability testing with the risks of product failures. It ensures Economic reliability is understood as, on the one hand, an ability of an object to be implemented under certain interaction with the environment and, on the other hand, as a quantitative estimate of an object, explicitly relating probability with time or other parameters of the implementation process. Some properties of economic reliability include: effectiveness, stability, self-organization, vitality, and communicativeness.

2.1 Origin of the Economic Reliability test plan

Kantam *et al*. (2006) [1] introduced Economic reliability test plan for Log logistic distribution. In this paper focuses on the log logistic distribution, which is used to model the life data of products. The distribution is particularly useful due to its flexibility and ability to fit various types of reliability data. The authors propose test plans that incorporate economic considerations into the reliability testing process. The frame work includes methods for calculating the optimal sample size and termination time required to achieve desired reliability levels at minimum cost. The paper provides numerical examples to illustrate the application of the proposed economic reliability test plans, demonstrating their effectiveness in real-world scenarios. Conclusion of this study is the termination time of the economic reliability test plan for Log logistic distribution is uniformly smaller than the corresponding time of the plan in Kantam *et al*. (2001). The cumulative distribution function of log logistic distribution is

$$F(x) = \frac{(x/\sigma)^{\beta}}{[1+(x/\sigma)^{\beta}]};\ x>0, \sigma>0, \beta>1$$

"Several authors have contributed to the field of economic reliability. In this section, we discuss some articles by various authors that utilize different statistical distributions."

Aslam and Shahbaz (2007) developed Economic reliability test plan for products whose lifetimes follow the Generalized Exponential distribution. The study focuses on determining the minimum termination time for a given sample size, producer's risk, and termination number. The proposed plan is compared with existing plan to demonstrate its cost-effectiveness and efficiency in terms of experiment duration. The cumulative distribution function for Generalized Exponential distribution is

$$F(x) = \frac{x/\sigma}{[1+(x/\sigma)^{\beta}]}, x>0, \sigma>0, \beta>1$$

Aslam (2008) develops an Economic reliability acceptance sampling plan tailored to products with lifetimes following the Generalized Rayleigh distribution. The author focuses on calculating the test termination ratio, taking into account the producer's risk for specified sample sizes and acceptance numbers. By comparing this new plan with existing ones, the study demonstrates its cost-effectiveness and efficiency. The CDF of this distribution is

$$F_k(t;\lambda) = 1 - \sum_{j=0}^{k} \frac{(t^2/\lambda)^j e^{-t^2/\lambda}}{j!}$$

Rao *et al*. (2009) [14] developed a Marshall-Olkin Extented Lomax distribution: An economic reliability test plan. Rao *et al*. (2011) developed a Economic reliability test plan for products with lifetimes that adhere to the Marshall-Olkin Extended Exponential distribution. The cumulative distribution functions of these distributions are

$$G(x;\alpha,\beta,\sigma) = \frac{\left(1+\frac{x}{\sigma}\right)^{\beta}-1}{\left(1+\frac{x}{\sigma}\right)^{\beta}-\alpha}, x>0, \alpha, \beta, \sigma>0$$

$$G(t;\alpha,\sigma) = \frac{1-e^{-t/\sigma}}{1-\bar{\alpha}e^{-t/\sigma}}, t>0, \alpha, \sigma>0, \bar{\alpha}=1-\alpha$$

The research aims to identify the termination time of the experiment based on a specified sample size, producer's risk and termination number. The suggested plan is evaluated against current plans to illustrate its effectiveness regarding experiment time and cost-efficiency.

Kantam and Sriram (2013) developed Economic reliability test plans for products whose lifetime follow the Rayleigh distribution, whose cdf is given by,

$$F_k(t;\lambda) = 1 - \sum_{j=0}^{k} \frac{(t^2/\lambda)^j e^{-t^2/\lambda}}{j!}$$

The study focuses on determining the termination number. The authors discuss the constant Failure Rate model, which is central to reliability test plans. This paper compares the proposed Rayleigh distribution based test plan with other existing plans, such as those based on the Gamma and Weibull distributions, To establish its preferability in terms of cost and time efficient. A numerical example is provided to illustrate the comparison.

Ramkumar and Sanjana (2013) developed Truncated life test plans for economic reliability based on the four-parametric Burr distribution. This study focuses on determining the optimal termination time for a given sample size, producer's risk and termination number. The proposed plan is compared with existing plan to demonstrate its efficiency in terms of

experiment duration and cost- effectiveness. The cumulative distribution function is given by,

$$F(t,\beta,k,\alpha) = 1 - \left(1 + \left(\frac{t}{\beta}\right)^{\alpha}\right)^{-k} \quad for\ t,\beta,k,\alpha > 0$$

Rosaiah *et al*. (2018) [8] developed Odds Exponential log logistic distribution for an Economic reliability test plan. The cdf of this distribution is

$$F(t,\sigma,\lambda,\theta) = 1 - e^{-\frac{1}{\lambda}\left(\frac{t}{\sigma}\right)^{\theta}}, t > 0, \sigma,\lambda,\theta > 0$$

Rosaiah *et al*. (2018) [8] developed an economic reliability test plans for Exponetial Pareto distribution and Ravikumar *et al*. (2019) developed Economic reliability test plan for Burr Type X distribution. The authors aim to identify the best termination time considering a specific sample size, producer's risk and termination number. By comparing the proposed plan with existing ones, the authors highlight its effectiveness in terms of reducing the duration and cost of experiments. The Operatic Characteristic (OC) curve is a graphical representation that shows the probability of accepting a lot given various levels of defect rates. In the context of these papers, the OC curve helps to visualize the performance of the proposed truncated life test plan. It illustrates how the probability of accepting a product changes with different defects rates, providing insights into the plan's effectiveness in distinguishing between acceptable and defective products. The cumulative distribution function of these distributions are given below.

$$F(t) = 1 - \left[e^{-\lambda\frac{t}{\sigma}^{\theta}}\right], t > 0;\ \lambda,\sigma,\theta > 0$$

$$F(x;k,\lambda) = \left(1 - e^{-(x/\lambda)^{2}}\right)^{k}; x > 0, k > 0, \lambda > 0$$

Gilliarose *et al*. (2022) [12] has developed an economic reliability test plan based on truncated life tests for Marshall–Olkin Power Lomax distribution with applications. This paper determines the minimum sample sizes needed to declare a specified mean life, based on certain life test terminations. The study also explores the operating characteristic function values for different model parameters. Practical applications and case studies are including to illustrate the implementation of this plan. The cumulative distribution function of the MOPL distribution is specified by,

$$G(x,\gamma,\beta,\theta,\lambda) = 1 - \frac{\gamma}{[1 + (x/\lambda)^{\beta}]^{\theta} - (1-\gamma)};\ x,\gamma,\beta,\theta,\lambda > 0$$

Jayalakshmi and Sivasanthiya (2025) [13] developed an economic reliability test plan based on Weighted Weibull distribution. It offers flexibility in modeling various product failure behaviors. Termination time is derived considering producer's risk, enabling early decisions. An OC curve is constructed to evaluate acceptance probability at different quality levels. Cost is minimized by optimizing sample size, duration and acceptance criteria. Numerical examples validate its practicality in industrial settings. By comparing this plan with Kantam and Sriram (2013). The cdf of Weighted Weibull distribution is

$$F(t;\sigma,\theta,\lambda) = 1 - e^{-(\sigma t^{\theta} + \sigma(\lambda t)^{\theta})}, \lambda,\sigma,\theta > 0$$

Mugahal *et al*. (2010) Introduced Economic reliability group acceptance sampling plans for Marshall-Olkin extended distribution.

3. Future Scope

- **Advanced Statistical Models:** Exploring more sophisticated statistical models and distributions to improve the accuracy and reliability of test plans. This includes hybrid and composite distributions that can better capture the complexities of real- world data.
- **Multidisciplinary Approaches:** Combining insights from different fields such as engineering, economics and management to develop holistic reliability plans. This can lead to more effective and practical solutions.
- **Real World Applications:** Implementing and testing the proposed reliability test plans in real world industrial settings. Case studies and practical applications can validate the effectiveness of these plans and provide benchmarks for future research.

By focusing on these areas, future research can significantly advance the field of economic reliability test plans, leading to more efficient, cost-effective and reliable solutions for ensuring product quality and performance.

4. Conclusion

In this review, we have explored various economic reliability test plans across different statistical distributions, including the Marshall-Olkin Extended Lomax distribution, the Hybrid Exponential distribution, the Odds Exponential Log Logistic distribution etc., The significance of these test plans lies in their ability to optimize the duration of reliability testing, ensuring that products meet the desired quality and reliability standards. Despite the advancements, several gaps remain in the current research. In conclusion, Economic reliability test plans play a crucial role in ensuring product quality and reliability while maintaining cost-effectiveness. Continued research and innovation in this field will contribute significantly to the development of efficient, reliable and economically viable testing methodologies, ultimately benefiting both producers and consumers.

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