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Design of Sampling Plan for Exponential Distribution under Neutrosophic Statistical Interval Method

Muhammad Aslam

Department of Statistics, Faculty of Science, King Abdulaziz University, Jeddah 21551, Saudi Arabia
Email: aslam_ravian@hotmail.com

Abstract

The sampling plan using the classical statistics under the exponential distribution can be applied only when there are certainty and clearness and in observations and parameters. But, in practice, it is not necessary that under some circumstances all the observations/parameters are determined. So, we cannot analyze them using the classical statistics which provides results in the determined values. The neutrosophic statistics which is the generation of the classical statistics can be applied to the analysis when parameters/observations are incomplete, indeterminate and vague imprecise. In this paper, we will design originally a sampling plan for the exponential distribution under the neutrosophic interval statistical method. The neutrosophic plan parameters of the proposed plan will be determined through the neutrosophic non-linear problem. The tables for various values of risk are presented for the use in the industrial. An example from the automobiles manufacturing industry is given to explain for the exponential distribution under the neutrosophic interval statistical method.

Key words: fuzzy environment; neutrosophic method; producer's risk, consumer's risk; neutrosophic parameters

1 Introduction

According to [1] "Inspection is one of the important parts of the quality control and quality assurance. The high quality cannot be achieved by accident. For the inspection, a careful planning is needed using the techniques and instruments. A product is made with several components having different specification limits for each component. Through a well-designed inspection plan, one can verify that each of the specifications is met". So, the sampling plan is one of the important tool for the inspection/testing of the product. A random sample is selected from the submitted lot of the product and lot is rejected if the number of defectives is larger than the specified number of failures. The plan parameters which are used in the testing/inspection of the product are determined such that given producer's risk, consumer's risk and specifications are met. So, the well-designed sampling plan minimizes the risk and sample size required for the testing of the product. A more details about the sampling plans can be seen in [2], [3], [4], [5], [6], [7], [8], [9], [10] and [11].

According to [12] and [13], the normal distribution may not be applied when data is not collected in a subgroup which is usually skewed. The exponential distribution is an excellent model to study the skewed and time between occurring events, see [1]. The applications of plans using the exponential distribution can be seen in [14], [1] and [15]. Several authors designed the sampling plans for the verity of statistical distributions, for example, [16], [17], [18], [19], [20], [21] and [22].

The existing sampling plans for various classical statistical distributions are designed under the assumption of the determined values. These sampling plans are only workable when the experimenter is sure about the percent/proportion defective in the product. The fuzzy approach has been widely applied in the area of sampling plans when there is indeterminate in the percent defective items. Several authors contributed their work on the design of sampling plans using the fuzzy environment including for example [23], [24], [25], [26], [27], [28], [29], [25], [30], [31], [32], [33], [34], [35], [36], [37] and [38].

The sampling plan using the classical statistics under the exponential distribution can be applied only when there are certainty and clearness in observations and parameters. But, in practice, it is not necessary that under some circumstances all the observations/parameters are determined values. So, we cannot analyze the data using the classical statistics under indeterminate environment. The neutrosophic statistics which is the generation of the classical statistics can be applied for the analysis when parameters/observations are incomplete, indeterminate, vague and imprecise [[39], [40] and [41]]. Recently, [42] designed a sampling plan using neutrosophic statistics. [43] proposed testing of the product using the sudden death testing under the neutrosophic statistics.

By exploring the literature and best of the author's knowledge, there is no work on the design of variable sampling plan for the exponential distribution under the neutrosophic interval statistical method. In this paper, we will originally design a sampling plan for the exponential distribution under the neutrosophic interval statistical method. The neutrosophic plan parameters of the proposed plan will be determined through the neutrosophic non-linear problem. The tables for various values of risk are presented for the use in the industrial. An example from the automobiles manufacturing industry is given to explain the sampling plan for the exponential distribution under the neutrosophic interval statistical method

2 Designing of the Proposed Plan

The neutrosophic number (NN) and neutrosophic statistics for the normal distribution are proposed by [39]. According to [39], "a NN $z = a + bI$ has determinate part a and indeterminate part bI, where a and b are real number and $I \epsilon \{I_L, I_U\}$ is indeterminacy". Based on [39] idea, we introduce NN for the exponential distribution $T_N = T_a + T_b I$, where T_a and T_b are real number and $I \epsilon \{I_L, I_U\}$ is indeterminacy. Suppose that $T_{Ni} \epsilon \{T_L, T_U\} = i = 1,2,3, \ldots, n$ be a random sample follows the neutrosophic exponential distribution having a neutrosophic scale parameter $\theta_N \epsilon \{\theta_L, \theta_U\}$, the neutrosophic fuzzy exponential distribution with the neutrosophic probability density function (npdf) is defined as follows

$$f(T_N) \frac{1}{\theta_N} e^{-t_N/\theta_N}; \theta_N > 0, T_{Ni} \epsilon \{T_L, T_U\}, \theta_N \epsilon \{\theta_L, \theta_U\} \quad (1)$$

Suppose that an item below lower specification limit L is declared as non-conforming. The proposed plan for the exponential distribution under the neutrosophic interval statistical method using the exact approach is stated as follows

Step-1: Take a random sample $T_{Ni} \epsilon \{T_L, T_U\} = i = 1,2,3, \ldots, n$ of size $n_N \epsilon \{n_L, n_U\}$ from the lot and calculate $\bar{T}_N = \sum_{i=1}^{n_N} \frac{T_{Ni}}{n_N}; T_{Ni} \epsilon \{T_L, T_U\}, n_N \epsilon \{n_L, n_U\}$ (2)

Step-2: Accept the lot if $\bar{T}_N > k_N L$; where $k_N \epsilon \{k_{aL}, k_{aU}\}$ is neutrosophic acceptance number.

The sampling plan for the exponential distribution under the neutrosophic interval statistical method has two neutrosophic plan parameters which are $n_N \epsilon \{n_L, n_U\}$ and $k_N \epsilon \{k_{aL}, k_{aU}\}$.

The neutrosophic operating characteristic function (NOC) of the sampling plan for the exponential distribution under the neutrosophic interval statistical method is derived by following [1] as

$$P_{Na} = \mathrm{P}\{\bar{T}_N > k_N L\} = \mathrm{P}\{\sum T_{Ni} > n_N k_N L\} = 1 - G_N(n_N k_N L);\ n_N \epsilon \{n_L, n_U\} \text{ and } k_N \epsilon \{k_{aL}, k_{aU}\} \quad (3)$$

Note that $G_N(T_{Ni})$ is neutrosophic cumulative distribution function (ncdf) of the neutrosophic gamma distribution having parameters $n_N \epsilon \{n_L, n_U\}$ and $\theta_N \epsilon \{\theta_L, \theta_U\}$ is defined as

$$G_N(T_N) = \sum_{j=n_N}^{\infty} \frac{e^{-T_N/\theta_N} (T_N/\theta_N)^j}{j!};\ n_N \epsilon \{n_L, n_U\}, \theta_N \epsilon \{\theta_L, \theta_U\} \quad (4)$$

The final form of NOC is given by

$$P_{Na} = \sum_{j=0}^{n_N - 1} \frac{e^{-n_N k_N L/\theta_N} (n_N k_N L/\theta_N)^j}{j!} \quad n_N \epsilon \{n_L, n_U\}, \theta_N \epsilon \{\theta_L, \theta_U\} \quad (5)$$

2.1 Neutrosophic Non-Linear Optimization

Suppose that α and β be producer's risk and consumer's risk, p_1 and p_2 are acceptable quality level (AQL) and limiting quality level (LQL), respectively. It is mentioned earlier that $p_N = \mathrm{P}\{T_N < L\}$ is labeled as defective and this neutrosophic probability is given by

$$p_N = \mathrm{P}\{T_N < L\} = 1 - e^{-L/\theta_N} \quad n_N \epsilon \{n_L, n_U\}, \theta_N \epsilon \{\theta_L, \theta_U\} \quad (6)$$

When AQL and LQL are specified, from Eq. (6), we have

$$\frac{L}{\theta_{N1}} = -\ln(1 - p_{N1});\ \theta_{N1} \epsilon \{\theta_{L1}, \theta_{U1}\} \quad (7)$$

and

$$\frac{L}{\theta_{N2}} = -\ln(1 - p_{N2});\ \theta_{N2} \epsilon \{\theta_{L2}, \theta_{U2}\}$$

The neutrosophic plan parameters should be determined such that α and β are minimized. So, the neutrosophic sample size $n_N \epsilon \{n_L, n_U\}$ will be minimized such that α at AQL and β at LQL are satisfied. So, we will consider following neutrosophic non-Linear optimization to find the neutrosophic plan parameters.

$$\text{Minimize } n_N \epsilon \{n_L, n_U\} \quad (8a)$$

Subject to

$$\sum_{j=0}^{n_N - 1} \frac{e^{-n_N k_N L/\theta_{1N}} (n_N k_N L/\theta_{1N})^j}{j!} \geq 1 - \alpha;\ n_N \epsilon \{n_L, n_U\},\ k_N \epsilon \{k_{aL}, k_{aU}\},\ \theta_{N1} \epsilon \{\theta_{L1}, \theta_{U1}\} \quad (8b)$$

$$\sum_{j=0}^{n_N - 1} \frac{e^{-n_N k_N L/\theta_{N2}} (n_N k_N L/\theta_{N2})^j}{j!} \leq \beta;\ n_N \epsilon \{n_L, n_U\},\ k_N \epsilon \{k_{aL}, k_{aU}\},\ \theta_{N2} \epsilon \{\theta_{L2}, \theta_{U2}\} \quad (8c)$$

The $n_N \epsilon \{n_L, n_U\}$, $k_N \epsilon \{k_{aL}, k_{aU}\}$ are determined using neutrosophic non-Linear optimization given in Eq. (8a) to Eq. (8c) by grid search method. During the simulation, it is observed that several combinations exist which satisfy Eq. (8a) to Eq. (8c). The combinations of $n_N \epsilon \{n_L, n_U\}$, $k_N \epsilon \{k_{aL}, k_{aU}\}$ is selected where $n_N \epsilon \{n_L, n_U\}$ is minimum. The following steps are used to find $n_N \epsilon \{n_L, n_U\}$, $k_N \epsilon \{k_{aL}, k_{aU}\}$ in Tables 1-2.

Step-1: Specify α, β, AQL and LQL.

Step-2: Calculate $\frac{L}{\theta_{N1}}$ and $\frac{L}{\theta_{N2}}$ using Eq. (7).

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Step-3: Solve Eq. (8b) and Eq. (8c) using the calculated values of $\frac{\mathrm{L}}{\theta_{\mathrm{N1}}}$ and $\frac{\mathrm{L}}{\theta_{\mathrm{N2}}}$.

Step-4: Determine $n_N \epsilon\{n_L, n_U\}$, $k_N \epsilon\{k_{aL}, k_{aU}\}$ such that Eq. (8b) and Eq. (8c) satisfy the given conditions.

Step-5: Choose that values of $n_N \epsilon\{n_L, n_U\}$, $k_N \epsilon\{k_{aL}, k_{aU}\}$ where $n_N \epsilon\{n_L, n_U\}$ is minimum or range $(R = n_U - n_L)$ of indeterminacy interval is minimum.

The values of $n_N \epsilon\{n_L, n_U\}$, $k_N \epsilon\{k_{aL}, k_{aU}\}$ for $\alpha = 0.05$ and $\beta = 0.05$ are placed in Table 1. The values of $n_N \epsilon\{n_L, n_U\}$, $k_N \epsilon\{k_{aL}, k_{aU}\}$ for $\alpha = 0.10$ and $\beta = 0.10$ are placed in Table 2.

From Tables 1-2, we note that for the fixed values of α, β and AQL, the $n_N \epsilon\{n_L, n_U\}$, $k_N \epsilon\{k_{aL}, k_{aU}\}$ decrease as LQL increases. The values of $n_N \epsilon\{n_L, n_U\}$, $k_N \epsilon\{k_{aL}, k_{aU}\}$ also decreases as α, β increases.

Table 1: Plan parameters of the exact approach when $\alpha = 0.05$ and $\beta = 0.05$

AQL(p_1)	LQL(p_2)	$n_N \epsilon\{n_L, n_U\}$	$k_N \epsilon\{k_{aL}, k_{aU}$	$P_{Na}(p_1)$	$P_{Na}(p_2)$
0.03	0.060	[26,34]	[22,24]	[0.9533,0.9676]	[0.0058,0.0426]
	0.090	[13,16]	[16,18]	[0.9786,0.9867]	[0.0099,0.0463]
	0.120	[6,8]	[14,16]	[0.9540,0.9547]	[0.0080,0.0438]
	0.150	[5,7]	[12,14]	[0.9616,0.9672]	[0.0042,0.0343]
	0.300	[3,5]	[6,8]	[0.9817,0.9918]	[0.0015,0.0456]
0.05	0.100	[43,46]	[12,15]	[0.9509,0.9981]	[0.0003,0.0494]
	0.150	[15,17]	[9,11]	[0.9808,0.9948]	[0.0032,0.0489]
	0.200	[6,9]	[8,10]	[0.9541,0.9605]	[0.0020,0.0445]
	0.250	[5,7]	[7,9]	[0.9534,0.9639]	[0.0010,0.0280]
	0.500	[3,5]	[4,6	[0.9753,0.9795]	[0.0000,0.0107]

Table 2: Plan parameters of the exact approach when $\alpha = 0.10$ and $\beta = 0.10$

AQL(p_1)	LQL(p_2)	$n_N \epsilon \{n_L, n_U\}$	$k_N \epsilon \{k_{aL}, k_{aU}\}$	$P_{Na}(p_1)$	$P_{Na}(p_2)$
0.03	0.060	[20,26]	[21,23]	[0.9501,0.9627]	[0.0241,0.0972]
	0.090	[18,20]	[14,16]	[0.9974,0.9990]	[0.0203,0.0946]
	0.120	[7,9]	[12,14]	[0.9831,0.9841]	[0.0207,0.0900]
	0.150	[5,7]	[10,12]	[0.9803,0.9841]	[0.0176,0.0926]
	0.300	[3,5]	[5,7]	[0.9887,0.9952]	[0.0054,0.0981]
0.05	0.100	[68,71]	[11,14]	[0.9954,1.000]	[0.0002,0.0990]
	0.150	[20,23]	[8,10]	[0.9975,0.9997]	[0.0047,0.0967]
	0.200	[6,8]	[7,9]	[0.9651,0.9772]	[0.0096,0.0949]
	0.250	[4,6]	[6,8]	[0.9605,0.9635]	[0.0063,0.0869]
	0.500	[2,4]	[3,5]	[0.9613,0.9794]	[0.0005,0.0806]

3 Comparison Study

In this section, we will compare the efficiency of the proposed plan for the exponential distribution under the neutrosophic interval statistical method with the sampling plan proposed by [1] under the classical statistics. As mentioned by [41] that a statistical method having the interval range is said to be a more effective method than the method having determined value. For the fair comparison, the same values of all specified parameters are chosen. To save the space, Table 3 is presented only for a few combinations of AQL and LQL when $\alpha = 0.05$ and $\beta = 0.05$. From Table 3, it can be noted the values of R are smaller for the proposed sampling plan. Furthermore, the proposed method is more effective as it has an interval range while classical statistics has determined values. Therefore, the proposed plan/method is effective and reasonable to apply under an indeterminate environment for the inspection of a lot of the product.

Table 3: The comparison of proposed plan and [1] plan when $\alpha = 0.05$ and $\beta = 0.05$

AQL(p_1)	LQL(p_2)	Proposed Plan	Existing Plan
		$n_N \epsilon \{n_L, n_U\}$	n
0.03	0.120	[6,8] (R=2)	6
	0.150	[5,7] (R=2)	5

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	0.300	[3,5] (R=2)	3
0.05	0.200	[6,9] (R=3)	6
	0.250	[5,7] (R=2)	5

4 Application

In this section, the application of the proposed sampling is given with the aid data from automobile manufacturing company in Korea. According to [1] " the variable under study is on the time until a service is requested for a certain subsystem of passenger car". The data is well fitted to the exponential distribution with $\theta_N \epsilon \{57.84,59.06\}$ The service time may neutrosophic when one does know the exact/certain service time so the experimenter is not certain to about the required sample size $n_N = \{n_L, n_U\}$ and corresponding acceptance number $k_N \epsilon \{k_{aL}, k_{aU}\}$. As mentioned above, the proposed plan/method is effective and reasonable to apply under an indeterminate environment for the inspection of a lot of the product. Suppose that for this experiment, AQL=0.03, LQL=0.060 and L =50. For these parameters, from Table 1, $n_N \epsilon \{26,34\}$ and $k_N \epsilon \{22,24\}$. Suppose he decided to select a random sample of size 28. The data of 28 automobiles having some uncertain, imprecise and indeterminate observations are reported in Table 4.

Table 4: The real data set

[17.5,18.9]	[49.6,49.6]	[155.3,158.5]	[11.07,11.07]
[81.98,85.96]	[3.36,3.36]	[4.14,4.98]	[0.18,0.18]
[23.24,23.24[	[71.5,77.37]	[34.29, 34.29]	[16.44,20.21]
[66.54, 66.54]	[12.32, 12.32]	[6.96,7.95]	[31.71, 31.71]
[95.46,99.20]	[213.26, 213.26]	[67.89, 67.89]	[42.49,45.54]
[34.52, 34.52]	[274.98, 274.98]	[14.84,17.32]	[13.57, 13.57]
[79.72, 79.72]	[28.07,30.09]	[39.08, 39.08]	[129.58,132.52]

The proposed plan for the service time data is implemented as

Step-1: Select a random sample size $n_N \epsilon \{26,34\}$, say 28.

Step-2: Compute statistic $\bar{T}_N$ as follows

$$\bar{T}_N \epsilon \left\{\frac{\sum_{i=1}^{n} T_i}{n_L}, \frac{\sum_{i=1}^{n} T_i}{n_U}\right\} = \{57.84,59.06\},$$

$k_N L \epsilon \{1100,1200\}$

2. The lot will be rejected as $\{57.84,59.06\} < \{1100,1200\}$

5 Conclusion

In this paper, we will design originally a sampling plan for the exponential distribution under the neutrosophic interval statistical method. We defined some necessary neutrosophic measures for the proposed sampling plans. The neutrosophic non-Linear optimization is proposed and neutrosophic plan parameters are determined by satisfying the given conditions. The proposed sampling plan is the alternative to the plan using the classical statistics. The proposed sampling plan can be applied in the industry where uncertainty in plan parameters or when observations are incomplete, indeterminate and vague imprecise. The application of the proposed plan is given when some observations are incomplete, indeterminate and vague imprecise. From the comparison, it is concluded that the proposed method/plan is more effective and reasonable to apply under an indeterminate environment for the lot sentencing purpose. It is concluded that the proposed plan can be applied in the automobile industry, food industry, and the aerospace industry. The proposed sampling plan by considering a big data will be considered as future research.

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