Received September 29, 2018, accepted October 22, 2018, date of publication October 24, 2018, date of current version November 19, 2018.

Digital Object Identifier 10.1109/ACCESS.2018.2877923

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
e-mail: aslam_ravian@hotmail.com

This work was supported by the Deanship of Scientific Research (DSR), King Abdulaziz University, Jeddah, under Grant No. 130-261-D1439.

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 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.

INDEX TERMS Fuzzy environment, neutrosophic method, producer's risk, consumer's risk, neutrosophic parameters.

I. 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]–[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 [1], [14], and [15]. Several authors designed the sampling plans for the verity of statistical distributions, for example, [16]–[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]–[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]–[41]. Recently, Aslam [42] designed a sampling plan using neutrosophic statistics. Aslam and Arif [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

II. DESIGNING OF THE PROPOSED PLAN

The neutrosophic number (NN) and neutrosophic statistics for the normal distribution are proposed by Smarandache [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 Smarandache's [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

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

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

$$\bar{T}_N = \sum_{i=1}^{n_N} \frac{T_{Ni}}{n_N}; \quad T_{Ni}\epsilon \{T_L, T_U\},\ n_N\epsilon \{n_L, n_U\} \quad (2)$$

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

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

Note that $G_N\left(T_{Ni}\right)$ 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

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

The final form of NOC is given by

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

A. 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

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

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

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

and

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

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.

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

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

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

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]

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.

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

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]

Step-1: Specify α,β, AQL and LQL.

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

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

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.

III. 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 Aslam *et al.* [1] under the classical statistics. As mentioned by Chen *et al.* [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.

IV. 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.

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 $\{57.84, 59.06\} < \{1100, 1200\}$

V. 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.

ACKNOWLEDGEMENTS

The author is deeply thankful to the editor and the reviewers for their valuable suggestions to improve the quality of this manuscript. The author, M. Aslam, therefore, gratefully acknowledge the DSR technical and financial support.

REFERENCES

[1] M. Aslam, M. Azam, and C.-H. Jun, "A new sampling plan under the exponential distribution," *Commun. Statist.-Theory Methods*, vol. 46, no. 2, pp. 644–652, 2017.
[2] R. R. L. Kantam, K. Rosaiah, and G. S. Rao, "Acceptance sampling based on life tests: Log-logistic model," *J. Appl. Statist.*, vol. 28, no. 1, pp. 121–128, 2001.
[3] K. Rosaiah and R. R. L. Kantam, "Acceptance sampling based on the inverse Rayleigh distribution," *Econ. Qual. Control*, vol. 20, no. 2, pp. 277–286, 2005.
[4] G. S. Rao, M. E. Ghitany, and R. R. L. Kantam, "Reliability test plans for Marshall–Olkin extended exponential distribution," *Appl. Math. Sci.*, vol. 3, no. 55, pp. 2745–2755, 2009.
[5] G. S. Rao, "A group acceptance sampling plans for lifetimes following a generalized exponential distribution," *Econ. Qual. Control*, vol. 24, no. 1, pp. 75–85, 2009.
[6] C.-H. Yen, M. Aslam, and C.-H. Jun, "A lot inspection sampling plan based on EWMA yield index," *Int. J. Adv. Manuf. Technol.*, vol. 75, nos. 5–8, pp. 861–868, 2014.
[7] B. S. Rao, C. S. Kumar, and K. Rosaiah, "Variable limits and control charts based on the half normal distribution," *J. Testing Eval.*, vol. 44, no. 5, pp. 1878–1884, 2016, doi: 10.1520/JTE20140429.
[8] A. Yan and S. Liu, "Designing a repetitive group sampling plan for Weibull distributed processes," *Math. Problems Eng.*, vol. 2016, Jul. 2016, Art. no. 5862071.
[9] G. S. Rao, "Double acceptance sampling plans based on truncated life tests for the marshall-olkin extended exponential distribution," *Austrian J. Statist.*, vol. 40, no. 3, pp. 169–176, 2016.
[10] O. H. Arif, M. Aslam, and C.-H. Jun, "Acceptance sampling plan for multiple manufacturing lines using EWMA process capability index," *J. Adv. Mech. Des., Syst., Manuf.*, vol. 11, no. 1, p. JAMDSM0004, 2017.
[11] S. Balamurali, M. Aslam, and A. Liaquat, "Determination of a new mixed variable lot-size multiple dependent state sampling plan based on the process capability index," *Commun. Statist.-Theory Methods*, vol. 47, no. 3, pp. 615–627, 2018.
[12] E. G. Schilling and P. R. Nelson, "The effect of non-normality on the control limits of X-charts," *J. Qual. Technol.*, vol. 8, no. 4, pp. 183–188, 1976.
[13] Z. G. B. Stoumbos and M. R. Reynolds, Jr, "Robustness to non-normality and autocorrelation of individuals control charts," *J. Stat. Comput. Simul.*, vol. 66, no. 2, pp. 145–187, 2000.
[14] M. Mohammed, "Using statistical process control to improve the quality of health care," *Qual. Saf. Health Care*, vol. 13, no. 4, pp. 243–245, 2004.
[15] C.-W. Wu, M.-H. Shu, and Y.-N. Chang, "Variable-sampling plans based on lifetime-performance index under exponential distribution with censoring and its extensions," *Appl. Math. Model.*, vol. 55, pp. 81–93, Mar. 2018.
[16] A. D. Al-Nasser and A. I. Al-Omari, "Acceptance sampling plan based on truncated life tests for exponentiated fréchet distribution," *J. Statist. Manage. Syst.*, vol. 16, no. 1, pp. 13–24, 2013.
[17] M. Aslam, M. Azam, S. Balamurali, and C.-H. Jun, "A new mixed acceptance sampling plan based on sudden death testing under the Weibull distribution," *J. Chin. Inst. Ind. Eng.*, vol. 29, no. 6, pp. 427–433, 2012.
[18] S. Balamurali and J. Subramani, "Conditional variables double sampling plan for weibull distributed lifetimes under sudden death testing," *Bonfring Int. J. Data Mining*, vol. 2, no. 3, pp. 12–15, 2012.
[19] R. Bhattacharya, B. Pradhan, and A. Dewanji, "Computation of optimum reliability acceptance sampling plans in presence of hybrid censoring," *Comput. Statist. Data Anal.*, vol. 83, pp. 91–100, Mar. 2015.
[20] W. Gui and M. Aslam, "Acceptance sampling plans based on truncated life tests for weighted exponential distribution," *Commun. Statist.-Simul. Comput.*, vol. 46, no. 3, pp. 2138–2151, 2017.
[21] M. Kumar and P. Ramyamol, "Design of optimal reliability acceptance sampling plans for exponential distribution," *Econ. Qual. Control*, vol. 31, no. 1, pp. 23–36, 2016.
[22] Y. L. Lio, T.-R. Tsai, and S.-J. Wu, "Acceptance sampling plans from truncated life tests based on the Birnbaum–Saunders distribution for percentiles," *Commun. Statist.-Simul. Comput.*, vol. 39, no. 1, pp. 119–136, 2009.
[23] A. Kanagawa and H. Ohta, "A design for single sampling attribute plan based on fuzzy sets theory," *Fuzzy Sets Syst.*, vol. 37, no. 2, pp. 173–181, 1990.
[24] F. Tamaki, A. Kanagawa, and H. Ohta, "A fuzzy design of sampling inspection plans by attributes," *J. Jpn. Soc. Fuzzy Theory Syst.*, vol. 3, no. 4, pp. 211–212, 1991.
[25] E. Turanoğlu, I. Kaya, and C. Kahraman, "Fuzzy acceptance sampling and characteristic curves," *Int. J. Comput. Intell. Syst.*, vol. 5, no. 1, pp. 13–29, 2012.
[26] S.-R. Cheng, B.-M. Hsu, and M.-H. Shu, "Fuzzy testing and selecting better processes performance," *Ind. Manage. Data Syst.*, vol. 107, no. 6, pp. 862–881, 2007.
[27] M. H. F. Zarandi, A. Alaeddini, and I. B. Turksen, "A hybrid fuzzy adaptive sampling—Run rules for Shewhart control charts," *Inf. Sci.*, vol. 178, no. 4, pp. 1152–1170, 2008.
[28] A. Alaeddini, M. Ghazanfari, and M. A. Nayeri, "A hybrid fuzzy-statistical clustering approach for estimating the time of changes in fixed and variable sampling control charts," *Inf. Sci.*, vol. 179, no. 11, pp. 1769–1784, 2009.

[29] B. S. Gildeh, E. B. Jamkhaneh, and G. Yari, "Acceptance single sampling plan with fuzzy parameter," *Iranian J. Fuzzy Syst.*, vol. 8, no. 2, pp. 47–55, 2011.
[30] P. R. Divya, "Quality interval acceptance single sampling plan with fuzzy parameter using poisson distribution," *Int. J. Adv. Res. Technol.*, vol. 1, no. 3, pp. 115–125, 2012.
[31] E. B. Jamkhaneh and B. S. Gildeh, "Acceptance double sampling plan using fuzzy poisson distribution," *World Appl. Sci. J.*, vol. 16, no. 11, pp. 1578–1588, 2012.
[32] A. Venkateh and S. Elango, "Acceptance sampling for the influence of TRH using crisp and fuzzy gamma distribution," *Aryabhatta J. Math. Inform.*, vol. 6, no. 1, pp. 119–124, 2014.
[33] E. B. Jamkhaneh and B. S. Gildeh, "Sequential sampling plan using fuzzy SPRT," *J. Intell. Fuzzy Syst.*, vol. 25, no. 3, pp. 785–791, 2013.
[34] E. B. Jamkhaneh, B. Sadeghpour-Gildeh, and G. Yari, "Inspection error and its effects on single sampling plans with fuzzy parameters," *Struct. Multidisciplinary Optim.*, vol. 43, no. 4, pp. 555–560, 2011.
[35] R. Afshari and B. S. Gildeh, "Construction of fuzzy multiple deferred state sampling plan," in *Proc. Joint 17th World Congr. Int. Fuzzy Syst. Assoc., 9th Int. Conf. Soft Comput. Intell. Syst. (IFSA-SCIS)*, Jun. 2017, pp. 1–7.
[36] R. Afshari, B. S. Gildeh, and M. Sarmad, "Multiple deferred state sampling plan with fuzzy parameter," *Int. J. Fuzzy Syst.*, vol. 20, no. 2, pp. 549–557, 2017.
[37] S. Elango, A. Venkatesh, and G. Sivakumar, "A fuzzy mathematical analysis for the effect of TRH using acceptance sampling plans," *Int. J. Pure Appl. Math.*, vol. 117, no. 5, pp. 1–11, 2017.
[38] R. Afshari, B. S. Gildeh, and M. Sarmad, "Fuzzy multiple deferred state attribute sampling plan in the presence of inspection errors," *J. Intell. Fuzzy Syst.*, vol. 33, no. 1, pp. 503–514, 2017.
[39] F. Smarandache, *Introduction to Neutrosophic Statistics: Infinite Study*. 2014.
[40] J. Chen, J. Ye, and S. Du, "Scale effect and anisotropy analyzed for neutrosophic numbers of rock joint roughness coefficient based on neutrosophic statistics," *Symmetry*, vol. 9, no. 10, p. 208, 2017.
[41] J. Chen, J. Ye, S. Du, and R. Yong, "Expressions of rock joint roughness coefficient using neutrosophic interval statistical numbers," *Symmetry*, vol. 9, no. 7, p. 123, 2017.
[42] M. Aslam, "A new sampling plan using neutrosophic process loss consideration," *Symmetry*, vol. 10, no. 5, p. 132, 2018.
[43] M. Aslam and O. H. Arif, "Testing of grouped product for the weibull distribution using neutrosophic statistics," *Symmetry*, vol. 10, no. 9, p. 403, 2018.

MUHAMMAD ASLAM received the M.Sc. degree in statistics, under the Chief Minister of Punjab Merit Scholarship, and the M.Phil. degree in statistics, under the Governor of Punjab Merit Scholarship, from GC University Lahore in 2004 and 2006, respectively, and the Ph.D. degree in statistics from the National College of Business Administration and Economics Lahore in 2010, under the supervision of Dr. M. Ahmad. He was a Lecturer of statistics with the Edge College System International from 2003 to 2006. He was a Research Assistant with the Department of Statistics, GC University Lahore, from 2006 to 2008. In 2009, he joined the Forman Christian College University as a Lecturer, where he was an Assistant Professor from 2010 to 2012 and an Associate Professor from 2012 to 2014. He was an Associate Professor of statistics with the Department of Statistics, Faculty of Science, King Abdulaziz University, Jeddah, Saudi Arabia, from 2014 to 2017. He taught summer course as a Visiting Faculty of statistics with Beijing Jiaotong University, China, in 2016. He has been an HEC approved Ph.D. Supervisor since 2011. He is currently a Full Professor of statistics with the Department of Statistics, King Abdul-Aziz University. He has authored over 270 research papers in national and international well reputed journals including, IEEE Access, the *Journal of Applied Statistics*, the *European Journal of Operation Research, Information Sciences*, the *Journal of Process Control*, the *Journal of the Operational Research Society*, *Applied Mathematical Modeling*, the *International Journal of Advanced Manufacturer Technology*, *Communications in Statistics*, the *Journal of Testing and Evaluation*, and the *Pakistan Journal of Statistics*. His papers have been cited more than 2100 times with *h*-index 25 and *i*-10 index 64 (Google Coalitions). His papers have been cited more than 1000 times with *h*-index 18 (Web of Science Coalitions). He has authored one book published in Germany. He supervised five Ph.D. dissertations, more than 25 M.Phil. dissertations, and three M.Sc. dissertations. He is currently supervising one Ph.D. dissertation and more than 5 M.Phil. dissertations in statistics. His areas of interests include reliability, decision trees, industrial statistics, acceptance sampling, rank set sampling, neutrosophic statistics, and applied statistics. He is an Editorial Board Member of the *Electronic Journal of Applied Statistical Analysis*, the *Asian Journal of Applied Science and Technology*, and the *Pakistan Journal of Commence and Social Sciences*. He is also a member of the Islamic Countries Society of Statistical Sciences. He is appointed as an External Examiner for 2016/2017–2018/2019 triennium at The University of Dodoma, Tanzania. He received the Meritorious Services Award in Research from the National College of Business Administration and Economics, Lahore, in 2011, and the Research Productivity Award for the year 2012 by the Pakistan Council for Science and Technology. He received the King Abdulaziz University Excellence Award in Scientific Research for the paper entitled Aslam, M., Azam, M., Khan, N. and Jun, C.-H. (2015). A New Mixed Control Chart to Monitor the Process, *International Journal of Production Research,*53 (15), 4684–4693. He received the King Abdulaziz University Citation Award for the paper entitled Azam, M., Aslam, M. and Jun, C.-H. (2015). Designing of a hybrid exponentially weighted moving average control chart using repetitive sampling, *International Journal of Advanced Manufacturing Technology,*77:1927–1933 in 2018. His name listed at Second Position among Statistician in the Directory of Productivity Scientists of Pakistan 2013. His name Listed at First Position among Statistician in the Directory of Productivity Scientists of Pakistan 2014. He got 371th position in the list of top 2210 profiles of Scientist of Saudi Institutions 2016. He is selected for the Innovative Academic Research & Dedicated Faculty Award 2017 by SPE, Malaysia. He is a Reviewer of over 50 well reputed international journals. He has reviewed more than 140 research papers for various well reputed international journals.