Mathematics

AIMS Mathematics, 8(6): 14558–14571.
DOI: 10.3934/math.2023744
Received: 08 November 2022
Revised: 28 February 2023
Accepted: 22 March 2023
Published: 19 April 2023

http://www.aimspress.com/journal/Math

Research article

Uncertainty-based sampling plans for various statistical distributions

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Abstract: This research work appertains to the acceptance sampling plan under the neutrosophic statistical interval method (ASP-NSIM) based on gamma distribution (GD), Burr type XII distribution (BXIID) and the Birnbaum-Saunders distribution (BSD). The plan parameters will be determined using the neutrosophic non-linear optimization problem. We will provide numerous tables for the three distributions using various values of shape parameters and degree of indeterminacy. The efficiency of the proposed ASP-NSIM will be discussed over the existing sampling plan in terms of sample size. The application of the proposed ASP-NSIM will be given with the aid of industrial data.

Keywords: acceptance sampling plan; producer's risk; consumer's risk; the ratio of mean lifetime; neutrosophic method; neutrosophic non-linear optimization problem
Mathematics Subject Classification: 62A86

1. Introduction

In most industries, an acceptance sampling plan (ASP) plays a vital role in testing the quality of the manufactured product. The ASP in statistical quality control has established its importance to decide on the acceptance or rejection of a lot of a product. At the stage of inspection, it may not possible to inspect a lot of the product. In such a case, a sampling plan is a very appropriate alternative for deciding whether a lot of the product should be accepted or rejected based on verification of the quality in a selected sample. Sampling plans are essential when lot sizes are very large, the chance of assessment errors is high, and the cost of the inspection is extremely significant. These ASPs were first applied at the time of the Second World War by the Americans. [1] developed an ASP and promoted its application in the industry. The authors said that "it is a method of inspecting a sample of products to decide whether the product lot is to be accepted or not, based on the results obtained and if the number of failures during the test time does not exceed the acceptance number then the lot is accepted." Hence, the ASP is the best indispensable method for the checkup/testing of the product. The plan parameters which are used in the checkup/testing of the manufactured goods are ascertained in accordance with the specified producer's risk as well as the consumer's risk. For more details, see [2]. Thus, the well-defined sampling plan will minimize the risks and provide a smaller sample size for testing the manufactured goods. More details on the ASPs from truncated life tests could be encountered in [3] for log-logistic distribution, [4] for Weibull distribution for repetitive group sampling, reference [5] reliability sampling plans based on hybrid censoring, [6] for reliability acceptance sampling plans for the exponential distribution, reference [7] for Birnbaum-Saunders distribution.

The aforementioned ASPs are classical sampling plans which are developed for different statistical distributions under the postulation of the known quantities. All of the ASPs mentioned above are only useful when the researcher confirms the percentage of nonconforming items in the manufactured goods. In recent years, the fuzzy approach has become a popular research methodology in the field of ASPs for uncertainty in the fraction of nonconformity. Various researchers boosted their research contribution on the design of ASPs based on the fuzzy atmosphere for different situations comprising as [8] studied a design for a single sampling attribute plan based on fuzzy sets theory, [9] developed the sampling plans by attributes using the fuzzy approach, [10] presented the fuzzy acceptance sampling plan and its characteristic curves, [11] studied single sampling plan with fuzzy parameter, [12] developed a single acceptance sampling plan with a fuzzy parameter for Poisson distribution, [13] proposed the double sampling plan using fuzzy Poisson distribution, [14] developed the sequential sampling plan using fuzzy SPRT, [15] proposed inspection error and its effects on single sampling plans with fuzzy parameters, [16] further studied the acceptance sampling for the influence of TRH using crisp and fuzzy gamma distribution and [17] studied a fuzzy mathematical analysis for the effect of TRH using acceptance sampling plans.

Because of its versatility in addressing the uncertainty in the data and the parameters of the distributions, neutrosophic statistics (NS) or neutrosophic logic has drawn the attention of more researchers during the past several years. [18] developed neutrosophic statistics and which is the generalization of traditional statistics which can be employed to analyze the data in uncertain situations. [19] studied a new attribute ASP-NSIM and pointed out that "in the case of uncertainty, the existing sampling plan cannot be applied for the inspection of a lot of the product due to in a practical situation it is not necessary that under some circumstances all the observations/parameters are determined values". For more information about the NS and its applications, please refer to [18]. The analysis of neutrosophic numbers from rock measurements is studied by [20] and [21]. In recent times, [22] developed different sampling plans using NS. Reference [23] suggested using a determinate sample size for the sampling plans.

To the best of our knowledge, there is no work based on ASP-NSIM for the GD, BXIID and BSD. In the present article, we will develop an ASP for the GD, BXIID and BSD under the NISM. For the proposed ASP-NSIM the neutrosophic plan parameters will be determined for various degrees of indeterminacy. Extensive tables will be presented for practical use. The application of the proposed ASP-NSIM will be given with help of industrial data.

2. Some continuous distributions under a neutrosophic environment

2.1. Gamma distribution

Let $Y_{Ni} \in [Y_L, Y_U]; i = 1,2,...,n_N$ denote the neutrosophic random variable where Y_L refers to the lower value of the indeterminacy interval and Y_U presents the upper value of indeterminacy interval. The neutrosophic form of Y_{Ni} is $Y_{Ni} = Y_{Li} + Y_{Ui} I_{Y_N}; I_{Y_N} \epsilon [I_{Y_L}, I_{Y_U}]$, where Y_{Li} is the lower value of a random variable and $Y_{Ui} I_{Y_N}$ is the indeterminate (upper) value of the random variable and $I_{Y_N} \epsilon [I_{Y_L}, I_{Y_U}]$ is the measure of the degree of indeterminacy.

The neutrosophic cumulative distribution function (NCDF) of GD is given below:

$$F_N(y_N; b_N, \sigma_N) = \frac{1}{\Gamma b_N} \gamma\left(b_N, \frac{y_N}{\sigma_N}\right); y_N \geq 0, b_N \in [b_L, b_U], \sigma_N \in [\sigma_L, \sigma_U] \tag{1}$$

where $\gamma\left(b_N, \frac{y_N}{\sigma_N}\right)$ is the lower incomplete gamma function, $b_N \in [b_L, b_U]$ is the neutrosophic shape parameter and $\sigma_N \in [\sigma_L, \sigma_U]$ is the neutrosophic scale parameter. The neutrosophic form of the shape parameter is $b_N = b_L + b_U I_{b_N}; I_{b_N} \epsilon [I_{b_L}, I_{b_U}]$ and the neutrosophic form of the scale parameter is $\sigma_N = \sigma_L + \sigma_U I_{\sigma_N}; I_{\sigma_N} \epsilon [I_{\sigma_L}, I_{\sigma_U}]$, where the first value shows the determinate value of shape and scale parameters and the second value shows the indeterminate parts and $I_{b_N} \epsilon [I_{b_L}, I_{b_U}]$ and $I_{\sigma_N} \epsilon [I_{\sigma_L}, I_{\sigma_U}]$ are the measure of degrees of indeterminacy, respectively.

For the present study, it is assumed that the neutrosophic shape parameter b_N is known. When b_N is unknown, it can be estimated from the available data. The average lifetime of neutrosophic GD is $\mu_N = b_N \sigma_N$. A product failure probability before the time y_{N0} is denoted as $p_N = F(Y_N \leq y_{N0})$ and is defined as

$$p_N = \frac{1}{\Gamma b_N} \gamma\left(b_N, \frac{y_{N0}}{\sigma_N}\right). \tag{2}$$

Here, we express neutrosophic termination time y_{N0} is a product of constant a and neutrosophic mean life μ_{N0}, i.e., $y_{N0} = a\mu_{N0}$. Therefore, Eq (2) could be rewritten in terms of neutrosophic mean μ_N as follows:

$$P_N = \frac{1}{\Gamma b_N} \Upsilon\left(b_N, \frac{a\mu_{N0}}{\sigma_N}\right)$$

$$= \frac{1}{\Gamma b_N} \Upsilon\left(b_N, \frac{a\mu_{N0}}{\mu_N / b_N}\right)$$

$$= \frac{1}{\Gamma b_N} \Upsilon\left(b_N, ab_N / \tfrac{\mu_N}{\mu_{N0}}\right). \tag{3}$$

2.2. Burr-type XII distribution

In the area of quality and reliability, the Burr-type XII distribution is the more intriguing distribution. Additional examples of this distribution's use in reliability analysis and quality control may be found in [24]. Consider a lifetime of the product follows a neutrosophic BXIID with NCDF is given below:

$$F(y_N;k_N,\nu_N,\lambda_N)=1-\left[1+\left(\frac{y_N}{\lambda_N}\right)^{k_N}\right]^{-\nu_N} \quad ;y_N\geq 0,\lambda_N>0,k_N>0,\nu_N>0 \tag{4}$$

whereas, $\lambda_N\in[\lambda_L,\lambda_U]$ is the neutrosophic scale parameter, $k_N\in[k_L,k_U]$ and $\nu_N\in[\nu_L,\nu_U]$ are neutrosophic shape parameters of neutrosophic BXIID. The neutrosophic form of the shape parameter is $k_N=k_L+k_U I_{k_N};I_{k_N}\epsilon[I_{k_L},I_{k_U}]$ and the neutrosophic form of the scale parameter is $v_N=v_L+v_U I_{v_N};I_{v_N}\epsilon[I_{v_L},I_{v_U}]$, where the first value shows the determinate value of shape and scale parameters and the second value shows the indeterminate parts and $I_{k_N}\epsilon[I_{k_L},I_{k_U}]$ and $I_{v_N}\epsilon[I_{v_L},I_{v_U}]$ are the measure of degrees, respectively.

The median lifetime of the product using neutrosophic BXIID is given as $\mu_N=\lambda_N\left(2^{1/\nu_N}-1\right)^{1/k_N}$. A product failure probability before the time y_{N0} is defined as

$$p_N=1-\left[1+\left(\frac{y_{N0}}{\lambda_N}\right)^{k_N}\right]^{-\nu_N}. \tag{5}$$

It is convenient to determine the neutrosophic termination time y_{N0} as a multiple of the specified median life μ_{N0}, that is $y_{N0}=a\mu_{N0}$. Hence, the neutrosophic failure probability given in Eq (5) can be expressed as follows:

$$p_N=1-\left[1+\left(\frac{a\left(2^{1/\nu_N}-1\right)^{1/k_N}}{\mu_N/\mu_{N0}}\right)^{k_N}\right]^{-\nu_N}. \tag{6}$$

2.3. Birnbaum-Saunders distribution

The NCDF of the neutrosophic BSD is given by

$$F(y_N)=\Phi_N\left[\frac{1}{\gamma_N}\left\{\left(\frac{y_N}{\delta_N}\right)^{½}-\left(\frac{\delta_N}{y_N}\right)^{½}\right\}\right];y_N\geq 0,\delta_N>0,\gamma_N>0, \tag{7}$$

where $\gamma_N\in[\gamma_L,\gamma_U]$ is the neutrosophic shape parameter, $\delta_N\in[\delta_L,\delta_U]$ is the neutrosophic scale parameter of NBS distribution and $\Phi_N(.)$ is NCDF of standard normal distribution. The neutrosophic form of the shape parameter is $\gamma_N=\gamma_L+\gamma_U I_{\gamma_N};I_{\gamma_N}\epsilon[I_{\gamma_L},I_{\gamma_U}]$, where the first value shows the determinate value of shape and the second value shows the indeterminate parts and $I_{\gamma_N}\epsilon[I_{\gamma_L},I_{\gamma_U}]$.

The mean of neutrosophic BSD is given by $\mu_N = \delta_N\left(1+\frac{\gamma_N^2}{2}\right)$. A product failure probability before the time y_{N0} is denoted by p_N and it is given below:

$$p_N = \Phi_N\left[\frac{1}{\gamma_N}\left\{\left(\frac{y_{N0}}{\delta_N}\right)^{1/2} - \left(\frac{\delta_N}{y_{N0}}\right)^{1/2}\right\}\right]. \tag{8}$$

The neutrosophic termination time y_{N0} is expressed as $y_{N0} = a\mu_{N0}$. The neutrosophic failure probability given in Eq (8) could be expressed as

$$p_N = \Phi_N\left[\frac{1}{\gamma_N}\left\{\left(\frac{a_N\left(1+\frac{\gamma_N^2}{2}\right)}{\mu_N/\mu_{N0}}\right)^{1/2} - \left(\frac{\mu_N/\mu_{N0}}{a_N\left(1+\frac{\gamma_N^2}{2}\right)}\right)^{1/2}\right\}\right]. \tag{9}$$

3. Methodology of acceptance sampling plans under NSIM

The proposed ASP-NSIM is stated as follows

Step1. Select a random sample of size n from a yielded lot and conduct the life test for sample items for the specified time y_{N0}.

Step2. Count the number of items that failed before the termination time y_{N0} and denoted as d.

Step3. The lot could be accepted when d is less than or equal to c before termination time y_{N0} otherwise reject the lot.

We are interested to determine the plan parameters (n, c) of the proposed ASP-NSIM through neutrosophic nonlinear optimization for which given, producer's risk (α) and consumer's risk (β) are satisfied.

The plan parameters (n, c) will be determined using a two-point approach, as the producer always wishes that the probability of acceptance of the lot should be greater than 1-α at an acceptable reliability level (ARL), say p_{N1} and the consumer wishes that the probability of acceptance should be smaller than β at the lot tolerance reliability level (LTRL), say p_{N2}. The neutrosophic operating characteristic (NOC) function will be used to determine the plan parameters. The NOC of the proposed ASP-NSIM is given below:

$$P_{aN}(p_N) = \sum_{d=0}^{c}\binom{n}{d}p_N^d(1-p_N)^{n-d}. \tag{10}$$

The plan parameters of the proposed plan can be determined through the following neutrosophic non-linear optimization

$$\text{Minimize} \quad n. \tag{11}$$

Subject to

$$P_{aN}(p_{N1}) = \sum_{d=0}^{c}\binom{n}{d}p_{N1}^d(1-p_{N1})^{n-d} \geq 1-\alpha \tag{12}$$

$$P_{aN}\left(p_{N2}\right)=\sum_{d=0}^{c}\binom{n}{d}p_{N2}^{d}\left(1-p_{N2}\right)^{n-d}\leq\beta \qquad n\geq 2, c\geq 0. \tag{13}$$

To find the plan parameters, the neutrosophic non-linear optimization is implemented as follows:
Step 1. Fix the values of α, β, shape parameter of specified distribution, a, degree of indeterminacy.
Step 2. Determine the values of n and c such that the above-mentioned constraints are met.
Step 3. There are many combinations of n and c that satisfied the given constraints. Choose that combination of n and c where n is minimum.

To obtain the plan parameters of the proposed ASP-NSIM, the quality of the product is constituted in terms of the ratio of true mean/median life and specified mean/median life. In this study, the quality level is measured through the ratio of its mean lifetime to the true mean lifetime, $r_N=\mu_N/\mu_{N0}$. To find the plan parameters of the proposed plan, the values of α and β are fixed in advance. As mentioned earlier, the producer requires the lot acceptance probability should be larger than $1-\alpha$ at ARL, say p_{N1}. The producer is interested to have sampling plan parameters at various values $r_N=\mu_N/\mu_{N0}=2,4,6,8,10,12$, on the other hand, the consumer is interested to have the plan parameters at $\mu_N/\mu_{N0}=1$.

The plan parameters plan parameters (n, c) are determined using the above-mentioned neutrosophic non-linear optimization. The plan parameters (n, c) for the three distributions are reported in Tables 1–3. The plan parameters n and c are chosen such that n is minimum for a given degree of uncertainty. The plan parameters n and c for GD when α =0.05; β =0.25, 0.10, 0.05; $r_N=2,4,6,8,10,12$; a =0.9, 1.0, 1.1 and b_N=0.10 are given in Table 1. The plan parameters n and c for BXIID when α =0.05; β =0.25, 0.10, 0.05, 0.01; $r_N=1.2,1.5,1.6,1.8,2,4$; a =0.9, 1.0, 1.1; k_N=2.0, v_N=0.5 are given in Table 2. The plan parameters n and c for BSD when α =0.05; β =0.25, 0.10, 0.05, 0.01; $r_N=2,4,6,8,10,12$; a =0.9, 1.0, 1.1 and γ_N=3 are given in Table 3.

From Tables 1–3, we noticed the succeeding points:

(1) For fixed α and shape parameters for various distributions the values of n and c decreases as ratio r_N increases.

(2) For other same parameters, the values of n and c decrease when the β increases.

Table 1. Neutrosophic plan parameters for GD when b_N=0.10.

β	r_N	a=0.90								a=1.0								a=1.10							
		I_{b_N}=0		I_{b_N}=0.05		I_{b_N}=0.10		I_{b_N}=0.20		I_{b_N}=0		I_{b_N}=0.05		I_{b_N}=0.10		I_{b_N}=0.20		I_{b_N}=0		I_{b_N}=0.05		I_{b_N}=0.10		I_{b_N}=0.20	
		n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c
0.25	2	55	30	24	14	24	14	20	12	23	12	21	11	23	12	22	12	25	12	21	10	19	9	19	9
	4	22	13	11	7	11	7	9	6	12	7	10	6	10	6	10	6	11	6	11	6	9	5	9	5
	6	13	8	6	4	6	4	6	4	5	3	5	3	5	3	5	3	7	4	7	4	7	4	5	3
	8	11	7	6	4	6	4	6	4	5	3	5	3	5	3	5	3	5	3	5	3	5	3	5	3
	10	9	6	6	4	6	4	4	3	5	3	5	3	5	3	3	2	5	3	5	3	5	3	5	3
	12	9	6	4	3	4	3	4	3	3	2	3	2	3	2	3	2	5	3	5	3	3	2	3	2
0.10	2	45	25	41	23	39	22	35	20	38	19	36	18	37	19	33	17	36	16	38	17	33	15	33	15
	4	18	11	15	9	16	10	16	10	18	10	16	9	16	9	14	8	14	7	14	7	12	6	12	6
	6	11	7	11	7	11	7	11	7	12	7	10	6	10	6	10	6	11	6	11	6	9	5	9	5
	8	9	6	9	6	9	6	9	6	8	5	8	5	8	5	8	5	7	4	7	4	7	4	7	4
	10	9	6	6	4	6	4	6	4	8	5	5	3	5	3	5	3	7	4	7	4	7	4	5	3
	12	6	4	6	4	6	4	6	4	5	3	5	3	5	3	5	3	5	3	5	3	5	3	5	3
0.05	2	26	15	24	14	24	14	20	12	23	12	21	11	23	12	22	12	25	12	21	10	19	9	19	9
	4	11	7	11	7	11	7	9	6	12	7	10	6	10	6	10	6	11	6	11	6	9	5	9	5
	6	9	6	6	4	6	4	6	4	5	3	5	3	5	3	5	3	7	4	7	4	7	4	5	3
	8	6	4	6	4	6	4	6	4	5	3	5	3	5	3	5	3	5	3	5	3	5	3	5	3
	10	6	4	6	4	6	4	4	3	5	3	5	3	5	3	3	2	5	3	5	3	5	3	5	3
	12	3	2	4	3	4	3	4	3	3	2	3	2	3	2	3	2	5	3	5	3	3	2	3	2

Table 2. Neutrosophic plan parameters for BXIID when k_N=2.0, v_N=0.5 and $I_{k_N} = I_{v_N} = I_N$.

β	r_N	a=0.90								a=1. 0								a=1.10							
		I_N =0		I_N=0.05		I_N=0.10		I_N=0.20		I_N =0		I_N=0.05		I_N=0.10		I_N=0.20		I_N =0		I_N =0.05		I_N =0.10		I_N =0.20	
		n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c
0.25	1.2	90	33	76	27	69	24	55	18	91	37	78	31	69	27	53	20	93	41	80	35	67	29	57	24
	1.5	33	10	28	8	26	7	21	5	30	10	28	9	23	7	21	6	30	11	28	10	23	8	21	7
	1.6	20	5	18	4	18	4	15	3	18	5	18	5	16	4	13	3	19	6	17	5	14	4	12	3
	1.8	15	3	15	3	12	2	12	2	13	3	13	3	13	3	11	2	15	4	12	3	12	3	10	2
	2.0	12	2	12	2	12	2	9	1	11	2	11	2	11	2	8	1	12	3	10	2	10	2	7	1
	4.0	12	2	9	1	9	1	9	1	11	2	11	2	8	1	8	1	10	2	10	2	7	1	7	1
0.10	1.2	67	25	63	23	51	18	42	14	70	29	59	24	55	22	39	15	71	32	63	28	52	23	44	19
	1.5	23	7	21	6	21	6	16	4	26	9	21	7	19	6	17	5	24	9	22	8	20	7	15	5
	1.6	16	4	13	3	13	3	11	2	14	4	14	4	12	3	9	2	15	5	13	4	13	4	11	3
	1.8	10	2	10	2	10	2	8	1	12	3	9	2	9	2	9	2	11	3	11	3	8	2	8	2
	2.0	10	2	7	1	7	1	8	1	9	2	9	2	7	1	7	1	9	2	9	2	8	2	6	1
	4.0	7	1	7	1	7	1	8	1	9	2	7	1	7	1	7	1	9	2	6	1	6	1	6	1
0.05	1.2	41	16	34	13	32	12	28	10	42	18	35	15	31	13	27	11	45	21	39	18	35	16	28	13
	1.5	15	5	13	4	13	4	11	3	16	6	14	5	12	4	10	3	15	6	13	5	13	5	11	4
	1.6	10	3	8	2	8	2	8	2	10	3	7	2	7	2	7	2	9	3	9	3	9	3	7	2
	1.8	8	2	5	1	6	1	6	1	7	2	7	2	5	1	5	1	7	2	7	2	7	2	4	1
	2.0	5	1	5	1	6	1	6	1	5	1	5	1	5	1	5	1	7	2	5	1	5	1	4	1
	4.0	5	1	5	1	6	1	6	1	5	1	5	1	5	1	2	0	5	1	5	1	5	1	4	1

Table 3. Neutrosophic plan parameters for BSD when γ_N=3.

β	r_N	a=0.90								a=1.0								a=1.1							
		I_{γ_N}=0		I_{γ_N}=0.05		I_{γ_N}=0.10		I_{γ_N}=0.20		I_{γ_N}=0		I_{γ_N}=0.05		I_{γ_N}=0.10		I_{γ_N}=0.20		I_{γ_N}=0		I_{γ_N}=0.05		I_{γ_N}=0.10		I_{γ_N}=0.20	
		n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c	n	c
0.25	2	246	138	234	130	224	123	196	105	246	144	231	134	221	127	199	112	242	147	229	138	221	132	199	117
	4	88	46	80	41	77	39	72	35	86	47	80	43	77	41	72	37	83	47	82	46	79	44	70	38
	6	51	25	46	22	45	21	40	18	49	25	49	25	46	23	42	20	52	28	49	26	46	24	42	21
	8	35	16	35	16	32	14	29	12	35	17	34	16	30	14	27	12	37	19	32	16	33	16	30	14
	10	28	12	26	11	24	10	23	9	26	12	27	12	23	10	24	10	25	12	27	13	24	11	23	10
	12	22	9	20	8	21	8	19	7	23	10	21	9	21	9	18	7	22	10	20	9	20	9	17	7
0.10	2	189	107	182	102	173	96	155	84	188	111	176	103	169	98	153	87	186	114	176	107	171	103	155	92
	4	68	36	65	34	62	32	54	27	65	36	64	35	61	33	55	29	66	38	63	36	62	35	56	31
	6	38	19	37	18	37	18	32	15	40	21	35	18	37	19	33	16	40	22	37	20	34	18	31	16
	8	28	13	24	11	26	12	21	9	28	14	27	13	23	11	22	10	27	14	27	14	24	12	23	11
	10	22	10	21	9	19	8	17	7	21	10	22	10	20	9	18	8	22	11	21	10	19	9	18	8
	12	19	8	17	7	15	6	16	6	18	8	16	7	14	6	15	6	17	8	17	8	17	8	14	6
0.05	2	114	66	108	62	104	59	90	50	111	67	107	64	103	61	91	53	112	70	108	67	99	61	89	54
	4	40	22	37	20	39	21	31	16	40	23	37	21	34	19	31	17	37	22	39	23	36	21	33	19
	6	23	12	25	13	20	10	21	10	22	12	24	13	21	11	21	11	23	13	23	13	20	11	20	11
	8	16	8	18	9	15	7	13	6	17	9	18	9	14	7	14	7	18	10	15	8	15	8	14	7
	10	13	6	11	5	11	5	12	5	12	6	12	6	13	6	11	5	15	8	14	7	10	5	12	6
	12	9	4	9	4	11	5	10	4	12	6	11	5	11	5	7	3	10	5	10	5	10	5	9	4

4. Comparison study

In this section, we will study the efficiency of the proposed ASP-NSIM for the GD, BXIID, and BSD distributions with ASPs under classical statistics. The proposed ASP-NSIM will be more flexible and informative than the traditional sampling plans, see [21]. For a fair comparison, we will consider the same values of specified parameters for the proposed ASP-NSIM and the existing sampling plans under classical statistics. The values of n for the proposed ASP-NSIM and the existing sampling under classical statistics for GD are shown in Table 4. The values of n for the proposed ASP-NSIM and the existing sampling under classical statistics for BXIID are shown in Table 5. The values of n for the proposed ASP-NSIM and the existing sampling under classical statistics for BSD are shown in Table 6. A plan which provides smaller values of the sample size is known as an efficient sampling plan. From Tables 4–6, it can be noted that the proposed ASP-NSIM provides smaller values of n as compared to the sampling plans under classical statistics. Moreover, the existing sampling plan does not yield information regarding the measure of indeterminacy. Thus, we conclude that the proposed ASP-NSIM GD, BXIID and BSD are more efficient than the sampling plan under classical statistics and capable of handling the uncertain situation.

Table 4. Comparison of sample sizes in the proposed plan and the existing plan for GD when I_{b_N}=0.20.

β	Ratio	a=0.90		a=1.0	
		Proposed	Classical	Proposed	Classical
0.25	2	20	55	22	23
	4	9	22	10	12
	6	6	13	5	5
	8	6	11	5	5
	10	4	9	3	5
0.10	2	35	45	33	38
	4	16	18	14	18
	6	11	11	10	12
	8	9	9	8	8
	10	6	9	5	8
0.05	2	20	26	22	23
	4	9	11	10	12
	6	6	9	5	5
	8	6	6	5	5
	10	4	6	3	5

Table 5. Comparison of sample sizes in the proposed plan and the existing plan for BXIID when $I_N = 0.20$.

β	Ratio	a=0.90 Proposed Plan	a=0.90 Classical plan	a=1. 0 Proposed Plan	a=1. 0 Classical plan
0.25	1.2	55	90	53	91
	1.5	21	33	21	30
	1.6	15	20	13	18
	1.8	12	15	11	13
	2	9	12	8	11
0.10	1.2	42	67	39	70
	1.5	16	23	17	26
	1.6	11	16	9	14
	1.8	8	10	9	12
	2	8	10	7	9
0.05	1.2	28	41	27	42
	1.5	11	15	10	16
	1.6	8	10	7	10
	1.8	6	8	5	7
	2	6	5	5	5

Table 6. Comparison of sample sizes in the proposed plan and the existing plan for BSD when $I_{\gamma_N} = 0.20$.

β	Ratio	a=0.90 Proposed Plan	a=0.90 Classical plan	a=1.0 Proposed Plan	a=1.0 Classical plan
0.25	2	196	246	199	246
	4	72	88	72	86
	6	40	51	42	49
	8	29	35	27	35
	10	23	28	24	26
0.10	2	155	189	153	188
	4	54	68	55	65
	6	32	38	33	40
	8	21	28	22	28
	10	17	22	18	21
0.05	2	90	114	91	111
	4	31	40	31	40
	6	21	23	21	22
	8	13	16	14	17
	10	12	13	11	12

5. Exemplification of the proposed plan

In this section, the application of the proposed ASP-NSIM will be discussed. [25] discussed that the lifetime is imprecise in practice. [26] used the lifetime data in intervals. More information on imprecise lifetime data can be seen in [27]. Assume that a producer wants to supply the mean life assertion for his manufactured goods, and he asserts that the true mean life of the manufactured goods is μ_{N0}= 1000 hours. The quality supervisor judges after verification of the product and decide whether the producer's claim for the lifetime of the manufactured goods is valid or not. Assume that the test time of the experiment is y_{N0}= 1000 hours. Thus, we get the termination ratio for the experiment is a =1.0. Considering the consumer's risk is as β=0.25, the producer's risk α =0.05, the ratio of its mean lifetime to the true mean lifetime, $\mu_N / \mu_{N0} = 2$, and the shape parameter of the GD is taken as b_N=0.10. By following [25], we assume a degree of uncertainty that is I_{b_N}=0.20. Using this information, from Table 1, the values of the plan parameters of the proposed ASP-NSIM are $n = 22$ and $c = 12$. It shows that the required sample size for testing a lot of the product is 22. Suppose the quality supervisor has picked out 22 samples from a lot of a product and the test is conducted up to the specified time of 1000 hours. The submitted lot of the product is accepted if no more than 12 items failed before the time 1000 hours. The proposed ASP-NSIM can be applied to other distributions on the same lines.

6. Conclusions

In this article, we developed the ASP-NSIM for the GD, BXIID and BSD. The plan parameters for the proposed ASP-NSIM were determined using neutrosophic non-linear optimization. Extensive tables were presented for practical use at various degrees of uncertainty. From the comparative study, it can be concluded that the proposed ASP-NSIM is more efficient than the sampling plans under classical statistics. The proposed test using other statistical distributions can be extended as future research. The proposed plan using a cost model can be studied in future research.

Acknowledgments

The authors are deeply thankful to the editor and reviewers for their valuable suggestions to improve the quality and presentation of the paper.

Conflict of interest

The authors declare no conflict of interest.

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