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Impact of Neutrosophic Statistics on Acceptance Sampling Plans – A Review

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Abstract---In Statistical Quality Control, the judgement about lot acceptance or rejection rely on the product quality of the product is done with the help of "Acceptance Sampling" method. In Classical Statistics, the nature of the data is determinate. But, in recent scenario, due to the technology advancement and industrial needs the data may result in vagueness, imprecise, and indeterminate leads to complexity in decision making process. In that situation, the decision about the quality of product is impossible. A new logic in statistics called "Neutrosophic Statistics" plays a vital role in studying the indeterminacy in data. This paper gives a light view on the significance and relevance of Neutrosophic Statistics in Acceptance Sampling plans such as Attribute and Variable Sampling Plans.

Keywords---SQC, Acceptance Sampling plan, Fuzzy Set, Neutrosophic Statistics, Attribute Sampling Plan, Variable Sampling Plan.

Introduction and Review of Literature

In this modern era, every company in the market is attaining its maximum quality of the product leading to Zero defectives especially in the huge production industries. Statistical Quality Control method helps in improving firms' quality standard in the production system. It is hard to do 100% inspection for all the products as it consumes much time and money. Therefore one has to adopt inspecting the samples instead of inspecting the whole population in the production. Acceptance sampling is one such method in SQC where the decision about accepting or rejecting the lots is based on the samples. Classical Sampling Plans have been studied by many researchers and are thoroughly discussed by Schilling (1982).The results of the acceptance sampling plans are based on the dichotomous classification such as defective or non-defectives In sampling plans like Single Sampling Plan, Double Sampling Plan and Special sampling plans such as Chain Sampling Plan, Skip-plot Sampling plans, Quick Switching System, the fraction of defective items is considered as a Crisp value, but in practice the fraction of defective item value must be known exactly where these values are estimated or provided by experiment. . However, in practical situations it is very hard to classify the item as strictly conforming or non-conforming when the quality data related are expressed as highly good, good, bad, not so bad and so on leading to vagueness in the value of proportion defective in the process or lots. In this situation, vagueness present in the value of 'p' may be estimated with the help of fuzzy logic and set theory more powerful mathematical tool used for modelling uncertain systems having incomplete and imprecise data.

Initially, Fuzzy Design methodology was presented by Ohta and Ichihashi (1988) for single stage and two-point attribute sampling plans suitable for a situation having both randomness and impreciseness. Fuzzy set theory was evaluated and applied in various contexts under SQC by many authors including Ohta and Ichihashi, Kanagawa et.al, Raz and Wang and Noori et.al. Fuzzy Probability distributions such as Binomial and Poisson distribution are used as base line distributions to study the fuzzy quality characteristic of the sampling plans. Several numerical illustrations are elaborated to prove the sensitivity of the strength of the resulting sampling plans with Operating Characteristic(OC)curves showing a band with a high and low bounds. The fuzzy statistics is applied for examining the uncertainty in the data. Fuzzy logic is an procedure to computing rely on "degrees of truth" rather than usual "true or false"(1 or 0). The Neutrosophic Statistics is an extension of the fuzzy statistics which deals with uncertainty and indeterminacy interval having three functions for **membership(truthiness),non-membership(falsity) and`` indeterminacy.** The NS consist of determined and undetermined parts. The Neutrosophic statistics is nowadays used in advanced technologies like Data Mining techniques for the data selection and the data preparation process in Knowledge Discovery Process(KDD).

Muhammad Aslam(2019) proposed a new attribute sampling plan using neutrosophic statistical interval method. Muhammad Aslam (2019) also proposed a variable acceptance sampling plan under neutrosophic statistical interval method. Somen Debnath (2021)studied the Neutrosophication of statistical data in a study to assess the knowledge, Attitude and Symptoms on Reproductive Tract Infection among women. Gurkan Isik lhsan Kaya (2020) studied the effects of Neutrosophic Binomial Distribution on Double Acceptance Sampling Plans.

Neutrosophic Statistics:

Neutrosophic Statistics is defined as a group of data, such that the data or a part of the data are vague in some degree, and to methods used to evaluate the data. By using the Classical Statistics, all data are evaluated. This is called the distinction between Neutrosophic Statistics and the Classical Statistics. In bags of cases, when indeterminacy is zero, the concept of Neutrosophic Statistics accompanies with the concept of Classical Statistics. The neutrosophic measure which is used for measuring the indeterminate data is used in those cases. The method of Neutrosophic Statistics will allow us to determine and classify the Neutrosophic data in order to identify the underlying patterns. Also emphasize that the Neutrosophic probability, that indeterminacy is different from randomness. While classical statistics is denoting to randomness only, Neutrosophic Statistics is referring to both randomness and particularly indeterminacy. In most of the classical statistics equations and formulas, one simply replaces several numbers by sets. And consequently, instead of operations with numbers, one uses operations with sets. One normally replaces the parameters that are indeterminate (imprecise, unsure, and even completely unknown). That's why we made the convention that any number a that is replaced by a set be noted '**aN**', meaning neutrosophic '**a**', or imprecise, indeterminate '**a**'.

A neutrosophic statistic is a random variable and as such has a neutrosophic probability distribution. The long-run behaviour of a neutrosophic statistic's values is described when one computes this statistic for many different samples, each of the same size.

Neutrosophic Data contains some indeterminacy. Like classical statistics, the Neutrosophic Statistics is classified as follows:

1. **Discrete Neutrosophic data**
The values are hidden points here. In case: $6 + i1$, where $i1 \in [0, 1]$, 7, $26 + i2$, where $i2 \in [3, 5]$
2. **Continuous Neutrosophic data**
The values in this case form one or more intervals, for example: [0, 0.8] or [0.1, 1.0] (i.e. not sure which one).
3. **Quantitative (numerical) Neutrosophic data**; a number for example in the interval [3, 5] (we do not know exactly), 47, 56, 64 or 68 (we do not know exactly);

4. **Qualitative (categorical) Neutrosophic data**; for example: blue or red (we don't know exactly), white, black or green or yellow (not knowing exactly).

5. **Univariate Neutrosophic data**, i.e. neutrosophic data that composed of observations on a neutrosophic single attribute;

6. **Multivariable Neutrosophic data**, i.e. neutrosophic data that composed of samples upon two or more attributes.

Definition of single-valued Neutrosophic Set (NS)

Let U be a universe of discourse, and a set ANS ⊆ U. Then ANS = { | x ∊ U}, where TA(x), IA(x), FA(x) : U → [0, 1] represents the degree of truth-membership, degree of indeterminacy-membership, and degree of false non membership respectively, with $0 \leq TA(x) + IA(x) + FA(x) \leq 3$.

The neutrosophic components TA(x), IA(x), FA(x) are not dependent with respect to each other.

Neutrosophic Logic

Neutrosophic logic, designed by Florentin Smarandache in the year 1995 and is an addition or advancement of the fuzzy logic, intuitionistic logic, paraconsistent logic, and the three-valued logics that utilize an imprecise value. In neutrosophic logic, entire logical variable (x) is defined by the ordered triple denoted by x= (t, i, f) , (t) be the degree of truthful, (f) be the degree of not truthful and (i) be the level of undetermined. The Indeterminate (I) classified into Contradiction and Uncertainty and get an addition of Belnap's four-valued logic. Additionally, (I) into contradiction, not certain, and not known and getting the five valued logic. In a general refined neutrosophic logic, (T) can be split into subcomponents (T1, T2, ..., Tp) and (I) into(I1, I2, ..., Ir) and(F) into (F1, F2,...,Fs) where [$p + r + s = n \geq 1$]. Even more: T, I, and/or F (or any of their subcomponents Tj, Ik , and/or Fl) can be countable or uncountable infinite sets. As example: a statement can be between [0.4, 0.6] true, {0.1} or between (0.15, 0.25) indeterminate, and either 0.4 or 0.6 false

Acceptance Sampling and Neutrosophic Statistics

ASP is a specific plan stating the sampling rules and acceptance criteria is adopted to decide on accepting or rejecting a lot by inspecting a small set of items. ASPs can be classified into two groups.

- Variable ASPs focus on quality characteristics modeled with a statistical distribution.
- Attribute ASPs are focusing on the defectiveness of the inspected items.

a) Attribute Sampling Plan:

In this section, a new attribute sampling plan with the Neutrosophic statistical interval method is studied. Let X be the quality of interest and the terms x^L and x^U are the minimum and the maximum value of the data. Let us consider a= [x^L , x^U] , the required range for the sample data. The neutrosophic interval probability (NIP) based on x^L and x^U is p = ([x^L , x^U] , (p_{ND}, p_I, p_D)), p_{ND} ,p_I, p_D be the non-defective probability belong to determine part, indeterminacy probability belong to an intermediate defective part and falsity-probability belong to failure range of interval p≤ [x^L, x^U], (p_{ND}, p_I, p_D), respectively. The total probability for the three cases satisfies $p_{ND}+p_I+p_D \geq 1$.

The proposed sampling plan using Neutrosophic statistics is stated as follows

Step-1 : Choose a random sample of size n from a lot of the product and determine x^L and x^U .

Step-2: Calculate mean $\bar{x} = \sum_{i=1}^{n} x_i/n$ and standard deviation SD=$\sqrt{\sum_{i=1}^{n} (x_i \ - x)2/n}$-1

Step -3: Fix a = [x^L , x^U] and determine the probability of non-defective items

$p_{ND} = n_{ND}/n$, the indeterminate probability $p_I=n_I/n$ and the probability of an defective item $p_D=n_D/n$, where n_{ND},n1 and n_D is the number of values in the non-failure interval [$\bar{x}$ - S, $\bar{x}$ + S], indeterminate/uncertain interval [$\bar{x}$ - 3S, $\bar{x}$ + 3S] and incredible/failure interval [x^L, $\bar{x}$ - 3S]; [$\bar{x}$ +3S, x^U]

Step-4: Accept a lot of the product if a number of defectives are smaller than the allowed number of defectives c, otherwise, reject it.

The proposed sampling plan composed of two parameters which are the acceptance number 'c' and sample size 'n'. The Neutrosophic Operating Characteristics (NOC) function of the proposed plan using Neutrosophic Binomial Distribution (NBD) is given as follows

$$L(p) = P_R + P_I + P_A; \qquad p_{ND} + p_I + p_D \geq 1$$

Where P_R, P_I and P_A represent the lot rejection, intermediate and acceptance probabilities , respectively,

$$P_R = \frac{n!}{c!} P(R)^c \sum_{k=0}^{c} \frac{P(I)^K P(F)^{n-c-k}}{k!(n-c-k)!},$$

$$P_I = \sum_{z=c+1}^{n} \frac{n!}{z!} P(I)^z \left[\sum_{k=0}^{c-z} \frac{P(R)^K P(F)^{n-z-k}}{k!(n-z-k)!}\right] \text{ and}$$

$$P_A = \sum_{y=c+1}^{n} T_y = \sum_{y=c+1}^{n} \frac{n!}{y!} P(I)^y \left[\sum_{k=0}^{n-y} \frac{P(R)^K P(F)^{n-y-k}}{k!(n-y-k)!}\right]$$

Where $P(R) = p_{ND}$, $P(I) = p_I$ and $P(A) = p_D$;

$p_{ND} + p_I + p_D \geq 1$.

The lot acceptance probability is the set of the lot rejection probability, indeterminate probability and lot acceptance probability is given by

$$L(P) = \{P_R, P_I, P_A\}.$$

This proposed plan is applied in practical by taking the data about color STN displays from the company. Each of the pixels is divided into R, G and B sub-pixels. In this study, membrane thickness of pixel is the quality characteristic. In total of 55 data collected, 37 items belong to undamaged group, 16 items belong to unpredictable group and 2 items belong to defective group. The procedure of the new attribute sampling plan is implemented and found the chance of lot acceptance is 0% and the indeterminacy of the lot is 100%.

b) Variable Sampling Plan:

In this section, a variable acceptance sampling plan using the Neutrosophic statistical interval method is studied. The operational procedure of the proposed plan is as follows:

Step-1: Select a random sample of size $n_L \leq n_N \leq n_U$; $n_N \in \{n_L, n_U\}$ from the lot of product. Compute the statistic $\vartheta = \frac{U-\bar{X}_N}{s_N}$, where $\bar{X}_N \in \{\bar{X}_L, \bar{X}_U\}$;$\bar{X}_L = \sum_{i=1}^{n} x_i^L / n_L$,

$\bar{X}_U = \sum_{i=1}^{n} x_i^U / n_U$, and $s_N \in \{s_L, s_U\}$, where $s_L = \sqrt{\sum_{i=1}^{n}(x_i^L - \bar{x}_L)^2 / n_L}$

And $s_U = \sqrt{\sum_{i=1}^{n}(x_i^U - \bar{x}_U)^2 / n_U}$, i= 1,2,3,…,n

Step-2: Accept the lot of product of $\vartheta \geq k_{Na}$; $k_N \in \{k_{aL}, k_{aU}\}$ where k_{Na} is the neutrosophic acceptance number.

The proposed sampling plan is applicable to test the hypothesis that the product is good versus the product is bad, based on information from the sample. If $\vartheta \geq k_N$, the null hypothesis is accepted otherwise, the rejected. The proposed plan has two parameters, $n_N \in \{n_L, n_U\}$ and $k_{Na} \in \{k_{aL}, k_{aU}\}$. The Neutrosophic Normal distribution, with mean $\mu_N \in \{\mu_L, \mu_U\}$

and standard deviation $\sigma_N \in \{\sigma_L, \sigma_U\}$, is defined by

$$X_N \sim N_N(\mu_N, \sigma_N) = \frac{1}{\sigma_{N\sqrt{2\pi}}} \exp\left(-\frac{(x-\mu_N)^2}{2\sigma_N^2}\right)$$

Where $N_N(\mu_N, \sigma_N)$ denotes the Neutrosophic Normal distribution.The Neutrosophic Operating Characteristic function is given by,

$$L_N(p) = \varphi\left((Z_{Npu} - K_{Na})\sqrt{\frac{n_N}{1+(\frac{k_{Na}^2}{2})}}\right) \; ; K_{Na} \in \{K_{aL}, K_{aU}\} \; ; n_N \in \{n_L, n\}$$

This proposed plan has the limitation that it can be applicable only the data follows the Neutrosophic Normal distribution.

Conclusion:

In this paper, a new attribute neutrosophic fuzzy sampling plan with the neutrosophic statistics is reviewed which is more flexible than the existing sampling plans using the classical statistics. This proposed plan can only be used in case of discrete data and recommended that this sampling plan should applicable for inspecting the lot of products under the uncertainty environment. And also a new variable neutrosophic variable sampling plan using the Neutrosophic statistics is reviewed. This proposed plan is considered as adequate, flexible, effective and reasonable method in the uncertainty environment and this plan can only be adopted when the data follows the Neutrosophic Normal distribution. The proposed plan, using some other sampling scheme and systems, will be considered for future research for various parameters of the plans and systems.

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