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An Investigative Study on Quick Switching System using Fuzzy and Neutrosophic Poisson Distribution

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Abstract: Stephens and Larson (1967) stated the sampling system as allotted grouping of two or three sampling plans and the rules for switching between the plans for sentencing the lots of manufactured products. Quick Switching System (QSS) by Romboski (1969) is a sampling system with reference to Single Sampling Plan (SSP) involves Normal and Tightened plans by adopting a switching rule. QSS provides quality protection and reduction in cost of inspection. The idea of Fuzzy Logic is adopted in system to handle the situations of fraction non-confirming or uncertainty or vagueness present in the parameters. The sampling plans based on Fuzzy Set Theory in literature is used for defuzzification of fuzzy numbers to the interval sets, able to solve problem with certain values for upper and lower limit of intervals. As one of expansion of Fuzzy Sets in this era, a new philosophy is stimulated as a substantial new theoretical development is Neutrosophy Sets (NSs) and used for rise in sensitiveness that makes flexibility in the plans and systems that can be applied in the manufacturing industries. This paper enhances the determination of QSS using Neutrosophic Poisson distribution and compared with the existing Fuzzy Poisson distribution through Operating Characteristic (OC) curves.

Keywords: QSS, OC, SSP, Fuzzy Set, Neutrosophic Set, Poisson distribution.

1. Introduction

Quick Switching System detailed in this article consists of two sampling plans - Normal and Tightened plans with a switching instantaneously between the two plans. Quick Switching System starts with Normal Plan for the good quality period of smaller sample size to reduce the cost of inspection and tightened plans is designed for a high level protection either by tightening the sample size or the acceptance number. Accordingly, QSS is branded into two means

i) Acceptance Number Tightening - **(n;** c_N , c_T**)**
ii) Sample Size Tightening - (n, k; c_0), k >1

Classical Acceptance sampling plans use certain mass quality metrics and quality specifications that may not be certain in some real-world applications due to including uncertainties in any form. Fuzzy Set (FS) theory defined by Zadeh (1965) and extended as an intuitionistic Fuzzy Set (IFS) by Attanasov (1986) applied in all the fields of domain especially in medical and manufacturing industries interms of cluster analysis, using similarity and distance measure approaches. However, FSs are not considered to be suitable to deal with indeterminate and inconsistent information which frequently exists in reality. As an advancement Samarandache (1996) introduced Neutroshophic

Logic and Neutroshopic Set (NS) theory which is the generalization of intuitionistic Fuzzy Set. NS is used to tackle uncertainty using the truth, indeterminacy and falsity membership grades which are considered as independent. The paper focused on comparing Quick Switching Systems under Fuzzy Logic and Neutrosophic Logic through Operating Characteristic (OC) curves of various acceptance numbers and fixed sample size in order to provide high level of protection.

2. Literature Review

QSS were originally proposed by Dodge (1967) and later investigated by Romboski (1969) and Govindaraju (1991). Based on Romboski's study, Devaraj Arumainayagam (1991) has studied Quick Switching System with reference to sampling plans like Single Sampling Plan, Double Sampling Plan for both acceptance number tightening and sample size tightening, Taylor (1992) designed QSS with Reduced and Tightened Sampling plans and evaluated with MILSTD 10E. Uma and Nandhinidevi (2018) studied the determination of QSS using both fuzzy Binomial distribution and fuzzy Poisson distribution with OC curves of various sample size and fixed acceptance number. Nandhinidevi and Uma (2018) analysed fuzzy logic importance on QSS by attributes using the Poisson distribution. Uma, Nandhinidevi and Manjula (2020) studied the impact of fuzzy logic on Quick Switching Single Double sampling plan with the acceptance number tightening criteria.

Aslam (2019) initiated to study both attribute and variable acceptance sampling plans and proposed a new attribute sampling plan by employing the Neutrosophic Interval method and the Neutrosophic Binomial distribution is utilized for computing the lot acceptance, rejection and indeterminate probabilities at various specified sample size and acceptance number parameters. Uma and Nandhitha (2022) reviewed the significance of Neutrosophic set on Acceptance Sampling plans (attribute and variable). Uma and Nandhitha (2023) have analyzed and evaluated the Quick Switching System using Neutrosophic Poisson Distribution with respective OC curve and necessary tables are constructed.

3. Quick Switching System

Dodge (1967) proposed a new sampling system consisting of pairs of normal and tightened plans. The application of the system is as follows

- Adopt a pair of sampling plans, a normal plan (N) and tightened plan (T), the plan T to be tightened OC curve wise than plan N.
- Use plan N for the first lot (optional): can start with plan T; the OC curve properties are the same; but first lot protection is greater if plan T is used.
- For each lot inspected; if the lot is accepted, use plan N for the next lot and if the lot is rejected, use plan T for the next lot'.

Due to instantaneous switching between normal and tightened plan, this system is referred as "Quick Switching System ". The OC function of QSS-1 is derived by Romboski (1969) as

$$P_a\,(p) = \frac{P_T}{(1-P_N+P_T)} \tag{1}$$

Conditions for Application

- The production is steady so that results on current and preceding lots are broadly indicative of a continuing process and submitted lots are expected to be essentially of the same quality.
- Lots are submitted substantially in the order of production.

- Inspection is by attributes with quality defined as fraction nonconforming.

Operating Procedure for QSS (n; c_N , c_T)

Step 1: From a lot, take a random sample of size 'n' at the normal level. Count the number of defectives 'd'

i) If d < c_N , accept the lot and repeat step 1

ii) If d > c_N, reject the lot and go to step 2.

Step 2: From the next lot, take a random sample of size n at the tightened level. Count the number of defectives 'd.

i) If d < c_T, accept the lot and use step 1

ii) If d > c_T, reject the lot and repeat step 2

Where c_N , c_T are the acceptance numbers in the Normal and Tightened Sampling plans

4. Preliminaries and Definitions

4.1 Fuzzy Set

Parameter 'p' (probability of a success in each experiment) of the crisp binomial distribution is known exactly, but sometimes we are not able to obtain exact some uncertainty in the value 'p' and is to be estimated from a random sample or from expert opinion. The crisp Poisson distribution has one parameter, which we also assume is not known exactly.

Definition 1: The fuzzy subset $\tilde{N}$ of real line IR, with the membership function μ_N: IR→ $[0,1]$ is a fuzzy number if and only if (a) $\tilde{N}$ is normal (b) $\tilde{N}$ is fuzzy convex (c)μ_N is upper semi continuous (d) supp ($\tilde{N}$) is bounded.

Definition 2: A triangular fuzzy number $\tilde{N}$ is fuzzy number that membership function defined by three numbers $a_1 < a_2 < a_3$where the base of the triangle is the interval $[a_1, a_3]$ and vertex is at $x = a_2$.

Definition 3: The α - cut of a fuzzy number $\tilde{N}$ is a non-fuzzy set defined as $N[\alpha] = \{x \in IR;\ \mu_N(x) \geq \alpha\}$. Hence $N[\alpha] = [N_\alpha^L, N_\alpha^U]$ where $N_\alpha^L = inf\{x \in IR;\ \mu_N(x) \geq \alpha\}$

$$N_\alpha^U = sup\{x \in IR;\ \mu_N(x) \geq \alpha\}$$

Definition 4: Due to the uncertainty in the l_i's values we substitute $\tilde{l_i}$, a fuzzy number, for each l_i and assume that 0<$\tilde{l_i} < 1$ all i. Then X together with the $\tilde{l_i}$ value is a discrete fuzzy probability distribution. We write $\tilde{p}$ for fuzzy P and we have $\tilde{P}(\{x_i\})$ = $\tilde{l_i}$

Let A = $\{x_1, x_2, \dots x_l\}$ be subset of X. Then define:

$$\tilde{P}(A)[a] = \frac{\sum_{i=1}^{l} l_i}{s} \tag{2}$$

For $0 < \alpha < 1$, where stands for the statement "$l_i \in \tilde{k_i}[a], 1 < i < n, \sum_{i=1}^{l} l_i = 1$". This is our fuzzy arithmetic.

Definition 5: Let x be a random variable having the Poisson mass function. If P(x) stands for the probability that X=x, then

$P(x) = \frac{e^{-\lambda}\lambda^{x}}{x!}$ (3)

For x=0,1,2, and **λ** >0.

Now substitute fuzzy number $\tilde{\lambda}$>0 for **λ** to produce the fuzzy Poisson probability mass function. Let P(x) to be the fuzzy probability that X=x. Then α −cut of this fuzzy number as

$\widetilde{P}$ (x)[a] =$\left\{\frac{e^{-\lambda}\lambda^{x}}{x!} \middle| \lambda \in \lambda[\alpha]\right\}$ (4)

For all $\alpha \in [0,1]$. Let X be a random variable having the fuzzy binomial distribution and $\tilde{P}$ in the definition 4 are small. That is all are p∈ $\tilde{p}$ sufficiently small. Then $\tilde{P}$[a,b] [α] using the fuzzy poisson approximation.

Then

$\widetilde{P}$ [a,b] [a] = $x = \sum_{x=a}^{b} \frac{e^{-\lambda}\lambda^{x}}{x!}$ (5)

4.2 Neutrosophic Sets

Type-1 fuzzy sets or classical fuzzy sets consider only the membership and only have $\mu(x) \in [0,1]$ in the membership function. Since non-membership is states as 1- $\mu(x)$, type-1 fuzzy sets are only usable in complete information case. Intuitionistic sets (ISs) have functions for both membership and non-membership. While $\mu(x) \in [0,1]$ is membership function and $\vartheta(x) \in [0,1]$ is non-membership function, the condition $0 \leq \mu(x) + \vartheta(x) \leq 1$ is satisfied (Atanassov, 2003). If the sum of membership and non-membership values is less than 1, it means incomplete information (Wang et al.,2005). NSs are the generalized form of ISs. It handles membership (truthiness), non-memership (falsity) and indeterminacy cases independent from each other. This independency makes possible to use inconsistent data in modelling (Smarandache, 2005). NSs can be formulated as in Eq. (5) (Wang et al., 2010):

(t, i, f) = (truthiness, indeterminacy, falsity)

$0 \leq t + i + f \leq 3, \quad t, i, f \in [0,1]$ (6)

Truthiness, indetermin6cy and falsity values can be real numbers or interval-valued numbers. If these are interval-valued numbers, the set is named as interval Neutrosophic set and it is represented with three intervals. Summation of the biggest upper limits of these three intervals must between o and 3 (Wang et al., 2005). Representation of interval NSs is shown in Eq. (6):

$$x = \langle [Tx_L Tx_U], [Fx_L Fx_U], [Ix_L Ix_U] \rangle$$

$$T_x, I_x, F_x \in [0,1]$$

$0 \leq sup\ T_x + sup\ F_x + sup\ I_x \leq 3$ (7)

5. Construction of QSS using Fuzzy Poisson Distribution

If the size of sample be large and 'p' is small then the random variable 'd' has a Poisson approximation distribution with $\lambda = np$.So, the probability for the number of defective items to be exactly equal to 'd' is

P(d) = $\frac{e^{-np}np^{d}}{d!}$ and the probability for acceptance of the lot (P_a) is:

$$P_a = P(d \leq c)$$

$$= \sum_{d=0}^{c} \frac{e^{-np}np^{d}}{d!}$$

Suppose that we want to inspect a lot with the large size of 'N', such that the proportion of damaged items is not known precisely. So we represent this parameter with a fuzzy number $\tilde{p}$ as follows:

$$\tilde{p} = (a_1, a_2, a_3), p \in \tilde{p}[1], q \in \tilde{q}[1],$$

$$P + q = 1.$$

A single sampling plan with a fuzzy parameter if defined by the sample size 'n', and acceptance number 'c', and if the number of observation defective product is less than or equal to 'c', the lot will be acceptance. If 'N' is a large number, then the number of defective items in this sample (d) has a fuzzy Poisson distribution with parameter $\tilde{\lambda} = \widetilde{np}$. So the fuzzy probability for the number of defective items in a sample size that is exactly equal to 'd' is

$$\tilde{P}(d - defective)[a] = [P^L[a], P^U[a]]$$

$$P^L[a] = \min \left\{ \frac{e^{-np} np^d}{d!} \middle| \lambda \in \widetilde{np}[a] \right\}$$

$$P^U[a] = \max \left\{ \frac{e^{-np} np^d}{d!} \middle| \lambda \in \widetilde{np}[a] \right\}$$

and fuzzy acceptance probability is as follows:

$$\tilde{P}_a = \left\{ \sum_{d=0}^{c} \frac{e^{-np} np^d}{d!} \middle| \lambda \in \tilde{\lambda}[a] \right\} = [P^L[a], P^U[a]] \quad (8)$$

$$P^L[a] = min \left\{ \sum_{d=0}^{c} \frac{e^{-np} np^d}{d!} \middle| \lambda \in \tilde{\lambda}[a] \right\} \quad (9)$$

$$P^U[a] = max \left\{ \sum_{d=0}^{c} \frac{e^{-np} np^d}{d!} \middle| \lambda \in \tilde{\lambda}[a] \right\} \quad (10)$$

5.1 OC Band with Fuzzy Parameter

Operating characteristic curve is one of the important criteria in the sampling plan. By this curve, one could be determined the probability of acceptance or rejection of a lot having some specific defective items. The OC curve represents the performance of the acceptance sampling plans by plotting the probability of acceptance a lot versus its production quality, which is expressed by the proportion of nonconforming items in the lot. OC curve aids in selection of plans that are effective in reducing risk and indicates discriminating power of the plan.

The fuzzy probability of acceptance a lot in terms of fuzzy fraction of defective items would be as a band with upper and lower bounds. The uncertainty degree of a proportion parameter is one of the factors that bandwidth depends on that. The less uncertainty value results in less bandwidth, and if proportion parameter gets a crisp value., lower and upper bounds will become equal, which that OC curve is in classic state. Knowing the uncertainty degree of proportion parameter and variation of its position on horizontal axis, we have different fuzzy number ($\tilde{P}$) and hence we will have different proportion (p) which the OC bands are plotted in terms of it.

6. Construction of QSS using Neutrosophic Poisson distribution

In this section, an attribute sampling plan having certain plan parameters and neutrosophic defection status is offered based on Poisson distribution. Difference from classical acceptance sampling plans is considering the indeterminacy case as a defection status.

Formulation of single sampling plan based on Poisson distribution has two frequency values as defect frequency λ_F= n.P(F) and indeterminacy frequency λ_I= n. P(I). If the neutrosophic set A has inconsistency, the probability values should be normalized by dividing each of them with total probability to make

t + I + f = 1. This normalization is offered by Smarandache [14].

The acceptance probability of lot (P_a) is calculated as shown in Eq (11).

For normal single sampling plan, the Neutrosophic probability of acceptance is represented as 'P_{aN}', the rejection probability is represented as 'P_{rN}' and the indeterminacy probability is represented as 'P_{iN}'.

$$P_{aN} = \sum_{d=0}^{C_N} \frac{\lambda_F^d}{d!} \left[\sum_{i=o}^{min(I,n-d)} \frac{\lambda_I^i}{i!} e^{-(\lambda_I+\lambda_F)}\right] \quad (11)$$

$$P_{rN} = \sum_{d=c_{N+}1}^{C_N} \frac{\lambda_F^d}{d!} \left[\sum_{i=o}^{n-d} \frac{\lambda_I^i}{i!} e^{-(\lambda_I+\lambda_F)}\right] \quad (12)$$

$$P_{iN} = \sum_{i=I+1}^{n} \frac{\lambda_I^i}{i!} \left[\sum_{d=o}^{min(N,n-i)} \frac{\lambda_F^d}{d!} e^{-(\lambda_I+\lambda_F)}\right] \quad (13)$$

$\boldsymbol{P_{aN} + P_{rN} + P_{iN} = 1}$ **…**………… total probability

Similarly, for tightened single sampling plan, the Neutrosophic probability of acceptance is represented as 'P_{aT}', the rejection probability is represented as 'P_{rT}' and the indeterminacy probability is represented as 'P_{iT}'

$$P_{aT} = \sum_{d=0}^{C_T} \frac{\lambda_F^d}{d!} \left[\sum_{i=o}^{min(I,n-d)} \frac{\lambda_I^i}{i!} e^{-(\lambda_I+\lambda_F)}\right] \quad (14)$$

$$P_{rT} = \sum_{d=c_{N+}1}^{C_N} \frac{\lambda_F^d}{d!} \left[\sum_{i=o}^{n-d} \frac{\lambda_I^i}{i!} e^{-(\lambda_I+\lambda_F)}\right] \quad (15)$$

$$P_{iT} = \sum_{i=I+1}^{n} \frac{\lambda_I^i}{i!} \left[\sum_{d=o}^{min(T,n-i)} \frac{\lambda_F^d}{d!} e^{-(\lambda_I+\lambda_F)}\right] \quad (16)$$

$\boldsymbol{P_{aT} + P_{rT} + P_{iT} = 1}$ **…………**.. total probability

Therefore, the probability of acceptance 'P_a'is calculated using,

$$P_a(p) = \frac{P_{(a)T}}{1-P_{(a)N}+P_{(a)T}} \quad (17)$$

Where, $P_{(a)N}$ is the proportion of lots expected to be accepted using Neutrosophic Normal SSP.$P_{(a)T}$ is the proportion of lots accepted to be accepted using Neutrosophic Tightened SSP.

Illustration 1:

To illustrate the application capability of the proposed plans in real world, an example scenario can be such that:

A company purchases tyres from a supplier to use it as an accessory of its products. Most of the defects are considered as slight defect but some of the defects are not acceptable. The operator may become undecided in some cases, the major customers choose and inspect 40 items of the available product to buy them. If the number of non-conforming items in this sample equals three or two, the customer will buy all the products.

If the number of non-conforming increases, the customer will not buy them, Because of the proportion of defective products has explained linguistically, a fuzzy number P^= (0,0.005,0.01) is considered. Therefore, the probability purchasing would be described in the following:

In the normal plan **n=40, C_N=3,** $\widehat{P}$= (0,0.005,0.01) and in the tightened plan **n=40, C_T=2,** $\widehat{P}$= (0,0.005,0.01) of acceptance of the system. Hence, Normal single sampling plan the

P_N = (1,0.9964,1) and tightened single sampling plan the P_T = [0.9920, 1] Then, the probability of acceptance of the QSSFP (40;3,2) is $\widehat{P}_a$ [0] = [0.9916, 1], that is it is executed that for every 100 lots in a manufacturing process, 99 to 100 lots will be accepted.

Table 1. Probability of acceptance for QSSFP (n=40, CN=3, CT=2)

Li	P	QSS_FP
0	[0,0.01]	[1,0.9916]
0.01	[0.01,0.02]	[0.9916,0.9446]
0.02	[0.02,0.03]	0.9446,0.8461]
0.03	[0.03,0.04]	[0.8461,0.7078]
0.04	[0.04,0.05]	[0.7078,0.5566]
0.05	[0.05,0.06]	0.5566,0.4175]
0.06	[0.06,0.07]	[0.4175,0.3034]
0.07	[0.07,0.08]	[0.3034,0.2163]
0.08	[0.08,0.09]	[0.2163,0.1527]
0.09	[0.09,0.10]	[0.1527,0.1073]
0.1	[0.1,0.11]	[0.1073,0.0752]

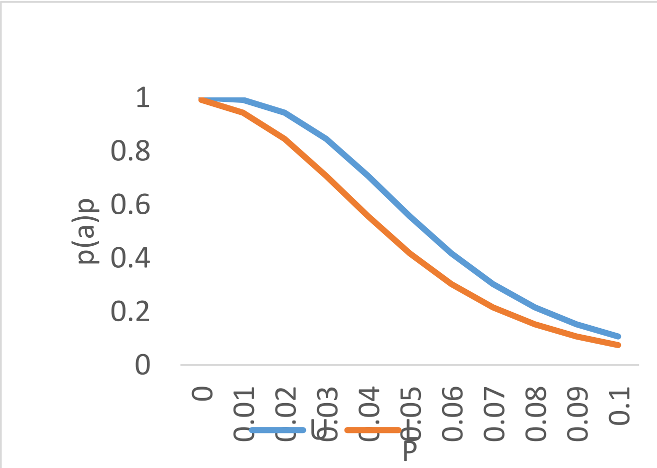

Figure 1. OC band for QSS using Fuzzy Poisson.

From the OC band, the systems are well defined since if the fraction of defective items is crisp, reduce to classical plans. The uncertainty degree of a proportion parameter is one of the factors that bandwidth depends on the band of the curve. The less uncertainty value results in less bandwidth, and greater uncertainty values results in wider bandwidth. From this it is suggested that, can adopt this system to predict the uncertainty level. Based on this system, one can achieve better outcome with minimum sampling cost and time.

Illustration 2:

To illustrate the application capability of the proposed plans in real world, an example scenario can be such that:

A company purchases tires from a supplier to use it as an accessory of its products. The tires can have several defects having different importance levels such as cap ply defects and skim stock defects. Some of the items can have multiple defects at the same time. Most of these defects are considered as slight defect but some are not acceptable. The operator may become undecided in some cases the items have multiple defects with multiple levels.

The agreement is made between the company and supplier depending on a quality level. The supplier declares an item non defectiveness probability, an item indeterminacy probability, and an item defectiveness probability for the incoming lots. The company controls the quality of the product by applying Quick Switching System based on Neutrosophic Poisson Distribution.

Step 1. From the lot, take a random sample of size 'n (40)' at the normal level and count the number of defective items that is 'd' and indeterminate items 'i'.

- a) If $d \le C_N$ (3) and $i \le I$ (2), accept the lot and repeat step 1 for the next lot.
- b) If $d > C_N$ (3), reject the lot and go to step 2.
- c) If $d \le C_N$ (3), $i > I$ (2), the lot is indeterminate.

Step 2. From the next lot, take a random sample of size 'n (40)' at the tightened level and count the number of defective items 'd' and number of indeterminate items 'i'.

- a) If $d \le C_T$ (2), $i \le I$ (2), accept the lot and repeat step 1 for the next lot.
- b) If $d > C_T$ (2), reject the lot and repeat step 2.
- c) If $d \le C_T$ (2), $i > I$ (2), the lot is indeterminate,

Table 2. Probability of acceptance for QSS_NP

N	n	c_N	c_T	I	P(S)	P(F)	P(I)	P_{aN}	P_{rN}	P_{iN}	P_{aT}	P_{rT}	P_{iT}	QSS (Pa)
600	30	3	2	2	0.95	0.05	0.05	0.779	0.057	0.164	0.6528	0.1902	0.154	0.747
600	30	2	1	2	0.95	0.04	0.02	0.862	0.118	0.02	0.4502	0.4146	0.178	0.7653
600	30	2	1	2	0.83	0.03	0.04	0.781	0.08	0.139	0.6788	0.2271	0.092	0.756
1200	30	3	2	2	0.95	0.05	0.05	0.779	0.057	0.164	0.6528	0.1902	0.154	0.747
1200	30	2	1	2	0.95	0.05	0.05	0.683	0.173	0.143	0.4502	0.797	0.106	0.5868
1200	40	3	2	2	0.95	0.05	0.05	0.458	0.113	0.488	0.4575	0.2492	0.207	0.4575

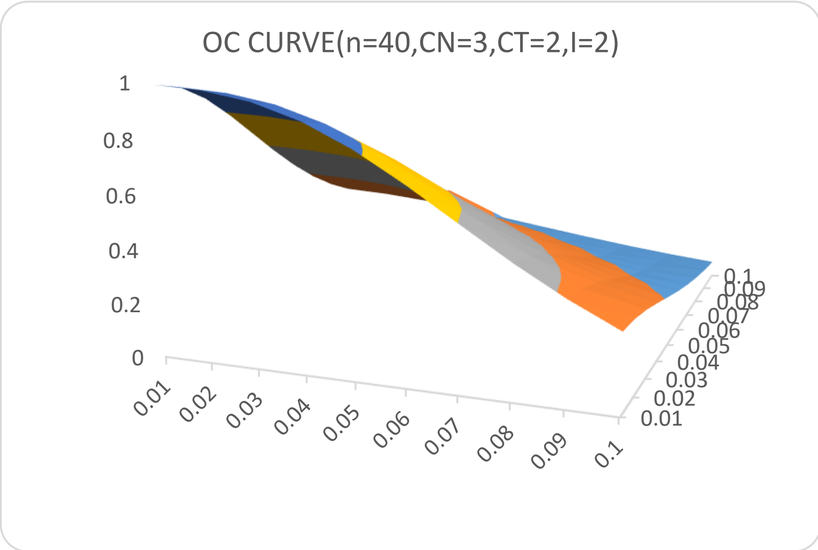

Figure 2. OC Surface for QSS using Neutrosophic Poisson distribution.

OC is formed as a surface depending on P(F), P(I) and P_a. The system has three possible outcomes: accept, reject and indeterminate. According to figure, rejection is dominant to indeterminate case. While C=I and P(F) =P(I), P_r is observed bigger than P_i.

7. Conclusion

In this article, Construction and designing of Quick Switching system QSS_{FP} and QSS_{NP} (n; C_N,C_T) with reference to Single sampling plan using Neutrosophic Poisson Distribution is studied and compared with Fuzzy Poisson Distribution for various Quality Characteristics. Both Fuzzy and Neutrosophic concepts are applied in uncertainty environment where NSs include indeterminacy term which is similar to human thinking. On comparison, it is concluded that QSS using Neutrosophic Poisson distribution gives high probability of acceptance and well suited for uncertainty environment than QSS Using Fuzzy Poisson distribution with the indeterminacy term. As a future study, these plans and systems can be extended for other distributions for various characteristic measures such as AQL, LQL, AOQL with NSs.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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