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FUZZY QUICK SWITCHING DOUBLE SAMPLING SYSTEM – SAMPLE SIZE TIGHTENING

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ABSTRACT

Sampling plans, systems and schemes are used to accept/reject the lots when a series of lots are inspected in the manufacturing industries. In this special sampling plan such as Quick Switching Systems requires fewer samples for processes running at low levels of defects. Quick Switching System (QSS)is nothing but switching of sampling plans according to the acceptance or rejection of an item. QSS is compared with single, double, multiple, chain and variable sampling plans and it is more advantageous in reducing the sample size, cost and time as well. This article presents Quick Switching Double Sampling System (QSDSS) when the fraction of non-conforming items is a fuzzy number and being modeled based on the fuzzy Poisson distribution. Operating Characteristic (OC) curves of the fuzzy system is like a band having high and low bounds whose width depends on the ambiguity of the proportion parameter. Tables are constructed and numerical illustrations are given. OC curve is also drawn.

KEYWORDS: SSP, DSP, QSDSS, OC, Fuzzy Poisson distribution.

INTRODUCTION AND REVIEW OF LITERATURE

Statistical Quality Control (SQC) is one of the best methods to improve the quality in production. SQC is used to accept or reject a lot. It is a means of establishing and achieving quality specification, which requires use of tools and techniques of statistics. Sampling refers to observation of a population or lot for the purpose of obtaining some information about it. Acceptance Sampling is a quality control technique.

Acceptance sampling is a major area in Statistical Quality Control to inspect the quality of the product or raw material at various stages against the specified quality standards. Inspections of raw materials, semi-finished products or finished products are one aspect of quality assurance.

Acceptance sampling is that branch of science that deals with procedure by which decision to accept or reject are based on the results of the inspection of the samples. Acceptance sampling is a decision making tool from where a conclusion is arrived regarding the acceptability of a lot. Various sampling plans, systems and schemes were developed and applied in industries based on the need of the shop floor situations.

Quick Switching System is a sampling inspection plan involving normal and tightened inspection which is usually referred as two-plan system. A quick switching system switches to tightened inspection when the rejection comes under normal inspection. Due to instantaneous switching between normal and tightened plans, this system is referred as '**Quick Switching System (QSS)**'.

Quick Switching Double Sampling System explored in this article has two sampling plans with a set of rules for switching between them. The first plan, called the Normal Double Sampling Plan, is used when the samples are of good quality with a smaller sample size in order to reduce inspection costs. The second sampling plan, called the Tightened Double Sampling Plan, is used when problems are encountered with sample size greater than Normal Double Sampling Plan with nk($k > 1$).

Arumainayagam and Soundararajan [1], [2] designed, developed and analyzed QSS with double sampling plan as a reference plan (QSDSS) and constructed Quick Switching Double Sampling System for Sample Size Tightening and highlighted the advantages by comparing with existing sampling plans and system such as Double Sampling Plan and Quick Switching System by highlighting its advantages with illustrations. Later, Uma and Devaraj Arumainayagam [22] developed Quick Switching Multiple Sampling System (QSMSS) for acceptance number tightening and constructed tables for ease use of shop floor situations. Suresh and Kaviyarasu [20] have given certain results and designed tables relating to QSS with conditional RGS plan as a reference plan. Suresh and Jayalakshmi [19] studied a procedure for selection of Quick Switching System with special type double sampling

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plans through Maximum Allowable Percent Defective and Maximum Allowable Average Outgoing Quality (MAPD and MAAOQ).

Devaraj Arumainayagam and Uma [6] have done a work on the construction and selection of Quick Switching System Using Weighted Poisson distribution for sample size tightening under the situation where there is a chance of getting atleast one defective item in the process. Uma and Komaladevi [23] have undergone a work on Quick Switching System with Fuzzy Parameter using Poisson distribution as a base line distribution for acceptance number tightening. Later Uma and Nandhini Devi [24] have studied Quick Switching System by attributes under Fuzzy Poisson Distribution for sample size tightening and constructed tables for the ease use in the shop floor situations.

This article shows how to evaluate and select Quick Switching System with reference to Double Sampling Plan (QSDSS) for sample size tightening using Fuzzy Poisson distribution under situation with more chance of uncertainty. It proposes an efficient method of describing the production provided by QSDSS during periods of changing quality called transitive operating characteristic (OC) curves.

FUZZY LOGIC

The term "fuzzy logic" was introduced with the 1965 proposal of fuzzy set theory by Lotfi A. Zadeh. Fuzzy logic has been applied to many fields, from control theory to artificial intelligence. Fuzzy logics however had been studied since the 1920s as infinite-valued logics notably by Łukasiewicz and Tarski.

Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling and controlling uncertain systems. Fuzzy logic has rapidly become one of the most successful of today's technologies for developing sophisticated control systems. Fuzzy Logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions. Fuzzy set theory is used to employ systems which are rigid to define unambiguously. As a procedure, fuzzy set theory amalgamates impreciseness and subjectivity into the model formation and solution process.

ACCEPTANCE SAMPLING AND FUZZY SET THEORY

Research on fuzzy quality management is classified into three areas, namely, acceptance sampling, statistical process control, and general quality management topics.

In various acceptance sampling plans the fraction of defective items, is treated as a crisp value, but in practice the fraction of defective items value must be known accurately. More often, these values are predicted or it is given by experiment. The ambiguity present in the value of p from personal judgment, experiment or estimation may be considered properly with the use of fuzzy set theory. As known, fuzzy set theory is powerful mathematical tool for designing uncertain resulting. In this basis defining the imprecise proportion parameter is as a fuzzy number. With this definition, the number of nonconforming items in the sample has a binomial distribution with fuzzy parameter. However if fuzzy number p is small we can use the fuzzy poison distribution to approximate values of the fuzzy binomial.

Ohta and Ichihashi [17] gave a fuzzy design method for single stage, two-point attribute sampling plans. An algorithm is presented and an example for sampling plans are developed when producer and consumer risk are resolved by triangular fuzzy numbers. Chakraborty [5] considered the problem for determining the sample size and critical value of a single sample attribute sampling plan when deception appears in the declaration of producer and consumer risk. A fuzzy goal programming model and solution procedure are explained. Certain numerical illustrations are given and the sensitivity of the strength of the resulting sampling plans is calculated. Earlier a paper defined how possibility theory and triangular fuzzy numbers are used in the single sample plan design problem.

Kanagawa and Ohta [15] identify two limitations in the sample plan design procedure of Ohta and Ichihashi [17]. First, Ohta and Ichihashi's [17] design method does not clearly reduce the sample size of the sampling plan. Second, the membership functions used, unrealistically model the consumer and producer risk. These defects are amended by using nonlinear membership function and accurate incorporation of the sample size in fuzzy mathematical programming solution methodology. Chakraborty [4], [5] finds the problem of designing single stage, Dodge-Roming lot tolerance percent defective (LTPD) sampling plans when the lot tolerance percent defective, consumer's risk and incoming quality level are shaped using triangular fuzzy numbers. In the Dodge-Roming theory, the design of an optimal LTPD sample plan includes solution to a nonlinear integer programming problem. The objective is to reduce average total inspection subject to a constraint based on the lot tolerance

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percent defective and the level of consumer risk. When fuzzy parameters are introduced, the method becomes a possibility (fuzzy) programming problem.

Classical acceptance sampling plans have been studied by many researchers. Single Sampling by attributes with flexible requirements was discussed by Ohta and Ichihashi [17], Kanagawa and Ohta [15], Tamaki, Kanagawa and Ohta [21], and Grzegorzewski [10], [11]. Grzegrozewski [12] also recognized sampling plan by variables with fuzzy requirements. Sampling plan by attributes for imprecise data were studied by Hryniewisz [13], [14]. EzzatallahBalouiJamkhaneh et.al. [8] have considered acceptance Single Sampling Plan with fuzzy parameter using Poisson distribution. EzzatallahBalouiJamkhaneh et.al. [9] have also considered the acceptance Double Sampling Plan with fuzzy parameter using Poisson distribution. Bahram Sadeghpour- Gildehet. al. [3] have designed acceptance Double Sampling Plan with Fuzzy Paramter. Muthulakshmi S and Malathi D [16] evaluated aSpecial Double Sampling Plan with Fuzzy Parameter and constructed tables using both Binomial and Poisson distribution. Divya P.R [7], evaluated Quality Interval Acceptance Single Sampling Plan with fuzzy parameter using Poisson Distribution.

Preliminaries and Definitions

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

Definition 2: A triangular fuzzy number $\widetilde{N}$ 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 $\widetilde{N}$ 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

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

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

Quick Switching Double Sampling System

QSS consists of pairs of normal and tightened plans with the switching rules constitute a sampling system. The application of system is as follows.

- Adopt a pair of sampling plans, a normal double sampling plan (N) and tightened double sampling plan (T), the plan T to be tighter 'OC' wiser than plan N.
- Use plan N for the first lot.
- 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.

Quick Switching Double Sampling System has the parameters $n(n_1=n_2=n)$, the sample size and c_1, c_2, $(c_1<c_2)$, the acceptance numbers and k(k>1).

Conditions of Application

The conditions for application under which the Quick Switching System can be applied and the operation procedures are as follows:

- The production is steady so that results on current and proceedings 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 of QSDSS (n, k; c_1, c_2)

Step 1: A random sample of size 'n' is taken from the lot and count the number of nonconforming units X_1.

(a) If $X_1 \leq c_1$, the lot is accepted and proceed with step 1 for the next lot.
(b) If $X_1 > c_2$, the lot is rejected and go to step 2.

(c) If $c_1 < X_1 \leq c_2$, a second random sample of size $n_2$is taken from the same lot and count the number of nonconforming units X_2.
(d) If $X_1 + X_2 \leq c_2$, the lot is accepted and proceed with step 1 for the next lot.
(e) If $X_1 + X_2 > c_2$, the lot is rejected and go to step 2.

Step 2: A random sample of size '*kn*' is taken from the lot and count the number of nonconforming units X_1.

(a) If $X_1 \leq c_1$, the lot is accepted and proceed with step 1 for the next lot.
(b) If $X_1 > c_2$, the lot is rejected and go to step 2 for the next lot.
(c) If $c_1 < X_1 \leq c_2$, a second random sample of size *kn*is taken from the same lot and count the number of nonconforming units X_2.
(d) If $X_1 + X_2 \leq c_2$, the lot is accepted and proceed with step 1 for the next lot.
(e) If $X_1 + X_2 > c_2$, the lot is rejected and go to step 2 for the next lot.

Measures of Performance

The OC function of QSS is derived by Romboski [18] as

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

Where

$P_N$is the proportion of lots expected to be accepted when using normal double sampling plan (n; c_1, c_2).

$P_T$is the proportion of lots expected to be accepted when using tightenend double sampling plan (kn; c_1, c_2).

Quick Switching Double Sampling System with Fuzzy Parameter using Poisson Distribution

If the size of the sample is big and 'p' is small then the random variable $'d_1'$ and $'d_2'$ has a Poisson approximation distribution with parameter $\lambda_1 = n_1 p$ and $\lambda_2 = n_2 p$. So, if we represent probability of acceptance on combined samples with p_α and also the probability of the lot's acceptance in first and second samples byP_a^I, P_a^{II}, respectively, then

$$P_a = P_a^I + P_a^{II} \tag{2}$$

wherep_a^I indicates the probability of the event $d_1 = c_1$. Thus

$$P_a^I = \sum_{d_1=0}^{c_1} \frac{e^{-n_1 p}(n_1 p)^{d_1}}{d_1!} \tag{3}$$

andp_a^{II} according to the independence of two random variables and their distributions will be calculated as follows:

$$P_a^{II} = P(d_1 + d_2 \leq c_2, c_1 < d_1 < c_2) \tag{4}$$

Suppose that we want to inspect a lot with the size of 'N', in which the proportion of defective items or the probability of the defectiveness is not known precisely and it is an uncertain value. So we represent this parameter with a fuzzy number $\tilde{p}$which is:

$$\tilde{p} = (a_1, a_2, a_3), p \in \tilde{p}[1], q \in \tilde{q}[1], p + q = 1 \tag{5}$$

A Quick Switching Double Sampling System with a fuzzy parameter is defined by the first sample size$'n_1'$, the acceptance number on the first stage$'c_1'$, the second sample size $'n_2'$ and the acceptance number on the second stage$'c_2'$.

If 'p' is small, then the random variables $'d_1'$ and $'d_2'$ have a fuzzy Poisson distribution with parameters $\lambda_1 = n_1 p$ and$\lambda_2 = n_2 p$. According to this case, if we show the fuzzy probability of the acceptance of lot in the combined samples with $\tilde{p}_a$and also the fuzzy probability of acceptance of the lot in the first and second samples,$\tilde{p}_a^I, \tilde{p}_a^{II}$, respectively, then

$$\tilde{p}_a = \{\tilde{p}_a^I + \tilde{p}_a^{II} \mid S\} \tag{6}$$

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OC Band with Fuzzy Parameter

The OC curve shows the performance of the system by plotting the probability of acceptance of a lot with its production quality, which is explicited by the proportion of nonconforming items in the lot. OC curve assists in choosing of system that are efficient in minimizing risk and reveals discriminating power of the system.

The fuzzy probability of acceptance of a lot in terms of fuzzy fraction of defective items is a band with upper and lower bounds. The uncertainty degree of a proportion parameter is one of the factors in which that bandwidth depends upon. The lower uncertainty value produces in lower bandwidth, and if proportion parameter obtains a crisp value, lower and upper bounds will become equal, which means that the OC curve is in typical 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) in which the OC bands are plotted in terms of it.

Properties of OC Curve

- For a QSS (n; c_N, c_T) the steepness of the operating characteristic (OC) curve and hence its discriminating power is depending upon the difference between c_N and c_T For a fixed n, and fixed c_N, as c_T decreases, the resulting composite OC curve gets steeper.
- For a QSS (n, kn; c_0) for k>0, the slope of the composite OC curve increases as k increases.

Example

A drug manufacturing company is in a position to produce a new drug for Corona Virus during COVID-19 situation. While in the production process, some of the drugs are identified to be defectives. Since the proportion of defective items are explained linguistically, in this stage if the Government considers the fuzzy number as $\tilde{p} = (0.004, 0.01, 0.018, 0.02)$and $\tilde{q} = (0.98, 0.982, 0.99, 0.996)$. The Government can use the newly designed Quick Switching System procedure to inspect the samples which lies in the range instead of single value. According to Normal plan, inspect a sample of 35 items from the manufactured drugs and count the number of defective drugs(d_1). If $d_1 \leq 0$, then accept the lot and if$d_1 > 1$, the reject the lot. But if$d_1 = 1$, then inspect a second random sample of 35 items from the lot and count the number of defective drugs(d_2). If $d_1 + d_2 \leq 1$, then the lot is accepted and if$d_1 + d_2 > 1$, then reject the lot and inform the management to improve the quality. According to Tightened plan, as per the procedure inspect a sample of 43 items from the manufactured drugs and count the number of defective drugs (d_1).If $d_1 \leq 0$, accept the lot and if$d_1 > 1$, reject the lot. But if $d_1 = 1$, then inspect a second random sample of 43 items from the lot and count the number of defective drugs(d_2).If $d_1 + d_2 \leq 1$, then accept the lot and if $d_1 + d_2 > 1$, then the lot gets rejected t rejects the lot and inform the management to improve the quality. Using the normal plan and the tightened plan, the system measures and its parameters are calculated. The probability of purchasing the drugs is determined and the corresponding Operating Characteristic curve is drawn for the various values of $'p'$.

Solution

From the above example, let, n = 35, k = 1.25, c_1 = 0, c_2 = 1, then the fuzzy probability of acceptance of $QSDSS_{FP}$ for plotting the OC curve is as follows:

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Table 1: probability of acceptance for $QSDSS_{FP}(n;k;c_1;c_2)$
$n_1 = n_2 = n = 35$, $k = 1.25$, $c_1 = 0$, $c_2 = 1$

l_i	$\tilde{p}$	Normal(35;0;1)			Tightened(35;1.25;0;1)			QSDSS
		$\tilde{p}_a^I$	$\tilde{p}_a^{II}$	$\tilde{p}_a$	$\tilde{p}_a^I$	$\tilde{p}_a^{II}$	$\tilde{p}_a$	
0	[0,0.02]	[1,0.4965]	[0,0.1726]	[1,0.6692]	[1,0.4168]	[0,0.1520]	[1,0.5689]	[1,0.6323]
0.01	[0.01,0.03]	[0.7046,0.3499]	[0.1738,0.1285]	[0.8784,0.4785]	[0.6456,0.2691]	[0.1823,0.0950]	[0.8280,0.3642]	[0.8720,0.4112]
0.02	[0.2,0.04]	[0.4965,0.2465]	[0.1726,0.0851]	[0.6692,0.3317]	[0.4168,0.1737]	[0.1520,0.0528]	[0.5689,0.2266]	[0.6323,0.2534]
0.03	[0.03,0.05]	[0.3499,0.1737]	[0.1285,0.0528]	[0.4785,0.2266]	[0.2691,0.1121]	[0.0950,0.0275]	[0.3642,0.1397]	[0.4112,0.1530]
0.04	[0.04,0.06]	[0.2465,0.1224]	[0.0851,0.0314]	[0.3317,0.1539]	[0.1737,0.0724]	[0.0528,0.0137]	[0.2266,0.0862]	[0.2534,0.0924]
0.05	[0.05,0.07]	[0.1737,0.0862]	[0.0528,0.0182]	[0.2266,0.1045]	[0.1121,0.0467]	[0.0275,0.0066]	[0.1397,0.0534]	[0.1530,0.0563]
0.06	[0.06,0.08]	[0.1224,0.0608]	[0.0314,0.0103]	[0.1539,0.0711]	[0.0724,0.0301]	[0.0137,0.0031]	[0.0862,0.0333]	[0.0924,0.0347]
0.07	[0.07,0.09]	[0.0862,0.0428]	[0.0182,0.0057]	[0.1045,0.0486]	[0.0467,0.0194]	[0.0066,0.0014]	[0.0534,0.0209]	[0.0563,0.0215]
0.08	[0.08,0.10]	[0.0608,0.0301]	[0.0103,0.0031]	[0.0711,0.0333]	[0.0301,0.0125]	[0.0031,0.0006]	[0.0333,0.0132]	[0.0347,0.0135]
0.09	[0.09,0.11]	[0.0428,0.0212]	[0.0057,0.0017]	[0.0486,0.0230]	[0.0194,0.0081]	[0.0014,0.0003]	[0.0209,0.0084]	[0.0215,0.0085]
0.10	[0.10,0.12]	[0.0301,0.0149]	[0.0031,0.0009]	[0.0333,0.0159]	[0.0125,0.0052]	[0.0006,0.0001]	[0.0132,0.0053]	[0.0135,0.0054]

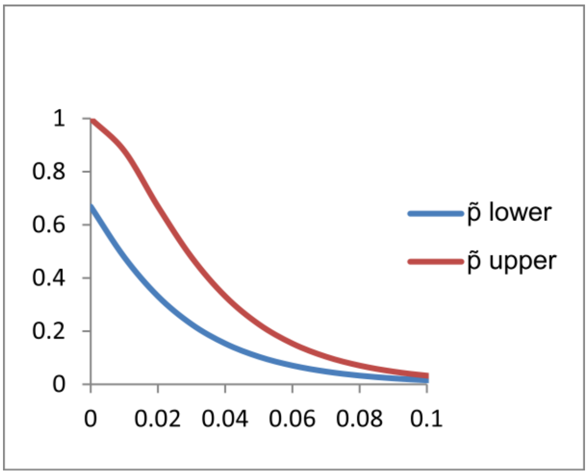

Fig 1: OC curve for Normal Plan

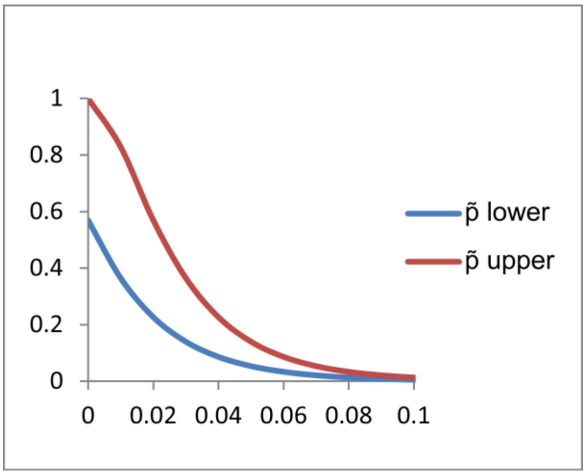

Fig 2: OC curve for Tightened Plan

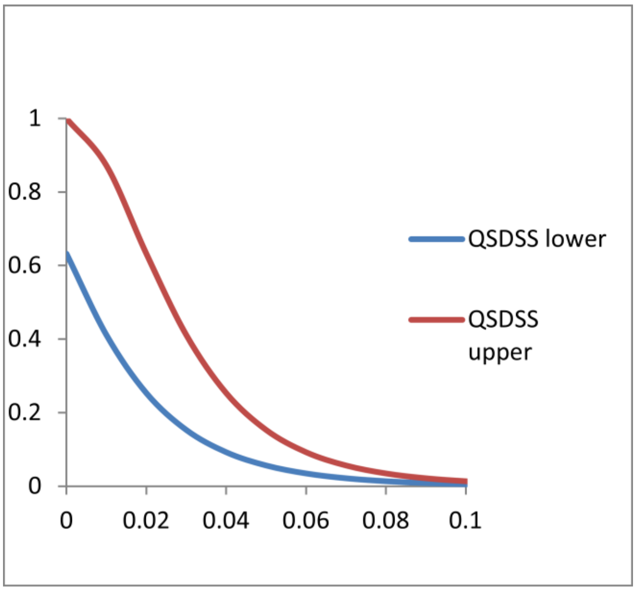

Fig 3: OC curve for $QSDSS_{FP}$(35,1.25; 0,1)

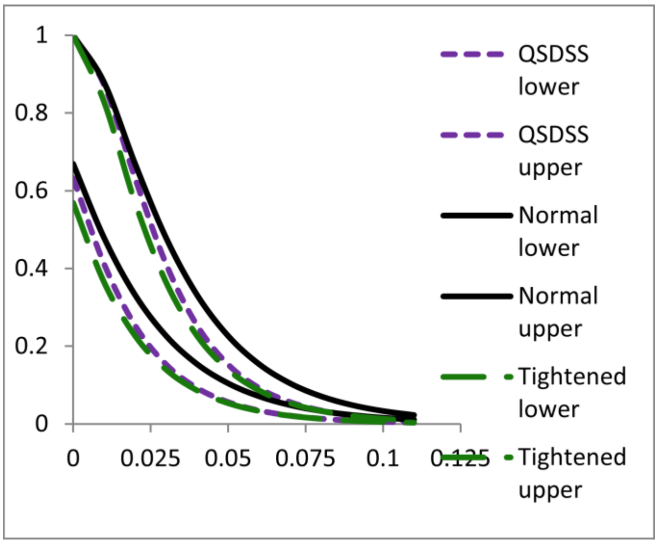

Fig 4: Comparison of Normal,Tightened and $QSDSS_{FP}$

CONCLUSION

In this present paper, fuzzy probability theory is used to solve problems of impreciseness arising in Statistical Quality Control especially in the sampling systems. Also proposed a method for designing Quick Switching Double Sampling System -**$QSDSS_{FP}(n;k;c_1;c_2)$**under sample size tightening using Fuzzy Poisson Distribution. These systems are well defined since if the fraction of defective items is crisp, they diminish to classical plans and system. The uncertainty degree of a proportion parameter is one of the factors that bandwidth depends on that. The lower uncertainty value results in lower bandwidth, and upper uncertainty values results in wider bandwidth. From this it is proposed that, this system using Fuzzy logic is adopted to predict the uncertainty level in an easy way by judging the bandwidth of OC curves. The OC curves of QSDSS shows more discriminating than

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that of the Double Sampling Plan using Fuzzy Poisson distribution. Based on the Fuzzy switching sampling system the better outcome can be achieved in the real life situations.

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