International Journal of Statistics and Applied Mathematics

ISSN: 2456-1452
Maths 2018; 3(4): 44-53

www.mathsjournal.com
Received: 06-05-2018
Accepted: 07-06-2018

V Kaviyarasu
Assistant Professor,
Department of Statistics,
Bharathiar University
Coimbatore, Tamil Nadu, India

Asif T Thottathil
M.Phil. Scholar, Department of statistics, Bharathiar University
Coimbatore, Tamil Nadu, India

Correspondence
V Kaviyarasu
Assistant Professor,
Department of statistics,
Bharathiar University
Coimbatore, Tamil Nadu, India

Designing STDS plan for zero-inflated Poisson distribution through various quality level

V Kaviyarasu and Asif T Thottathil

Abstract
Due to technological development, the manufacturing process is well developing, so that the number of non-defective items will be found more. The appropriate probability distribution to obtain the number of defects in such cases, Zero-Inflated Poisson (ZIP) distribution can be utilized. Acceptance sampling plans are plays an important role to ensure the quality of the product. Whenever sampling plans are designed for product characteristics costly or destructive testing by attributes, a Special Type Double sampling Plan can be carried out. In this article, an attempt has been made to model and analyze the proposed inspection method through STDS plan, when the number of defect is less, which follows a ZIP distribution. The operating characteristic (OC) function of the sampling plan is derived and their plan parameters are obtained for the proposed plan. The procedures for designing the plan parameters are developed through AQL, LQL and IQL. A quality description called an operating ratio is developed to designing the sampling plan and few illustrations have been tabulated for the construction and selection of the plan.

Keywords: Acceptance sampling plan, special type double sampling plan, zero-inflated Poisson distribution, operating characteristic function, operating ratio

1. Introduction

The Poisson distribution is the standard model for the analysis of count data. However, in many situations this type of observations exhibits a substantially larger proportion of zeros than what is expected for the Poisson model. For instance, this is often the case with count data coming from medical and public health research (see Bohning *et al.* [1]). This phenomenon usually arises when the distribution generating the data is a mixture of two populations, the first of which yields Poisson-distributed counts whereas the second one always contributes with a zero. Often, a Poisson or Negative Binomial model cannot accommodate the numbers of zeros in the sample properly. Both models would under predict them. There is said to be an "*excess zeros*" problem. New models are needed to deal with these type of data. Zero-inflated Poisson models are designed to deal with situations where there is an "excessive" number of individuals with a count of 0. In most count data sets, the conditional variance is greater than the conditional mean, often much greater, a phenomenon known as over-dispersion. If data consist of non-negative, highly skewed sequence counts with a large proportion of zeros, Zero-inflated models are useful for analyzing such data.

In the present scenario of industrial field, the technological development results the production processes are well designed in such way that the products are in perfect state, so that the number of zero defects will be more in those cases. However, random fluctuations in the production processes may lead some products to an imperfect state. The appropriate probability distribution to describe such situations is a zero-inflated Poisson (ZIP) distribution. The ZIP distribution can be viewed as a mixture of a distribution which degenerates at zero and a Poisson distribution. ZIP distribution has been used in a wide range of disciplines such as agriculture, epidemiology, econometrics, public health, process control, medicine, manufacturing, etc. Some of the applications of ZIP distribution can be found in Bohning *et al.* [1], Lambert [5], Naya *et al.* [8] and Ridout *et al.* [9]. Loganathan and Shalini [6] designed single sampling plans by attributes under the condition of Zero-inflated Poisson distribution.

Construction of control charts using ZIP distribution are discussed inXie *et al.* [11]. Some theoretical aspects of ZIP distributions are mentioned in McLachlan and Peel [7].
The probability mass function (p.m.f) of the ZIP (ω, λ) distribution is given by Lambert [5] and McLachlan and peel [7]

$$p(D=d|\omega,\lambda)=\omega f(d)+(1-\omega)P(D=d|\lambda)$$

Where

$$f(d)=\begin{cases}1, if\ d=0\\0, if\ d\neq 0\end{cases}$$

And

$$P(D=d|\lambda)=\frac{e^{-np}\lambda^{d}}{d!}, when\ d=0,1,2,\ldots$$

The above probability mass function can also be indicated as

$$P(D=d|\omega,\lambda)=f(x)=\begin{cases}\omega\ +(1-\omega)e^{-\lambda}, when\ d=0\\ (1-\omega)\dfrac{e^{-\lambda}\lambda^{d}}{d!}, when\ d=1,2,\ldots,0<\omega<1,\lambda>0\end{cases}$$

In this distribution, ω may be named as the mixing proportion which is alsoalso is known as the probability of extra zeros. ω and λ are the parameters of the ZIP distribution. According to mc Lachlan and Peel [10], a ZIP distribution is a special kind of mixture distribution.
The mean of the ZIP (ω, λ) is $(1-\omega)\lambda$ and the variance is $\lambda(1-\omega)(1+\lambda\omega)$.
When sampling plans are construct for product characteristics that concerning costly or destructive (harmful) testing by attributes, it is usual practice to use a single sampling plan with acceptance number such as Ac=0 and Ac=l Dodge [2]. However, the OC curves of single sampling plans with Ac=0 and Ac=l, lead to inconsistent interest between the producer and the consumer. The Ac=0 plan performs favorably to consumer while the Ac=l plan favors to the producer. For example if the AQL is set at 0.01 for a SSP with sample size 10, the producer’s risk for Ac=0 plan is 0.095 while for the Ac=l plan it is 0.005. Similarly if the LQL is set at 0.30, one may observe that the consumer's risk for the Ac=0 plan becomes 0.05 and for the Ac=l plan it becomes 0.199. While fixing a plan for the above situation, the consumer will favor Ac=0 plan and the producer will favor the Ac=l plan. Such struggle can be overcome if one is able to design a suitable plan having an OC curve lying between the 0C curves of Ae=0 and Ac=l plans.
Special type of double sampling plan (STDSP), invented by Govindaraju [3], is a lot-by-lot sampling plan by attributes in which requirements are made to utilize only small acceptance numbers such as 0 or 1, and to inspect the submitted lot by drawing a second random sample even if the first random sample comprises zero defective items. A special feature, which led to the development of *STDSP*, is that the operating characteristics of the plan lies between those of *c* = 0 and *c* = 1 single sampling plans, and thus provides better discrimination over the single sampling plans with wide range of operating ratios. (See, Govindaraju [3]). Kaviyarasuand Deepa [4] designed Special Type Double Sampling Plan using Fuzzy Poisson distribution. Vinothand Kaviyarasu [10] studied on Quick Switching System with Special Type Double Sampling Plan as Reference Plan.

2. The operating procedure of the STDS plan is as follows

1. From a lot, select a random sample of size n_1 units and count the number of defectivesd_1. If $d_1\geq 1$ reject the lot. If $d_1=0$, select a second random sample of size $n_2$and count the number of defectivesd_2.
2. If $d_2\leq 1$, accept the lot; otherwise, that is, if $d_2\geq 2$, reject the lot.

Table 1: A compact representation of STDS plan is given below

Stage	Sample Size	Ac	Re
1	n_1	+	1
2	n_2	1	2

+Cannot accept
Although this plan is valid under general conditions for application of attributes sampling inspection, this will be specially useful to product characteristics involving costly or destructive tests.

3. Expression for Operating Characteristic function

Let us consider the number of defects in the lot follows the Zero-Inflated Poisson model having probability mass function is given by

$$P(D=d|\omega,\lambda)=f(x)=\begin{cases}\omega\ +(1-\omega)e^{-\lambda}, when\ d=0\\ (1-\omega)\dfrac{e^{-\lambda}\lambda^{d}}{d!}, when\ d=1,2,\ldots,0<\omega<1,\lambda>0\end{cases}$$

The probability of getting no defects from a sample of size n_1 will be

$P(D = 0) = \omega + (1 - \omega)e^{-n_1 p}$.

The probability of getting one defect from a sample of size $n_2$will be

$P(D = 1) = (1 - \omega)e^{-n_2 p}$.

The probability of getting one or less defects from a sample of size n_2 will be

$P(D \leq 1) = \omega + (1 - \omega)e^{-n_2 p}(1 + n_2 p)$

An STDS plan accepts a lot only when no defects are found in a sample of size $n_1$and one or less defects are found in a sample of sizen_2. Therefore $P_a(p)$of STDS plan will given by

$$P_a(p) = [\omega + (1 - \omega)e^{-n_1 p}][\omega + (1 - \omega)e^{-n_2 p}(1 + n_2 p)] \quad (1)$$

$$= \left[\omega + (1 - \omega)e^{-(n - n_2)p}\right][\omega + (1 - \omega)e^{-n_2 p}(1 + n_2 p)] \quad (2)$$

Here n is the combined sample size. If $\varphi = \frac{n_2}{n}$ and $x = np$, equation (2) becomes

$$P_a(p) = \left[\omega + (1 - \omega)e^{-(1-\varphi)x}\right][\omega + (1 - \omega)e^{-\varphi x}(1 + \varphi x)] \quad (3)$$

Here φ is the ratio of the size of the second sample to that of the combined sample. When$n_2 = 0$, equation (2) becomes

$$P_a(p) = \left[\omega + (1 - \omega)e^{-(1-\varphi)x}\right] \quad (4)$$

Which is the OC function of single sampling plan with Ac=0. When $n_2 = n$ equation (2) [or when φ=1, equation 3] becomes

$$P_a(p) = [\omega + (1 - \omega)e^{-x}(1 + x)] \quad (5)$$

Which is the OC function of single sampling plan with Ac=1

4. Designing STDS Plans for given p_1, p_2, α and β

Any of the Tables 2 or 3 can be used to select for a STDS plan for givenp_1, p_2, α, β and ω. For an example, to construct an STDS plans, find the value of the ratio $\frac{p_2}{p_1}$in the column of table 2 for ω=0.0001 and appropriate α and β that is equal to or just greater than the desired ratio. Corresponding to the located tabular value of $\frac{p_2}{p_1}$ are the values of np_1 and φ. The combined sample size n is determined by dividing $np_1$by $p_1$and the second sample size as$n_2 = n\varphi$. The first sample size can be found as$n_1 = n - n_2$.

Illustration 1

Tofind an STDS plan for$p_1 = 0.005, \alpha = 0.05, p_2 = 0.1, \beta = 0.1$ and $\omega = .0001$, compute $\frac{p_2}{p_1}$ which is$\frac{0.1}{0.005} = 20$, enter Table 2 for α=0.05 and β=0.10 and select the value of the ratio $\frac{p_2}{p_1}$in the column for α=0.05 and β=0.10 equal to or just greater than 20. The value is 21.0134, which has associated with a value of $np_1 = 0.1719$ and φ=0.75. The combined sample size is then $n = \frac{np_1}{p_1} = \frac{0.1719}{0.005} = 34.38 \cong 34$. The first sample size will be$n_1 = 34(1 - 0.75) = 8.5 \cong 9$. The second sample size will be $n_2 = n - n_1 = 35 - 9 = 26$.

According to Govindraju [6], the STDS plan under the condition of Poisson distribution is also$n_1 = 9$ and $n_2 = 26$ for the same$p_1 = 0.005, \alpha = 0.05, p_2 = 0.1, \beta = 0.1$ and $\omega = .0001$. It indicates that the sampling plan, STDS under the conditions of Poisson distribution can be obtained under the conditions of ZIP distributions.

It may also be noted that observing non-defects would not be an event occurring frequently when ω is small. In such case, the STDS under conditions of ZIP distribution would be same as the STDS under the conditions of Poisson distribution. Hence, the STDSP's designed under the conditions of Poisson distribution will be a special case of the STDS under ZIP distribution.

Illustration 2

Tofind an STDS plan for $p_1 = 0.004, \alpha = 0.05, p_2 = 0.1, \beta = 0.1$ and $\omega = .0001$, compute $\frac{p_2}{p_1}$ which is$\frac{0.1}{0.004} = 25$, enter Table 2 for α=0.05 and β=0.10 and select the value of the ratio $\frac{p_2}{p_1}$in the column for α=0.05 and β=0.10 equal to or just greater than 25. The value is 25.5829 which has associated with it a value of $np_1 = 0.1361$ and φ=0.65. The combined sample size is then $n = \frac{np_1}{p_1} = \frac{0.1361}{0.004} = 34.025 \cong 34$. The first sample size will be$n_1 = 34(1 - 0.65) = 11.9 \cong 12$.The second sample size will be$n_2 = n - n_1 = 34 - 12 = 22$.

The values of $\frac{p_2}{p_1}$ tabulated against φ for given $P_a(p)$ for different values of ω of a STDS plan are given in following pages.

5. Plotting the OC curve of Given STDS Plan

An OC curve for an STDS plan characterized by n_1 *and* n_2, can be constructed using table 4 and 5 for different values of ω, by dividing each entry in the row for the given $\varphi = \frac{n_2}{(n_1+n_2)}$ by the value of $n = n_1 + n_2$. The result of each division is the value of p, whose probability of acceptance $P_a(p)$ is given in the column heading. The tables of np values provide some points to plot the OC curves for different ω values.

For example, for the STDS plan $n_1 = 6, n_2 = 14$, division of the entries opposite $\varphi = \frac{14}{20} = .70$ of table 4 and 5 by 20 leads to table 6 for plotting the OC curves for different values of ω. Figure- 1 gives the OC curve for φ=0.70 and ω=0.01.

Table 1: Operating ratio values for STDS plan

ω	φ	$\frac{p_2}{p_1}$ for α=0.05				$\frac{p_2}{p_1}$ for α=0.01			
		β=0.25	β=0.15	β=0.1	np_1	β=0.25	β=0.15	β=0.1	np_1
0.0001	0	27.2275	37.2534	45.2674	0.0508	137.743	188.464	229.006	0.01005
	0.05	27.1583	37.1352	45.1246	0.0535	137.438	187.927	228.358	0.01057
	0.1	26.8247	36.5996	44.3389	0.0568	142.149	193.949	234.961	0.01073
	0.15	26.7436	36.3849	44.1045	0.0597	147.123	200.163	242.63	0.01086
	0.2	26.1193	35.4021	42.7275	0.064	133.177	180.508	217.859	0.01255
	0.25	25.9319	34.9909	42.0445	0.0673	140.81	190	228.301	0.0124
	0.3	25.224	33.8961	40.5767	0.0721	135.998	182.755	218.774	0.01337
	0.35	24.3959	32.5797	38.9255	0.0775	130.234	173.922	207.798	0.01452
	0.4	23.4238	31.1077	37.0478	0.0838	123.213	163.632	194.878	0.01593
	0.45	22.3106	29.4643	34.9737	0.0912	122.535	161.825	192.084	0.0166
	0.5	21.0454	27.665	32.6884	0.0998	109.154	143.487	169.541	0.01925
	0.55	19.727	25.7152	30.3026	0.1101	97.9151	127.638	150.407	0.02218
	0.6	18.3061	23.7955	27.9795	0.1221	89.7709	116.69	137.208	0.0249
	0.65	16.8965	21.8091	25.5829	0.1361	81.1947	104.802	122.937	0.02833
	0.7	15.544	19.9892	23.3901	0.152	72.3861	93.0869	108.925	0.03264
	0.75	14.0865	17.9882	21.0134	0.1718	62.6859	80.0485	93.5109	0.03862
	0.8	12.4673	15.8638	18.4315	0.1987	52.7907	67.1727	78.0449	0.04693
	0.85	11.0487	14.0032	16.2279	0.2293	42.1478	53.4186	61.905	0.06011
	0.9	9.7814	12.3633	14.3143	0.2643	34.8492	44.0477	50.9988	0.07417
	0.95	8.6573	10.8958	12.5672	0.3048	25.0999	31.5899	36.4359	0.10514
	1	7.6245	9.5307	10.9866	0.3531	18.1219	22.6525	26.113	0.14854
0.01	0	27.5109	37.9656	46.5007	0.0515	140.41	193.769	237.33	0.01009
	0.05	27.8097	38.3497	46.9308	0.05352	147.224	203.024	248.452	0.01011
	0.1	27.4113	37.7178	46.0776	0.05697	152.926	210.425	257.063	0.01021
	0.15	27.1249	37.196	45.3044	0.06029	145.73	199.837	243.4	0.01122
	0.2	26.7148	36.4705	44.2792	0.06399	136.116	185.824	225.61	0.01256
	0.25	26.1712	35.5399	42.9822	0.06814	134.642	182.842	221.13	0.01324
	0.3	25.4561	34.3677	41.3936	0.07292	140.157	189.222	227.905	0.01324
	0.35	24.6288	33.0442	39.646	0.0783	124.902	167.58	201.06	0.01544
	0.4	23.6625	31.5478	37.6985	0.08448	119.616	159.477	190.569	0.01671
	0.45	22.5408	29.8634	35.5475	0.09175	119.625	158.487	188.652	0.01729
	0.5	21.3236	28.0771	33.2976	0.10015	106.765	140.579	166.718	0.02
	0.55	19.9909	26.165	30.9224	0.11013	99.2748	129.936	153.56	0.02218
	0.6	18.5472	24.1381	28.4389	0.12217	91.0945	118.554	139.677	0.02487
	0.65	17.0727	22.1463	26.0167	0.1361	82.2392	106.679	125.323	0.02825
	0.7	15.5148	20.0188	23.4557	0.15375	72.9169	94.0849	110.238	0.03271
	0.75	13.8819	17.8282	20.8404	0.17615	62.9986	80.9075	94.5775	0.03882
	0.8	12.5927	16.1079	18.7914	0.19879	53.2901	68.166	79.5222	0.04697
	0.85	11.1009	14.1181	16.4422	0.23113	42.7678	54.3922	63.3459	0.05999
	0.9	9.88493	12.5296	14.5727	0.26531	35.4847	44.9785	52.3128	0.07391
	0.95	8.6897	10.9874	12.7624	0.30826	25.4537	32.1841	37.3833	0.10524
	1	7.69409	9.70241	11.2689	0.35541	18.0373	22.7454	26.4177	0.15161

Table 2: Operating ratio values for STDS plan

ω	φ	$\frac{p_2}{p_1}$ for α=0.05				$\frac{p_2}{p_1}$ for α=0.01			
		β=0.25	β=0.15	β=0.1	np_1	β=0.25	β=0.15	β=0.1	np_1
0.05	0	29.0539	41.9625	54.682	0.05359	161.618	233.424	304.179	0.00963
	0.05	29.1632	41.9622	54.7446	0.05603	161.065	231.752	302.347	0.01014
	0.1	28.505	40.9016	52.8831	0.06005	159.698	229.149	296.275	0.01072
	0.15	28.1626	40.0915	51.1371	0.06355	159.344	226.838	289.334	0.01123
	0.2	27.6391	39.0234	49.3998	0.06747	148.477	209.634	265.375	0.01256
	0.25	26.9551	37.6798	47.1573	0.07187	146.275	204.474	255.905	0.01324
	0.3	26.1192	36.1329	44.6464	0.07686	136.554	188.907	233.416	0.0147
	0.35	25.1416	34.4122	42.0565	0.08255	134.42	183.985	224.855	0.01544
	0.4	23.9732	32.5836	39.5028	0.08907	127.774	173.667	210.545	0.01671
	0.45	22.8192	30.564	36.9009	0.09663	127.538	170.824	206.241	0.01729
	0.5	21.4621	28.5748	34.2654	0.10542	107.468	143.084	171.579	0.02105
	0.55	20.0753	26.5431	31.5855	0.11587	99.658	131.765	156.797	0.02334
	0.6	18.588	24.3923	29.0022	0.12844	94.0824	123.461	146.793	0.02538
	0.65	17.1223	22.3305	26.4824	0.14294	82.3238	107.365	127.327	0.02973
	0.7	15.6108	20.2502	23.9834	0.16064	72.9705	94.6568	112.107	0.03437
	0.75	13.9303	18.0447	21.3058	0.18442	62.9166	81.4996	96.2282	0.04083
	0.8	12.6808	16.3899	19.3568	0.20756	53.3138	68.9077	81.3813	0.04937
	0.85	11.2202	14.491	17.1461	0.24042	42.7941	55.2689	65.3958	0.06304
	0.9	10.0523	10.0614	15.4258	0.27522	32.8993	32.9292	50.4859	0.08409
	0.95	8.99992	11.6759	14.0426	0.31563	26.0986	33.8585	40.7216	0.10884
	1	7.98594	10.4351	12.7714	0.36572	18.5882	24.2889	29.7271	0.15712
0.09	0	30.7319	48.2401	78.6473	0.0565	171.745	269.589	439.519	0.0101
	0.05	30.6673	47.8306	75.2617	0.0594	162.353	253.216	398.436	0.0112
	0.1	30.3438	46.7577	69.95	0.0628	168.004	258.882	387.291	0.0113
	0.15	29.8461	45.1783	64.2577	0.0664	159.122	240.865	342.585	0.0125
	0.2	29.1513	43.0917	58.7161	0.0705	163.645	241.901	329.611	0.0126
	0.25	28.2804	41.0375	54.2027	0.0751	158.774	230.396	304.309	0.0134
	0.3	27.2373	49.9982	38.9171	0.0803	148.786	273.119	212.588	0.0147
	0.35	26.0625	36.5993	45.8916	0.0862	145.576	204.431	256.335	0.0154
	0.4	24.7731	34.366	42.4131	0.093	137.923	191.33	236.132	0.0167
	0.45	23.3384	31.9994	39.2262	0.1009	122.724	168.267	206.269	0.0192
	0.5	21.9476	29.6607	35.9618	0.1101	120.783	163.231	197.907	0.02
	0.55	20.414	27.3573	32.9465	0.1209	111.254	149.095	179.556	0.0222
	0.6	18.8834	25.0655	30.1074	0.1336	101.45	134.662	161.749	0.0249
	0.65	17.3336	22.9056	27.394	0.1489	91.3293	120.688	144.336	0.0283
	0.7	15.7956	20.7899	24.8366	0.1672	73.5386	96.7905	115.63	0.0359
	0.75	14.2959	18.7818	22.5345	0.1892	69.672	91.5343	109.823	0.0388
	0.8	12.8597	16.9088	20.2931	0.2157	59.0469	77.6386	93.178	0.047
	0.85	11.5299	15.1859	18.409	0.2472	47.5164	62.5833	75.866	0.06
	0.9	10.3259	13.7138	16.8637	0.2844	35.8018	47.5487	58.47	0.082
	0.95	9.2751	12.5576	16.0659	0.3272	28.8345	39.0391	49.9459	0.1052
	1	8.4347	11.748	17.2012	0.3751	20.8718	29.0706	42.5647	0.1516

ω	φ	$P_a(p)$							
		0.99	0.95	0.90	0.75	0.50	0.25	0.15	0.10
0.0001	0	0.0100	0.0508	0.1053	0.2868	0.6932	1.3841	1.8938	2.3012
	0.05	0.0106	0.0535	0.1101	0.3026	0.7276	1.4533	1.9871	2.4147
	0.10	0.0107	0.0568	0.1162	0.3179	0.7656	1.5246	2.0801	2.5200
	0.15	0.0109	0.0597	0.1234	0.3356	0.8061	1.5977	2.1737	2.6349
	0.20	0.0126	0.0640	0.1309	0.3551	0.8488	1.6716	2.2657	2.7345
	0.25	0.0124	0.0673	0.1383	0.3765	0.8939	1.7457	2.3556	2.8304
	0.30	0.0134	0.0721	0.1487	0.3999	0.9400	1.8179	2.4429	2.9244
	0.35	0.0145	0.0775	0.1594	0.4256	0.9889	1.8911	2.5255	3.0174
	0.40	0.0159	0.0838	0.1715	0.4535	1.0395	1.9633	2.6074	3.1052
	0.45	0.0166	0.0912	0.1853	0.4840	1.0915	2.0342	2.6864	3.1887
	0.50	0.0192	0.0998	0.2011	0.5170	1.1446	2.1011	2.7620	3.2635
	0.55	0.0222	0.1101	0.2191	0.5513	1.1977	2.1717	2.8309	3.3359
	0.60	0.0249	0.1221	0.2398	0.5898	1.2529	2.2349	2.9050	3.4158
	0.65	0.0283	0.1361	0.2636	0.6311	1.3075	2.3002	2.9690	3.4828
	0.70	0.0326	0.1520	0.2905	0.6743	1.3624	2.3627	3.0384	3.5553
	0.75	0.0386	0.1718	0.3208	0.7190	1.4165	2.4208	3.0913	3.6111
	0.80	0.0469	0.1987	0.3554	0.7654	1.4684	2.4773	3.1522	3.6624
	0.85	0.0601	0.2293	0.3928	0.8131	1.5216	2.5333	3.2108	3.7209
	0.90	0.0742	0.2643	0.4361	0.8597	1.5742	2.5849	3.2672	3.7828

	0.95	0.1051	0.3048	0.4828	0.9113	1.6253	2.6389	3.3213	3.8308
	1	0.1485	0.3531	0.5288	0.9614	1.6757	2.6919	3.3649	3.8789
0.01	0	0.0101	0.0515	0.1055	0.2906	0.7033	1.4168	1.9552	2.3947
	0.05	0.0101	0.0535	0.1113	0.3057	0.7396	1.4885	2.0526	2.5119
	0.10	0.0102	0.0570	0.1181	0.3219	0.7782	1.5616	2.1487	2.6250
	0.15	0.0112	0.0603	0.1250	0.3401	0.8191	1.6354	2.2426	2.7315
	0.20	0.0126	0.0640	0.1325	0.3592	0.8622	1.7095	2.3338	2.8335
	0.25	0.0132	0.0681	0.1412	0.3818	0.9075	1.7833	2.4216	2.9287
	0.30	0.0132	0.0729	0.1505	0.4048	0.9548	1.8563	2.5061	3.0185
	0.35	0.0154	0.0783	0.1612	0.4317	1.0039	1.9284	2.5873	3.1042
	0.40	0.0167	0.0845	0.1732	0.4594	1.0546	1.9990	2.6652	3.1848
	0.45	0.0173	0.0918	0.1874	0.4900	1.1066	2.0681	2.7400	3.2615
	0.50	0.0200	0.1002	0.2032	0.5227	2.1344	2.1356	2.8120	3.3349
	0.55	0.0222	0.1101	0.2192	0.5578	2.8755	2.2016	2.8815	3.4055
	0.60	0.0249	0.1222	0.2403	0.5959	1.2668	2.2658	2.9488	3.4742
	0.65	0.0283	0.1361	0.2649	0.6375	1.3216	2.3237	3.0142	3.5410
	0.70	0.0327	0.1538	0.2911	0.6829	1.3764	2.3855	3.0780	3.6064
	0.75	0.0388	0.1762	0.3212	0.7262	1.4307	2.4453	3.1405	3.6711
	0.80	0.0470	0.1988	0.3592	0.7736	1.4846	2.5033	3.2021	3.7355
	0.85	0.0600	0.2311	0.3975	0.8194	1.5378	2.5658	3.2632	3.8003
	0.90	0.0739	0.2653	0.4375	0.8705	1.5903	2.6225	3.3242	3.8662
	0.95	0.1052	0.3083	0.4877	0.9204	1.6419	2.6787	3.3869	3.9341
	1	0.1516	0.3554	0.5361	0.9706	1.6925	2.7345	3.4483	4.0051

Table 5: Table values for probability of acceptance for STDS plan

ω	ϕ	Pa(p)							
		0.99	**0.95**	**0.9**	**0.75**	**0.5**	**0.25**	**0.15**	**0.1**
0.05	0	0.0096	0.0536	0.1108	0.3053	0.7455	1.5571	2.2489	2.9306
	0.05	0.0101	0.0560	0.1166	0.3210	0.7849	1.6339	2.3510	3.0671
	0.10	0.0107	0.0601	0.1235	0.3386	0.8243	1.7118	2.4562	3.1757
	0.15	0.0112	0.0636	0.1302	0.3560	0.8672	1.7898	2.5479	3.2498
	0.20	0.0126	0.0675	0.1385	0.3781	0.9135	1.8647	2.6328	3.3329
	0.25	0.0132	0.0719	0.1474	0.4007	0.9604	1.9373	2.7081	3.3893
	0.30	0.0147	0.0769	0.1573	0.4252	1.0090	2.0075	2.7772	3.4315
	0.35	0.0154	0.0825	0.1685	0.4520	1.0591	2.0753	2.8406	3.4716
	0.40	0.0167	0.0891	0.1812	0.4810	1.1104	2.1354	2.9023	3.5186
	0.45	0.0173	0.0966	0.1955	0.5125	1.1627	2.2049	2.9533	3.5656
	0.50	0.0211	0.1054	0.2118	0.5459	1.2151	2.2626	3.0125	3.6124
	0.55	0.0233	0.1159	0.2306	0.5815	1.2680	2.3260	3.0754	3.6597
	0.60	0.0254	0.1284	0.2525	0.6200	1.3235	2.3875	3.1330	3.7251
	0.65	0.0297	0.1429	0.2784	0.6617	1.3774	2.4474	3.1919	3.7854
	0.70	0.0344	0.1606	0.3048	0.7071	1.4313	2.5077	3.2530	3.8527
	0.75	0.0408	0.1844	0.3372	0.7508	1.4853	2.5690	3.3278	3.9292
	0.80	0.0494	0.2076	0.3707	0.7979	1.5395	2.6320	3.4019	4.0177
	0.85	0.0630	0.2404	0.4092	0.8476	1.5951	2.6975	3.4839	4.1222
	0.90	0.0841	0.2752	0.4527	0.8952	1.6485	2.7666	2.7691	4.2455
	0.95	0.1088	0.3156	0.4992	0.9456	1.7039	2.8406	3.6852	4.4322
	1	0.1571	0.3657	0.5478	0.9969	1.7638	2.9206	3.8163	4.6707
0.09	0	0.0101	0.0565	0.1164	0.3208	0.7966	1.7364	2.7256	4.4436
	0.05	0.0112	0.0594	0.1225	0.3375	0.8375	1.8220	2.8417	4.4714
	0.10	0.0113	0.0628	0.1292	0.3557	0.8806	1.9043	2.9343	4.3898
	0.15	0.0125	0.0664	0.1367	0.3755	0.9257	1.9822	3.0004	4.2675
	0.20	0.0126	0.0705	0.1449	0.3971	0.9727	2.0552	3.0381	4.1396
	0.25	0.0134	0.0751	0.1542	0.4206	1.0213	2.1239	3.0820	4.0707
	0.30	0.0147	0.0803	0.1645	0.4462	1.0712	2.1873	4.0152	3.1253
	0.35	0.0154	0.0862	0.1762	0.4740	1.1222	2.2476	3.1562	3.9576
	0.40	0.0167	0.0930	0.1894	0.5040	1.1740	2.3050	3.1975	3.9462
	0.45	0.0192	0.1009	0.2043	0.5364	1.2263	2.3551	3.2291	3.9584
	0.50	0.0200	0.1101	0.2213	0.5712	1.2758	2.4160	3.2651	3.9588
	0.55	0.0222	0.1209	0.2406	0.6083	1.3288	2.4673	3.3064	3.9820
	0.60	0.0249	0.1336	0.2626	0.6477	1.3824	2.5234	3.3495	4.0232
	0.65	0.0283	0.1489	0.2877	0.6894	1.4361	2.5805	3.4100	4.0782
	0.70	0.0359	0.1672	0.3162	0.7330	1.4901	2.6404	3.4753	4.1518
	0.75	0.0388	0.1892	0.3484	0.7785	1.5447	2.7043	3.5529	4.2628
	0.80	0.0470	0.2157	0.3842	0.8256	1.6000	2.7737	3.6470	4.3770
	0.85	0.0600	0.2472	0.4239	0.8743	1.6565	2.8507	3.7546	4.5514
	0.90	0.0820	0.2844	0.4672	0.9244	1.7145	2.9370	3.9007	4.7966
	0.95	0.1052	0.3272	0.5137	0.9758	1.7746	3.0344	4.1083	5.2561
	1	0.1516	0.3751	0.5633	1.0285	1.8416	3.1643	4.4073	6.4530

Table 6: Values of p and $P_a(p)$ for plotting the OC curve of a specified STDS plan (φ=0.7)

ω=0.0001		ω=0.01		ω=0.05		ω=0.09	
$P_a(p)$	p	$P_a(p)$	p	$P_a(p)$	p	$P_a(p)$	p
0.99	0.0016	0.99	0.00164	0.99	0.0017	0.99	0.0018
0.95	0.0076	0.95	0.00769	0.95	0.0080	0.95	0.0084
0.90	0.0145	0.90	0.01456	0.90	0.0152	0.90	0.0158
0.75	0.0337	0.75	0.03415	0.75	0.0354	0.75	0.0367
0.50	0.0681	0.50	0.06882	0.50	0.0716	0.50	0.0745
0.25	0.1181	0.25	0.11927	0.25	0.1254	0.25	0.1320
0.15	0.1519	0.15	0.15390	0.15	0.1627	0.15	0.1738
0.10	0.1778	0.10	0.18032	0.10	0.1926	0.10	0.2076

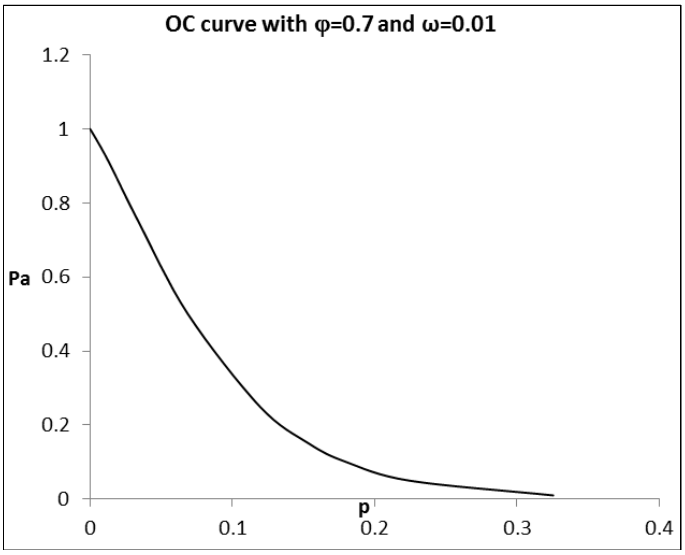

Fig 1: OC Curve for STDS plan

As described early the operating procedure of STDS plan is as follows:

1. From a lot, select a random sample of size n_1 units and count the number of defectives d_1. If $d_1 \geq 1$ reject the lot. If $d_1 = 0$, select a second random sample of size n_2 and count the number of defectives d_2.
2. If $d_2 \leq 1$, accept the lot; otherwise, that is, if $d_2 \geq 2$, reject the lot.

For fixed n_2 and p, equation (2) becomes a function of n denoted as $f(n) = [\omega + k'e^{-np}]k''$, where k' and k" are constants independent of n. it can be easily shown that $f(n) > f(n+1)$ for $0 < p < 1$. For, $f(n) > f(n+1)$ implies, $1 > e^{-p}$, which is always true. That is, $P_a(p)$ is a decreasing function of n for fixed n_2 and p.
For fixed n and p, equation (2) becomes $f(n_2) = (\omega + k'e^{-n_2 p})(\omega + k''e^{-n_2 p}(1 + n_2 p))$ Where k' and k" are constants independent of n_2. For $0 < p < 1$, it can be shown that $f(n_2) < f(n_2 + 1)$. For $f(n_2) < f(n_2 + 1)$ implies $0 < k''$. That is, $P_a(p)$ is an increasing function of n_2 for fixed n and p.

6. Expression for ASN function

Assuming no curtailment of inspection, the expression for ASN will be derived. A first sample of size n_1 will always taken. A second sample of size n_2 will be taken only when no defects are found in the first sample of n_1 units. Therefore,

$$ASN(p) = n_1 + n_2[\omega + (1-\omega)e^{-n_1 p}] \quad (6)$$

The following properties of ASN can be observed

a) ASN (p) is decreasing function of p when n_1 and n_2 are fixed.
b) At p=0, ASN (p) occurs it is maximum value, because for fixed n_1 and n_2, ASN (p) is maximum only when $e^{-n_1 p}$ is maximum. The maximum value of $e^{-n_1 p}$ for 0≤p≤1 is 1 when p=0. Therefore ASN (p) will decrease from $n = n_1 + n_2$ to n_1 as p increases from 0 to 1.

From equation (3.6), one gets,

$$\frac{ASN(p)}{n} = 1 - \varphi + \varphi\left(\omega + (1-\omega)e^{-(1-\varphi)x}\right) \quad (7)$$

Equation (7) gives the ratio of average sample size of STDS plan to the combined sample size as function of φ and x.

7. Plotting of ASN curve of a given STDS Plan

Assuming no curtailment of inspection in both the first and second stages of sampling, an ASN curve of a given STDS plan can be constructed using Table 7 or 8 by multiplying each entry in the row for the given φ by the value of n. The result of each multiplication is the ASN at p that has a probability of acceptance $P_a(p)$ shown in the column heading. The value of p that has a known $P_a(p)$can be found using Table of 'np' values for different ω by dividing np by n. Simultaneous use of Tables of np values and Table 7 or 8 gives some points to plot the ASN curve. For example for given$n_1 = 6 \; and \; n_2 = 14$, multiplication of the entries of Table 7 opposite to $\varphi = \frac{14}{20} = 0.70$ by 20, and division of the entries of Table of np values opposite to 0.70, lead to Table 9 for plotting the ASN curve for ω=0.0001 and ω=0.01.

Table 7: Table values of$\frac{ASN}{n}$for STDS plan

ω	φ	$P_a(p)$									
		0.99	**0.95**	**0.9**	**0.75**	**0.5**	**0.25**	**0.15**	**0.1**	**0.05**	**0.01**
0.0001	0	1	1	1	1	1	1	1	1	1	1
	0.05	0.9995	0.9975	0.995	0.9875	0.975	0.9626	0.9576	0.955	0.9525	0.9506
	0.1	0.999	0.995	0.9901	0.9751	0.9502	0.9254	0.9154	0.9104	0.9053	0.9012
	0.15	0.9986	0.9926	0.9851	0.9628	0.9256	0.8886	0.8736	0.866	0.8584	0.8521
	0.2	0.998	0.99	0.9801	0.9505	0.9014	0.8525	0.8326	0.8224	0.812	0.803
	0.25	0.9977	0.9877	0.9754	0.9385	0.8779	0.8175	0.7927	0.7799	0.7665	0.7544
	0.3	0.9972	0.9852	0.9703	0.9267	0.8554	0.784	0.7543	0.7387	0.7255	0.7063
	0.35	0.9967	0.9828	0.9655	0.9154	0.834	0.7524	0.7178	0.6992	0.6829	0.6647
	0.4	0.9962	0.9804	0.9609	0.9047	0.8144	0.7232	0.6837	0.6621	0.6379	0.6129
	0.45	0.9959	0.978	0.9564	0.8948	0.7969	0.697	0.6527	0.6279	0.5995	0.5684
	0.5	0.9952	0.9757	0.9522	0.8861	0.7821	0.6749	0.6257	0.5978	0.5645	0.5258
	0.55	0.9945	0.9734	0.9484	0.8792	0.7708	0.657	0.6039	0.5726	0.5341	0.4867
	0.6	0.9941	0.9714	0.9451	0.8739	0.7635	0.6454	0.5877	0.553	0.5096	0.4524
	0.65	0.9936	0.9698	0.9427	0.8712	0.7613	0.6406	0.5799	0.5421	0.4935	0.425
	0.7	0.9932	0.9688	0.9416	0.8718	0.7651	0.6446	0.5813	0.5409	0.4879	0.4068
	0.75	0.9928	0.9685	0.9422	0.8766	0.7763	0.6595	0.5963	0.5541	0.4966	0.4051
	0.8	0.9925	0.9688	0.9451	0.8865	0.7964	0.6874	0.6259	0.5846	0.5248	0.4247
	0.85	0.9924	0.9713	0.9514	0.9024	0.8265	0.7313	0.6751	0.6364	0.5784	0.4762
	0.9	0.9933	0.9765	0.9616	0.9259	0.8689	0.795	0.7492	0.7165	0.6668	0.5727
	0.95	0.995	0.9856	0.9773	0.9577	0.9259	0.8826	0.8546	0.8344	0.8019	0.737
	1	1	1	1	1	1	1	1	1	1	1
0.01`	0	1	1	1	1	1	1	1	1	1	1
	0.05	0.9995	0.9975	0.995	0.9874	0.9748	0.9622	0.9571	0.9546	0.9521	0.9501
	0.1	0.9991	0.995	0.9899	0.9748	0.9496	0.9245	0.9145	0.9094	0.9044	0.9003
	0.15	0.9986	0.9925	0.9849	0.9623	0.9248	0.8874	0.8723	0.8647	0.857	0.8506
	0.2	0.998	0.99	0.9799	0.95	0.9003	0.8509	0.8309	0.8207	0.8103	0.8014
	0.25	0.9975	0.9875	0.9749	0.9378	0.8766	0.8156	0.7907	0.7778	0.7643	0.7524
	0.3	0.9972	0.9851	0.97	0.926	0.8538	0.7818	0.7519	0.7363	0.7195	0.7042
	0.35	0.9965	0.9826	0.9652	0.9144	0.8322	0.7499	0.7151	0.6965	0.6762	0.6565
	0.4	0.996	0.9802	0.9605	0.9036	0.8124	0.7205	0.6808	0.6592	0.6349	0.61
	0.45	0.9957	0.9779	0.9559	0.8937	0.7948	0.6943	0.6497	0.6248	0.5961	0.565
	0.5	0.995	0.9756	0.9517	0.885	0.672	0.6719	0.6226	0.5944	0.5608	0.5219
	0.55	0.9945	0.9734	0.9483	0.8779	0.6008	0.6542	0.6004	0.5688	0.5301	0.4824
	0.6	0.9941	0.9714	0.945	0.8728	0.7615	0.6424	0.5845	0.5495	0.5053	0.4472
	0.65	0.9936	0.9698	0.9425	0.87	0.7593	0.6382	0.5763	0.5382	0.4884	0.4186
	0.7	0.9932	0.9684	0.9415	0.8703	0.7632	0.6422	0.578	0.5373	0.4821	0.3993
	0.75	0.9928	0.9677	0.9421	0.8755	0.7745	0.657	0.5921	0.5496	0.4899	0.3936
	0.8	0.9925	0.9688	0.9445	0.8853	0.7945	0.6849	0.6217	0.579	0.5168	0.408
	0.85	0.9924	0.971	0.9508	0.9017	0.8249	0.7285	0.671	0.6307	0.5695	0.4524
	0.9	0.9934	0.9764	0.9615	0.925	0.8677	0.7924	0.7455	0.7114	0.6575	0.5363
	0.95	0.995	0.9855	0.9771	0.9573	0.9251	0.8809	0.852	0.8304	0.7944	0.6994
	1	1	1	1	1	1	1	1	1	1	1

Table 8: Table values of $\frac{ASN}{n}$ for STDS plan

ω	φ	$P_a(p)$							
		0.99	**0.95**	**0.9**	**0.75**	**0.5**	**0.25**	**0.15**	**0.1**
0.05	0	1	1	1	1	1	1	1	1
	0.05	0.9995	0.9974	0.9948	0.9869	0.9737	0.9606	0.9554	0.9527
	0.10	0.999	0.9947	0.9895	0.9737	0.9476	0.9214	0.911	0.9057
	0.15	0.9986	0.9921	0.9843	0.9608	0.9218	0.8828	0.8672	0.8595
	0.20	0.998	0.9895	0.979	0.9478	0.8963	0.845	0.8243	0.8139
	0.25	0.9975	0.9869	0.9738	0.9351	0.8717	0.8085	0.7828	0.7697
	0.30	0.9969	0.9843	0.9687	0.9228	0.848	0.7736	0.7429	0.7272
	0.35	0.9965	0.9817	0.9637	0.9109	0.8258	0.7408	0.7052	0.6867
	0.40	0.996	0.9792	0.9588	0.8997	0.8055	0.7111	0.6701	0.6484
	0.45	0.9957	0.9767	0.9541	0.8895	0.7874	0.6838	0.6387	0.6133
	0.50	0.9948	0.9743	0.9498	0.8806	0.7723	0.6613	0.6109	0.5821
	0.55	0.9943	0.9721	0.9458	0.8734	0.7609	0.6431	0.5878	0.556
	0.60	0.9939	0.97	0.9424	0.8682	0.7534	0.6309	0.5714	0.5352
	0.65	0.9933	0.9683	0.9397	0.8656	0.7514	0.626	0.5627	0.5228
	0.70	0.9928	0.9671	0.9388	0.8662	0.7556	0.6299	0.5638	0.5204
	0.75	0.9924	0.9662	0.9394	0.8717	0.7674	0.6446	0.5764	0.5308
	0.80	0.9921	0.9675	0.9428	0.882	0.788	0.6726	0.6051	0.5582
	0.85	0.992	0.9699	0.9494	0.8985	0.8191	0.7171	0.654	0.608
	0.90	0.9925	0.9756	0.9602	0.9229	0.8632	0.7825	0.7823	0.6887
	0.95	0.9948	0.9851	0.9766	0.9561	0.9224	0.8742	0.8401	0.8112
	1	1	1	1	1	1	1	1	1
0.09	0	1	1	1	1	1	1	1	1
	0.05	0.9995	0.9973	0.9945	0.9863	0.9726	0.9589	0.9534	0.9507
	0.10	0.999	0.9945	0.989	0.9726	0.9453	0.918	0.9071	0.9019
	0.15	0.9984	0.9918	0.9836	0.959	0.9183	0.8778	0.8617	0.854
	0.20	0.998	0.989	0.9781	0.9456	0.8918	0.8386	0.8176	0.8073
	0.25	0.9975	0.9863	0.9727	0.9324	0.8662	0.8008	0.7748	0.7618
	0.30	0.9969	0.9836	0.9674	0.9195	0.8417	0.7649	0.718	0.7337
	0.35	0.9965	0.9809	0.9621	0.9072	0.8188	0.7312	0.695	0.6767
	0.40	0.996	0.9783	0.957	0.8956	0.7978	0.7003	0.6587	0.6375
	0.45	0.9953	0.9757	0.9522	0.885	0.7792	0.6732	0.6262	0.601
	0.50	0.995	0.9732	0.9476	0.8758	0.7642	0.6494	0.5977	0.5691
	0.55	0.9945	0.9709	0.9436	0.8683	0.7525	0.6312	0.5742	0.5417
	0.60	0.9941	0.9688	0.9402	0.863	0.7452	0.6187	0.5571	0.52
	0.65	0.9936	0.967	0.9377	0.8607	0.7432	0.6134	0.5471	0.506
	0.70	0.9925	0.9658	0.9366	0.8618	0.7477	0.617	0.5468	0.5015
	0.75	0.9928	0.9654	0.9374	0.8674	0.7597	0.6315	0.5585	0.5084
	0.80	0.9925	0.9662	0.9408	0.8782	0.7809	0.6594	0.5858	0.5334
	0.85	0.9924	0.9691	0.9476	0.8955	0.813	0.7043	0.634	0.5795
	0.90	0.9926	0.9748	0.9589	0.9205	0.8582	0.7709	0.7093	0.6571
	0.95	0.995	0.9846	0.9759	0.9548	0.9193	0.8663	0.8236	0.7804
	1	1	1	1	1	1	1	1	1

Table 9: ASN (p) values for STDS plan

φ=0.70								
pa	**0.0001**		**0.01**		**0.05**		**0.09**	
	p	**ASN**	**p**	**ASN**	**p**	**ASN**	**p**	**ASN**
0.99	0.0016	19.8636	0.0016	19.8633	0.0017	19.8564	0.0016	19.8633
0.95	0.0076	19.3759	0.0077	19.3689	0.0080	19.3413	0.0084	19.3152
0.90	0.0145	18.8316	0.0146	18.8291	0.0152	18.7766	0.0158	18.7329
0.75	0.0337	17.4359	0.0341	17.4065	0.0353	17.3242	0.0367	17.2363
0.50	0.0681	15.3030	0.0688	15.2641	0.0716	15.1126	0.0745	14.9534
0.25	0.1181	12.8913	0.1193	12.8443	0.1254	12.5978	0.1320	12.3403
0.15	0.1519	11.6269	0.1539	11.5604	0.1627	11.2759	0.1738	10.9356
0.10	0.1778	10.8185	0.1803	10.7452	0.1926	10.4072	0.2076	10.0291

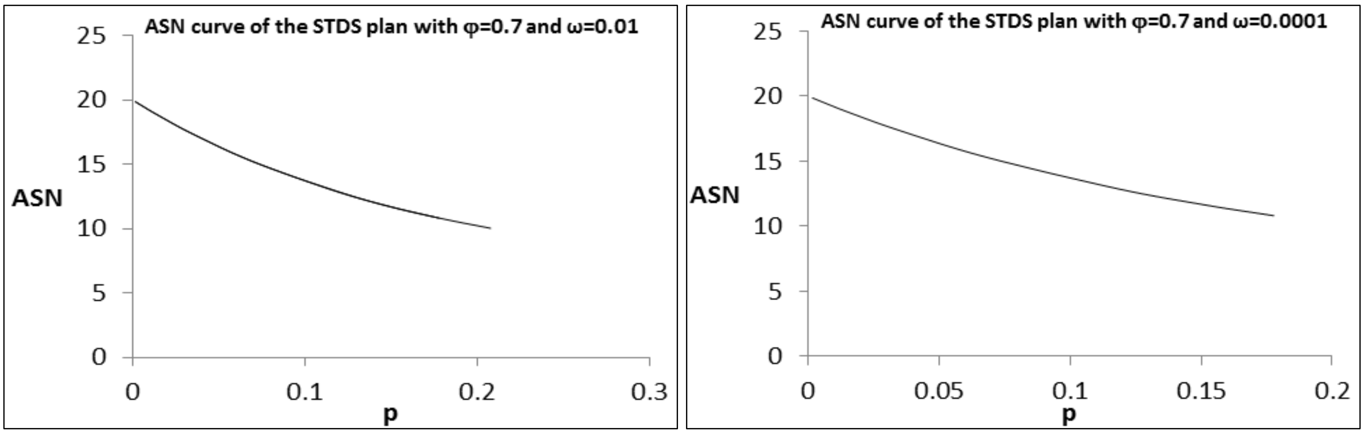

Fig 2: ASN curve for STDS plan

Figure-2 shows the ASN curve of STDS plan for φ=0.70 under ZIP distribution with ω=0.0001 and 0.01. The ASN value decreases from n as p increases from 0. For very small proportion defective, the ASN value is higher because a second sample must be taken more frequently to make a decision. For very large values of p, the value of ASN approaches the first sample sizen_1.

8. Conclusion

This paper deals with Zero-Inflated Poisson distribution which is the one of the important discreet probability distribution in a manufacturing sector. In a production process being well-monitored, occurrence of non-defects would be more frequent and a ZIP distribution is the appropriate probability distribution to the number of defects per unit.

The aim is to development a sampling plan which meets the requirements with respect to the producer's and consumer's risk can be obtained that is optimal with respect to the sample size. The OC function of the STDS plan under the conditions of ZIP distribution has been derived. The procedure for designing STDS using unity values under the conditions of ZIP distribution is presented. Tables providing the SSPs are presented for some specified strength.

A comparison is also made with OC function of SSP and STDS plan under the condition of Zero-Inflated Poisson distribution. The STDS plans under Poisson distribution become special cases of the STDS plans under ZIP distribution.

9. References

1. Bohning D, Dietz E, Schlattmann P. The zero-inflated Poisson model and the decayed, missing and filled teeth index in dental epidemiology. Journal of royal statistical society, Series A. 1999; 162:195-209.
2. Dodge HF, Roming HG. Sampling Inspection tables. Second Edition, New York, wiley, 1959.
3. Govindaraju K. Contribution to the Study of Certain Special Purpose Plans. PhD Thesis, Bharathiar University-641046, Tamilnadu, 1984.
4. Kaviyarasu V, Deepa A. Designing of Special Type Double Sampling Plan using Fuzzy Poisson Distribution. M. Phil Thesis, Department of Statistics, Bharathiar University-641046, 2014.
5. Lambert D. Zero-inflated Poisson regression with an application to defects in manufacturing. Technometrics. 1992; 34:1-14.
6. Loganathan A, Shalini K. Determination of Single Sampling Plans by Attributes Under the Conditions of Zero-Inflated Poisson Distributions. Communication in Statistics- Simulation and Computation. 2014; 43(3):538-548.
7. McLachlan G, Peel D. Finite Mixture Models. New York: John Wiley & Sons, 2000.
8. Naya H, Urioste JI, Chang YM, Motta MR, Kremer R, Gianola D. A comparison between Poisson and zero inflated Poisson regression models with an application to number of black spot in corriedale sheep. Genetics Selection Evolution. 2008; 40:379-394.
9. Ridout M, Demtrio CGB, Hinde J. Models for Count Data with Many Zeros. Cape Town: International Biometric Conference, 1998.
10. Vinoth Kaviyarasu V. Quick Switch System with Special Type Double Sampling plan a as reference plan. M. Phil Thesis, Department of Statistics, Bhararthiar University, Coimbatore-641046, 2014.
11. Xie M, He B, Goh TN. Zero-inflated Poisson model in statistical process control. Computational Statistics & Data Analysis. 2001; 38:191-201.