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Zero One Sampling System

Arumainayagam S.D[1], Vennila J[2]
Department of Statistics[1]
Government Arts College,
Coimbatore – 641 018,
Tamil Nadu, India.
Email: devarajs567@gmail.com[1]
Department of Statistics[2]
KMCH College of Pharmacy,
Coimbatore – 641 048,
Tamil Nadu, India
Email: nilajagan92@gmail.com

Abstract- This paper introduces a new switching system meant for costly and destructive testing. Measures of performance, designing of system for various entry parameters and comparison with existing plans are given.

Index Terms- Acceptance Sampling System, Quick Switching System, Destructive Testing.

1. INTRODUCTION

Dodge (1967) introduced a new sampling system called "Quick Switching System" (QSS-1) for attributes acceptance sampling plan, involving both normal and tightened plans. The application of the system is as follows:

1. 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.
2. 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.
3. 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'.

Further, Romboski (1969) has developed two QSSs, namely QSS (n, c_N, c_T) and QSS(n, kn, c_0). Soundararajan and Arumainayagam (1988) provided the tables for the selection of modified QSS. Soundararajan and Arumainayagam (1990, 1991, 1992, 1994 and 1995) have developed QSS using single, double and repetitive sampling plans as reference plans. Soundararajan and Arumainayagam (1992) developed systems based on QSS for products involving costly and destructive testing. Suresh (1993) has proposed a procedure for selection of QSS indexed through various quality limits.

Arumainayagam and Uma (2008) constructed the tables for matched single, double and multiple sampling plans using QSS. Suresh and Kaviyarsu(2008) studied quick switching system with conditional group sampling plan as reference plan. Arumainayagam and Uma (2009 and 2013) have developed QSS using single sampling plan as reference plan with weighted Poison distribution. Suresh and Jayalakshmi (2009) have developed QSS with special type of double sampling plan as reference plan.

Arumainayagam and Uma (2011) have studied QSS using triple sampling plan as reference plan. Uma and Nandhinidevi (2015) have studied the quick switching system with fuzzy logic system in Poisson distribution. Uma and Gunasekaran (2016) have developed QSS Zero Inflated Poisson Distribution as reference plan and compared ZIP with Poisson distribution for the purpose of consumer protection. Uma and Ramya (2017) studied QSS with double sampling plan fuzzy binomial distribution as the baseline distribution. Divya and Arumainayagam (2018) studied QSS using multiple sampling plans as reference plan.

This paper introduces a new sampling inspection system meant for costly and destructive testing based on the switching rules of QSS. This system employs double sampling plan with o and 1 as acceptance numbers for normal plan while the tightened plan uses single sampling plan with zero acceptance numbers. When the lot contains costly and destructive items and when the quality is good, DSP (0,1) plan is employed to give some advantage to the producers. However, when a lot is rejected, then SSP with zero acceptance number is employed to eliminate the lots with defective items thus giving protection to the consumer.

2. ZERO ONE SAMPLING SYSTEM

This system is designated as zero one sampling system ZOSS (n; k), where the normal double sampling has the parameters of $n_1=n_2=n$, $c_1=0$ and $c_2=1$ and tightened single sampling has the parameters kn, $k \geq 1$.

2.1. *Conditions for Application*

i. The product to be inspected is of a series of successive lots produced by a continuing process.
ii. Normally, lots are expected to be essentially of the same quality.
iii. Lots are submitted substantially in the order of production.
iv. Inspection is by attributes, with quality defined as the fraction non-conforming.

2.2. *Operating Procedure*

Step 1: From a lot, take a random sample of size n and count the number of defectives x_1.

(i) If $x_1 = 0$, then accept the lot, repeat step 1 for the next lot.
(ii) If $x_1 > 1$, then reject the lot and continue step 2 for the next lot.
(iii) If $x_1 = 1$, then take a second random sample of size n form the same lot, and count the number of defectives x_2.
(iv) $x_1 + x_2 = 1$, then accept the lot and repeat step 1 for the next lot
(v) $x_1 + x_2 > 1$, then reject the lot and go to step 2 for the next lot.

Step 2: From the next lot, take a random sample of size kn at tightened inspection level and count the number of defectives x.

(i) If $x \leq 0$, accept the lot and go to step 1 for the next lot.
(ii) If $x > 0$, reject the lot and repeat step 2 for the next lot.

3. MEASURES OF PERFORMANCE

The OC function of ZOSS (n; k) is given below

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

Where
P_N = Proportion of lots expected to be accepted when using normal double sampling plan
P_T = Proportion of lots expected to be accepted when using tightened single sampling plan

Under the assumption of Poisson Model (Hamaker and Van Strik (1995)), values of P_N and P_T are given by

$$\left.\begin{aligned} P_N &= e^{-(np)} + np\, e^{-(2np)} \\ P_T &= e^{-knp} \end{aligned}\right\} \qquad (2)$$

3.1. *Properties of the OC Curve*

1. Figures. 1 and 2 give the normal, tightened and composite OC curve of ZOSS. The composite OC curve lies between normal and tightened OC curves. For good quality, the normal plan has more probability being applied in the system and hence it is closer to the composite OC curve. From these curves; it is observed that, when comparing the composite OC curve with its corresponding normal and tightened OC curves, it is in better shape than the other curves.
2. Figures 3 and 4 give a set of composite OC curves. In these curves, the normal plan is fixed and in the tightened plan k is allowed to increase. That is tightening is made severe. It is observed that as the value of p increases, the OC curve approaches to the shape of an ideal OC curve.

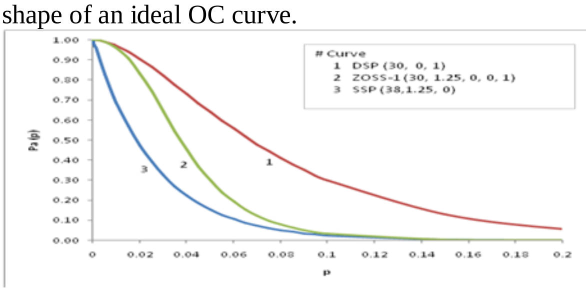

Figure 1: Normal, Tightened and Composite OC curves of ZOSS

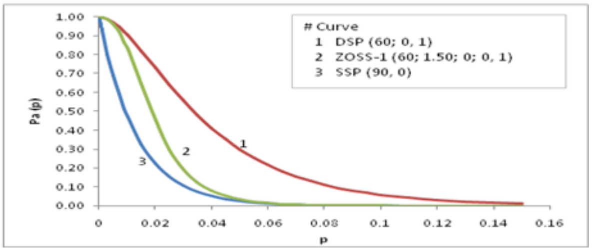

Figure 2: Normal, Tightened and Composite OC curves of ZOSS

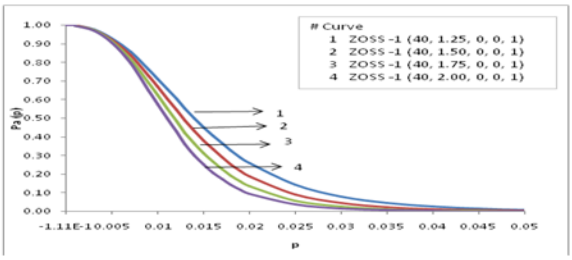

Figure 3: Composite OC curves of ZOSS

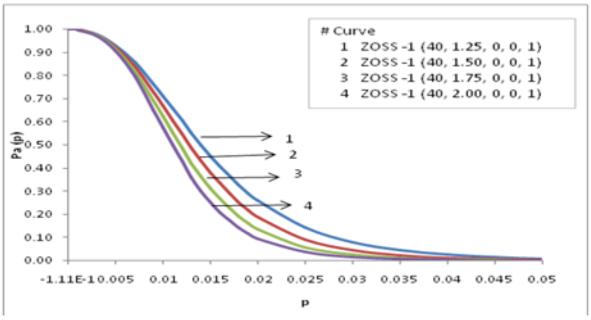

Figure 4: Composite OC curves of ZOSS

4. ASN

Based on the work of Stephens and Larson (1967), the ASN function for the ZOSS is given below

$$ASN = ASN_N P^N + ASN_T P^T \quad (3)$$

Where

ASN_N = ASN of Normal double sampling plan
ASN_T = ASN of Tightened single sampling plan
P^N = the expected proportions of lots inspected during normal inspection
P^T = the expected proportions of lots inspected during tightened inspection

The ASNs of the normal double and tightened single sampling plans of ZOSS (n, k) are given by

$$ASN_N = n + n(1 - (e^{-np} + npe^{-2np})) \quad (4)$$

$ASN_T = n$

$P^N = e^{-np} + np\, e^{-2np}$ and

$$P^T = 1 - e^{-np} \quad (5)$$

On substituting equations (4) and (5) into equation (3), we get the ASN of ZOSS (n, k) as

$$ASN(p) = ne^{-np}[1 + 2np\, e^{-np} + e^{-np} + (np)^2\, e^{-2np}] + kn\ [1 - e^{-knp}] \quad (6)$$

The average total inspection of ZOSS (n; k) is given by

$$I = ATI_N P^N + ATI_T P^T \quad (7)$$

Where ATI_N and ATI_T are the average total inspection of the normal double sampling plan and tightened single sampling plan respectively. From Duncan (1986), ATI_N and ATI_T for ZOSS (n; k) under Poisson model are given by

$$ATI_N = n + n\,(1 - P_a) + (N - n)\,(1 - P_1) \quad (8)$$

$$ATI_T = n + (1 - P_a)(N - n) \quad (9)$$

Where N is the lot size and substituting equations (5), (8) and (9) into equations (7), we get the ATI of ZOSS (n, k) as given below

$$I = 2n + \left[1 - e^{-np} + np\, e^{-2np}\right]\,(N - n)\left[e^{-np} + np\, e^{-2np}\right] + N\left[1 - e^{-knp}\right] \quad (10)$$

5. AOQ VALUE

Assuming the nonconforming units are replaced by good units in samples taken from accepted lots and also that nonconforming units are completely replaced in rejected lots, the average outgoing quality of ZOSS is given by

$$AOQ = p\left(\frac{N - I}{N}\right) \quad (11)$$

$$= p.P_a(p) \quad when \quad n/N \ \ is\ Small \quad (12)$$

Also, $AOQL = p_m . P_a\,(p_m)$ (13)

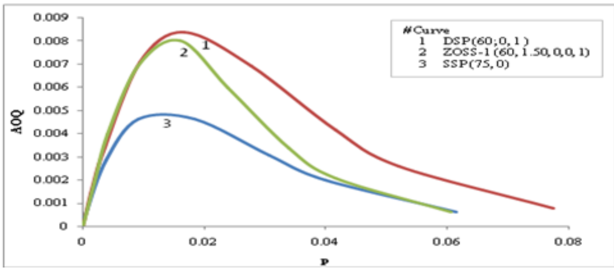

Figure 5: Average Outgoing Quality Curves of Normal SSP, Tightened DSP and ZOSS

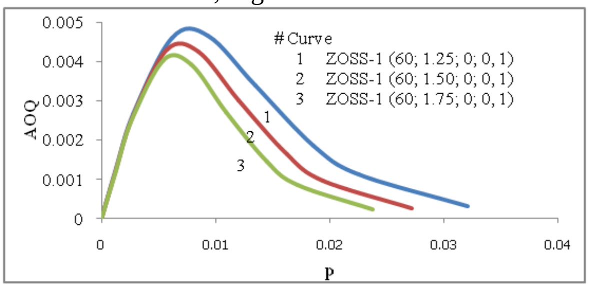

Figure 6: Average Outgoing Quality Curves of Normal SSP, Tightened DSP and ZOSS

From the above AOQ curve,

1. Figure 5 gives the average outgoing quality curve of ZOSS using equation (12) and its normal single sampling and tightened double sampling plans. The AOQ curve of the system lies between those of normal single sampling plan and tightened double sampling plan. In this curves can observed that the small values of p, the outgoing quality of the system lies between those of the normal single sampling and tightened double sampling plans.

2. Figure 6 gives a set of AOQ curves of ZOSS (n, k). In this curve, it is observed that, for good quality the outgoing quality resulting from the three systems are same whereas for poor quality, as the tightening become severe, the outgoing quality p decreases.

6. DESIGNING SYSTEM

6.1. *Plotting the OC Curve*

Table 1 can be used to obtain the values of p and Pa(p) to plot the OC curve of a given ZOSS (n, k).

Example
For ZOSS n=50, k=1.50 c=0; c_1= 0 c_2=1, division of entries opposite to c=0, c_1=0 and c_2=1 row of in Table 1 by 50 leads to the following Table:

Table 1 - Values for OC curve of ZOSS (50, 1.50, 0, 0, 1)

Pa(p)	0.99	0.95	0.75	0.50	0.25	0.10	0.05	0.01
p	0.0016	0.0036	0.0088	0.0143	0.0225	0.0331	0.0415	0.0620

6.2. *Designing the Systems, Given p_1, p_2, α and β*

Table 4 can be used to design ZOSS (n; k) for given p_1, p_2, α and β by the following steps:

1. Find the value of p_2/p_1.
2. Determine the value of p_2/p_1 in Table 4 in the column for appropriate α and β that is closer to the computed p_2/p_1.
3. Find the values of k corresponding to the ratio located.
4. Corresponding to the selected k, from Table 3, find the value of np_1
5. The sample size of the system is found by dividing np_1 by p_1.

Example:
To obtain ZOSS (n; k) for the given values of p_1 = 0.01, α = 0.05, p_2 = 0.09 and β = 0.10, the following steps are to be followed:

1. Compute p_2/p_1 = 0.09 / 0.01 = 9.00
2. The value of p_2/p_1 which is nearly equal to 9.00 in Table 4 under the column of α = 0.05 and β = 0.10 is 9.0922
3. The value of k corresponding to 4.5083 are k = 1.50.
4. For k=1.50, value of np_1 obtained from Table 3 is 0.1823.
5. The sample size is determined as n = np_1 / p_1 = 0.1823 / 0.01 = 18.
6. The designed system is Z0SS – 1 (18; 1.50; 0; 0, 1).

6.3. *Designing system given AQL and AOQL*

Table 5 can be used to design ZOSS (n; k) for specified values of AQL and AOQL.

Example
To determine a ZOSS (n; k), having AQL (α = 0.05) = 0.01 and AOQL = 0.0006, compute AOQL/p_1 = 0.0006 / 0.01 = 0.06. From Table 5, under the column headed AOQL/p_1, value closer to the desired value is 0.0605, which corresponds to a value of k=1.65. Corresponding to these parameters, value of np_1 obtained from Table 5 is 0.1799. The normal double sampling plan sample size is obtained by n = np_1 / p_1 = 0.1799 / 0.01 = 18. The designed system is ZOSS (18; 1,65; 0 ;0 ,1).

6.4. *Indifference Quality Level and h_0*

Table 5 can be used to design ZOSS (n; k) indexed by point of control and point of control.

Example
To design a ZOSS having p_0 = 0.02 and h_0 = 1.2, from Table 5, under the column headed h_0 find the value which is closer to the desired value. The value is 1.2020 which has associated with it a value of k = 1.65, c = 0, c_1 = 0 and c_2 = 1. Corresponding to these parameters, value of np_0 is 0.6860. The sample size of normal double sampling plan is obtained as n = np_0 / n = 0.6860 / 0.02 ≈ 34. The designed system is ZOSS (34; 1.65, 0; 0, 1).

6.5. *Calculating AOQL of the system*

Table 5 provides the np_m and nAOQL values for ZOSS (n; k). This table can be used to determine np_m and nAOQL of a system.

Example:
Determine the pm and AOQL of ZOSS (34; 1.65; 0; 0, 1). From Table 5, corresponding to k=1.65, nAOQL = 0.0109 and np_m = 3.4991. so AOQL = nAOQL / n = 0.0109 / 34 = 0.0003% and p_m = np_m / n = 3.4991 / 34 = 0.10%.

6.6. *Conversion of Parameters*

For ZOSS (n; k), if p_1=0.02, p_2=0.04, α=0.05 and β=0.10, the system satisfying the requirements can be obtained from Table 5 as n = 34, k= 1.65, c = 0, c_1 = 0 and c_2 = 1. Corresponding to k= 1.65, c = 0, c_1 = 0 and c_2 = 1., from Table 3, 4 and 5, one can get the following:

np_1 = 0.1799, np_m = 3.4991, nAOQL = 0.0109
np_0 = 0.6860 and h_0 = 1.2020.

So,AOQL = nAOQL/n = 0.0109/34 = 0.0003
p_0 = np_0 / n = 0.1799/34 = 0.0053.

So, when p_1=0.02, α = 0.05, p_2 = 0.04 and β = 0.10, the other similar sets of parameters are given by
1. p_1 = 0.02 (α = 0.05) and AOQL = 0.0003
2. p_0 = 0.0053 and h_0 = 1.2020.

7. COMPARISON & CONCLUSION

Four QSS-1 (n, k_n, c_0), QSS-2 (n, k_n, c_0), QSS-3 (n, k_n, c_0) and their equivalent ZOSS (n, k) values are given in Table 2. The measure operating ratio is used as the basis for 'matching'. QSS-1 (n, k_n, c_0), QSS-2 (n, k_n, c_0), QSS-3 (n, k_n, c_0) plan values are taken from Soundararajan and Arumainayagm (1988). From this table, it is observed that the new system requires lesser sample size and it's shown to be more efficient than the existing one.

8. CONSTRUCTION OF TABLES

The OC function of ZOSS (n; k) is given below

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

Where

$$P_N = e^{-(np)} + np\, e^{-(np)}\left[e^{-(np)}\right]$$

$$P_T = e^{-knp} \quad (2)$$

For given values of c, c_1, c_2 and $P_a(p)$, equation (1) is solved for np using unit value approach technique in MATLAB program. Table 3 provides np values for given c, c_1, c_2 and $P_a(p)$. From these values, operating ratio p_2/p_1 is calculated and that values are tabulated in Table 4 for assumed values of α and β. Assuming nAOQ=np*P_a(p), for given values of c, c_1, c_2, the values of np_m which maximise nAOQ can be obtained from equation (1). Values of np_m and nAOQL are tabulated for given c, c_1 and c_2 values in Table 5. The values of AOQL/p_1 of Table 5, for given values of c, c_1 and c_2 values are obtained by dividing nAOQL by np_1 for the appropriate c, c_1 and c_2 values. Using the np_0 values of Table 5, h_0 values are calculated and tabulated in Table 5.

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Table 3: Values of np tabulated against k for the given valuesof $P_a(p)$ for ZOSS (n, k)

k	0.99	0.95	0.75	0.50	0.25	0.10	0.05	0.01
1.00	0.0828	0.1909	0.4909	0.8603	1.4675	2.3251	3.0032	4.6056
1.10	0.0824	0.1891	0.4790	0.8252	1.3767	2.1420	2.7480	4.1921
1.15	0.0823	0.1882	0.4733	0.8091	1.3366	2.0627	2.6376	4.0128
1.20	0.0821	0.1873	0.4679	0.7939	1.2996	1.9902	2.5369	3.8487
1.25	0.0819	0.1865	0.4626	0.7795	1.2651	1.9235	2.4445	3.6980
1.30	0.0818	0.1856	0.4575	0.7658	1.2331	1.8621	2.3594	3.5592
1.35	0.0816	0.1848	0.4526	0.7528	1.2031	1.8052	2.2808	3.4309
1.40	0.0814	0.1839	0.4478	0.7404	1.1749	1.7524	2.2081	3.3120
1.45	0.0813	0.1831	0.4431	0.7286	1.1485	1.7033	2.1405	3.2015
1.50	0.0811	0.1823	0.4386	0.7172	1.1236	1.6574	2.0775	3.0986
1.55	0.0809	0.1815	0.4342	0.7064	1.1001	1.6144	2.0186	3.0025
1.60	0.0808	0.1807	0.4300	0.6960	1.0778	1.5741	1.9636	2.9126
1.65	0.0806	0.1799	0.4259	0.6860	1.0567	1.5361	1.9119	2.8283
1.70	0.0805	0.1791	0.4218	0.6764	1.0366	1.5004	1.8633	2.7490
1.75	0.0803	0.1784	0.4179	0.6671	1.0175	1.4666	1.8175	2.6745
1.80	0.0802	0.1776	0.4141	0.6583	0.9994	1.4346	1.7743	2.6041
1.85	0.0800	0.1769	0.4104	0.6497	0.9820	1.4043	1.7334	2.5377
1.90	0.0798	0.1761	0.4068	0.6414	0.9654	1.3756	1.6947	2.4749
1.95	0.0797	0.1754	0.4032	0.6334	0.9496	1.3482	1.6580	2.4154
2.00	0.0795	0.1747	0.3998	0.6257	0.9344	1.3222	1.6231	2.3590
2.05	0.0794	0.1740	0.3964	0.6182	0.9198	1.2973	1.5899	2.3054
2.10	0.0792	0.1733	0.3932	0.6110	0.9058	1.2736	1.5582	2.2543
2.15	0.0791	0.1726	0.3899	0.6040	0.8923	1.2509	1.5281	2.2058
2.20	0.0789	0.1719	0.3868	0.5972	0.8793	1.2292	1.4992	2.1594
2.25	0.0788	0.1712	0.3837	0.5906	0.8669	1.2084	1.4717	2.1152
2.30	0.0786	0.1706	0.3807	0.5842	0.8548	1.1884	1.4453	2.0730
2.35	0.0785	0.1699	0.3778	0.5780	0.8432	1.1693	1.4200	2.0326
2.40	0.0783	0.1693	0.3749	0.5720	0.8320	1.1509	1.3957	1.9939
2.45	0.0782	0.1686	0.3721	0.5661	0.8212	1.1331	1.3724	1.9568
2.50	0.0780	0.1680	0.3694	0.5604	0.8107	1.1161	1.3501	1.9212
2.55	0.0779	0.1674	0.3667	0.5549	0.8006	1.0996	1.3285	1.8870
2.60	0.0778	0.1667	0.3640	0.5495	0.7908	1.0838	1.3078	1.8542
2.65	0.0776	0.1661	0.3614	0.5442	0.7813	1.0685	1.2878	1.8226
2.70	0.0775	0.1655	0.3589	0.5391	0.7720	1.0537	1.2685	1.7922
2.75	0.0773	0.1649	0.3564	0.5340	0.7631	1.0394	1.2499	1.7629
2.80	0.0772	0.1643	0.3540	0.5292	0.7544	1.0255	1.2320	1.7347
2.85	0.0770	0.1637	0.3516	0.5244	0.7460	1.0122	1.2146	1.7074
2.90	0.0769	0.1631	0.3492	0.5197	0.7378	0.9992	1.1978	1.6812
2.95	0.0768	0.1625	0.3469	0.5152	0.7298	0.9866	1.1816	1.6558
3.00	0.0766	0.1620	0.3446	0.5107	0.7220	0.9744	1.1659	1.6312

Table 4: Values of p_2/p_1 tabulated against k values of α and β and values for ZOSS (n, k)

k	p_2 / p_1 for			np_1 for α=0.05	p_2 / p_1 for			np_1 for α =0.10
	α=0.05 β =0.10	α=0.05 β =0.05	α=0.05 β =0.01		α=0.01 β = 0.10	α=0.01 β= 0.05	α=0.01 β = 0.01	
1.00	12.1774	15.7289	24.1218	0.1909	28.0850	36.2758	55.6324	0.0828
1.10	11.3269	14.5314	22.1682	0.1891	25.9811	33.3316	50.8484	0.0824
1.15	10.9595	14.0143	21.3207	0.1882	25.0713	32.0596	48.7739	0.0823
1.20	10.6239	13.5424	20.5452	0.1873	24.2395	30.8982	46.8759	0.0821
1.25	10.3161	13.1099	19.8329	0.1865	23.4761	29.8337	45.1330	0.0819
1.30	10.0327	12.7121	19.1766	0.1856	22.7726	28.8544	43.5275	0.0818
1.35	9.7709	12.3452	18.5700	0.1848	22.1221	27.9504	42.0439	0.0816
1.40	9.5282	12.0055	18.0078	0.1839	21.5187	27.1135	40.6691	0.0814
1.45	9.3026	11.6903	17.4853	0.1831	20.9573	26.3363	39.3917	0.0813
1.50	9.0922	11.3968	16.9986	0.1823	20.4334	25.6127	38.2020	0.0811
1.55	8.8956	11.1230	16.5442	0.1815	19.9434	24.9373	37.0913	0.0809
1.60	8.7113	10.8670	16.1190	0.1807	19.4839	24.3052	36.0521	0.0808
1.65	8.5383	10.6269	15.7203	0.1799	19.0520	23.7125	35.0778	0.0806
1.70	8.3754	10.4014	15.3458	0.1791	18.6453	23.1555	34.1627	0.0805
1.75	8.2218	10.1891	14.9933	0.1784	18.2614	22.6311	33.3015	0.0803
1.80	8.0767	9.9890	14.6609	0.1776	17.8985	22.1363	32.4897	0.0802
1.85	7.9393	9.7999	14.3471	0.1769	17.5547	21.6686	31.7231	0.0800
1.90	7.8091	9.6209	14.0503	0.1761	17.2286	21.2260	30.9982	0.0798
1.95	7.6854	9.4513	13.7692	0.1754	16.9188	20.8063	30.3116	0.0797
2.00	7.5679	9.2904	13.5025	0.1747	16.6240	20.4077	29.6604	0.0795
2.05	7.4559	9.1373	13.2493	0.1740	16.3430	20.0287	29.0419	0.0794
2.10	7.3491	8.9917	13.0084	0.1733	16.0750	19.6679	28.4538	0.0792
2.15	7.2471	8.8529	12.7791	0.1726	15.8189	19.3238	27.8939	0.0791
2.20	7.1497	8.7204	12.5604	0.1719	15.5740	18.9954	27.3601	0.0789
2.25	7.0564	8.5938	12.3518	0.1712	15.3394	18.6815	26.8507	0.0788
2.30	6.9671	8.4728	12.1525	0.1706	15.1146	18.3812	26.3641	0.0786
2.35	6.8814	8.3569	11.9618	0.1699	14.8989	18.0936	25.8987	0.0785
2.40	6.7991	8.2458	11.7793	0.1693	14.6917	17.8178	25.4532	0.0783
2.45	6.7200	8.1392	11.6045	0.1686	14.4925	17.5532	25.0263	0.0782
2.50	6.6440	8.0369	11.4367	0.1680	14.3009	17.2990	24.6170	0.0780
2.55	6.5708	7.9385	11.2757	0.1674	14.1163	17.0546	24.2240	0.0779
2.60	6.5003	7.8439	11.1210	0.1667	13.9384	16.8194	23.8465	0.0778
2.65	6.4323	7.7528	10.9723	0.1661	13.7668	16.5929	23.4835	0.0776
2.70	6.3667	7.6650	10.8292	0.1655	13.6012	16.3747	23.1342	0.0775
2.75	6.3034	7.5804	10.6913	0.1649	13.4411	16.1642	22.7979	0.0773
2.80	6.2422	7.4987	10.5585	0.1643	13.2865	15.9610	22.4737	0.0772
2.85	6.1830	7.4199	10.4304	0.1637	13.1368	15.7647	22.1612	0.0770
2.90	6.1258	7.3436	10.3068	0.1631	12.9920	15.5750	21.8595	0.0769
2.95	6.0703	7.2700	10.1874	0.1625	12.8518	15.3916	21.5683	0.0768
3.00	6.0166	7.1987	10.0721	0.1620	12.7158	15.2140	21.2868	0.0766

Table 5: Parametric values for ZOSS (n, k)

k	h_0	np_m	nAOQL	AOQL/p_1 for 0.05	np_1
1.00	0.99	5.7581	0.0102	0.0535	0.1909
1.10	1.03	5.2356	0.0165	0.0873	0.1891
1.15	1.05	5.0086	0.0158	0.0839	0.1882
1.20	1.07	4.8006	0.0151	0.0807	0.1873
1.25	1.08	4.6094	0.0145	0.0778	0.1865
1.30	1.10	4.4329	0.0139	0.0751	0.1856
1.35	1.11	4.2696	0.0134	0.0725	0.1848
1.40	1.13	4.1180	0.0129	0.0702	0.1839
1.45	1.15	3.9770	0.0124	0.0680	0.1831
1.50	1.16	3.8454	0.0120	0.0659	0.1823
1.55	1.17	3.7225	0.0116	0.0640	0.1815
1.60	1.19	3.6072	0.0112	0.0622	0.1807
1.65	1.20	3.4991	0.0109	0.0605	0.1799
1.70	1.22	3.3973	0.0105	0.0588	0.1791
1.75	1.23	3.3015	0.0102	0.0573	0.1784
1.80	1.24	3.2110	0.0099	0.0558	0.1776
1.85	1.25	3.1254	0.0096	0.0545	0.1769
1.90	1.27	3.0445	0.0094	0.0531	0.1761
1.95	1.28	2.9677	0.0091	0.0519	0.1754
2.00	1.29	2.8948	0.0089	0.0507	0.1747
2.05	1.30	2.8255	0.0086	0.0495	0.1740
2.10	1.31	2.7596	0.0084	0.0484	0.1733
2.15	1.32	2.6967	0.0082	0.0474	0.1726
2.20	1.33	2.6368	0.0080	0.0464	0.1719
2.25	1.34	2.5795	0.0078	0.0454	0.1712
2.30	1.35	2.5248	0.0076	0.0445	0.1706
2.35	1.37	2.4724	0.0074	0.0436	0.1699
2.40	1.38	2.4223	0.0072	0.0427	0.1693
2.45	1.39	2.3742	0.0071	0.0419	0.1686
2.50	1.39	2.3281	0.0069	0.0411	0.1680
2.55	1.40	2.2838	0.0068	0.0403	0.1674
2.60	1.41	2.2412	0.0066	0.0396	0.1667
2.65	1.42	2.2002	0.0065	0.0389	0.1661
2.70	1.43	2.1608	0.0063	0.0382	0.1655
2.75	1.44	2.1228	0.0062	0.0375	0.1649
2.80	1.45	2.0862	0.0061	0.0369	0.1643
2.85	1.46	2.0509	0.0059	0.0363	0.1637
2.90	1.47	2.0169	0.0058	0.0356	0.1631
2.95	1.48	1.9840	0.0057	0.0351	0.1625
3.00	1.48	1.9522	0.0056	0.0345	0.1620

Table 2 – Comparison of Single Sampling, Double Sampling and ZOSS

QSS-1 (n, k_n, c_0)					QSS-2 (n, k_n, c_0)					QSS-3 (n, k_n, c_0)					ZOSS (n, k)				E_1*	E_2*	E_3*
c	k	$np_{0.95}$	$np_{0.10}$	OR	c	k	$np_{0.95}$	$np_{0.10}$	OR	c	k	$np_{0.95}$	$np_{0.10}$	OR	k	$np_{0.95}$	$np_{0.10}$	OR			
1	1.25	0.35	3.12	9.01	1	1.25	0.35	3.19	9.11	1	1.25	0.34	3.11	9.08	1.50	0.18	1.66	9.09	1.90	1.92	1.88
1	1.50	0.34	2.61	7.74	1	1.50	0.35	2.74	7.91	1	1.50	0.33	2.59	7.86	1.95	0.16	1.35	7.68	1.92	1.96	1.88
1	1.75	0.33	2.25	6.68	1	7.50	0.34	2.41	6.97	1	1.75	0.32	2.23	6.99	2.50	0.17	1.12	6.64	1.95	2.02	1.89
1	2.00	0.32	1.97	6.18	1	2.0	0.33	2.16	6.4	1	2.00	0.31	1.95	6.31	2.85	0.16	1.10	6.18	1.95	2.00	1.87

Where

*****E_1 = $np_{0.95}$ of QSS-1(n, kn, c_0) / $_{0.95}$ of ZOSS (n, k)
*E_3 = $np_{0.95}$ of QSS-3(n, kn, c_0) / $np_{0.95}$ of ZOSS (n, k)
*E_2 = $np_{0.95}$ of QSS-2(n, kn, c_0) / $np_{0.95}$ of ZOSS (n, k) and