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Construction and Selection of Double Inspection Single Sampling Plan for an Independent Process Using Bivariate Poisson Distribution

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Abstract There are more sampling concepts active in production Industries, for inspecting the samples and analysing performance of the population. Also the sampling plans reduce errors in the production and produce the error free products. In this study, construction and selection of Double Inspection with reference to Single Sampling Plan i.e., DISSP, by attribute are investigated by using the Bivariate Poisson distribution. The Methodology, DISSP, was proposed based on two quality characteristics of the same sample size, and the planning parameters (n, c_1, c_2) are based on the operating characteristics, the conventional two-point condition by the planning table parameters (AQL and LQL). It is based on selected quality requirements and risks designed to allow manufacturers to easily determine the required sample size and corresponding acceptance criteria. A Comparison was done based on the efficiency of the plan with an existing single sampling plan and gave a numerical example to expose the operating tables. Also, the study shows the advantages of the proposed plan, and performance of the curves like, Operating characteristics, Average Outgoing Quality, and Average Total Inspection to expose the proposed double inspection sampling plan.

Keywords Sampling Plan, Single Sampling Plan, DISSP, Operating Characteristics Curve, Average Outgoing Quality Curve

1. Introduction

Quality is a foremost element to connect the product with producer and consumer. Acceptance sampling is the comprehensive order of accepting (or) rejecting the lot based on samples. Acceptance sampling plans are widely apply in production sectors, to control the quality of the products. Single-attribute sampling plans are the basis for determining other sampling plans. It is used for inspection by assessing the number of defects found in the sample (Poisson distribution), or the proportion of defective processes or large lots (binomial distribution) or individual lots (hypergeometric distribution). A single sample is arguably the most widely used sampling method. In the modern world, according to the tendency of customer satisfaction for the quality of the product, the manufactured products involve more than one quality characteristics is quite common.

Therefore, in this Paper, a double inspection single sampling plan, DISSP is developed for lot sentencing when the product is inspected with more than one quality characteristic. Edward. G. Shilling and V Neuberger [2] have presented Acceptance Sampling in Quality Control. Aydemir and Olgun [3] have developed a single and double acceptance sampling program application for manufacturing systems. Golub [1] is designed to help determine the optimal single sample test plan after the sample size has been fixed. Senthilkumar and Rafiee [8] have designed a Six Sigma single sampling plan variable design indexed by Six Sigma quality level and created a table for easy sampling plan selection. Senthilkumar and Rafiee [9] have investigated the Six Sigma single sampling scheme indexed by Six Sigma AQL and AOQL. Senthilkumar and Sabarish [10] have developed the construction and selection of double-inspection single-sampling plans. Senthilkumar and Sabarish [11] have developed Selection and Development of Double Inspection Single Sampling Plan".

Unlike the single sampling plan, the double sampling plan includes the ability to test two independent observations on the same sample of units from a lot. Double-check single-sampling plans are established only when needed. Focus on the bivariate situation where exactly two tests are performed on each unit. The two quality criteria are called X (number of errors in the first test) and Y (number of errors in the second test). Kawamura [4] developed the structure of the bivariate Poisson distribution. X and Y are acquired for each unit, so the data for one observation is a pair (X, Y) and is independent. The two joint random variables X and Y are probabilistically independent only if their joint function is the product of the marginal distribution functions.

$$f_{xy}(X,Y) = f_x(X).\ f_y(Y)$$

2. Glossary of Symbols

n – Sample size
c_1 –Acceptance number of the First inspection
c_2 – Acceptance number of the Second inspection
d_1 – No. of defectives Present in first inspection
d_2 – No. of defectives Present in Second inspection
P_{a1} (p) - First Inspection Probability of Acceptance
P_{a2} (p) - Second Inspection Probability of Acceptance
P_a (p) - DISSP Probability of Acceptance

3. Problem Procedural Statement

1. During the production process, due to various reasons defectives may occur.
2. Both Inspections are independent
3. Passing rule is not allowed during the inspection
4. Go on with the inspection process till it rejects the lot (or) accept the lot.

4. Operating Procedural Statement

1. Select a random sample of size 'n' units from the lot and test each unit for conformance to the specified attribute requirements.
2. Count the No. of defectives in the first inspection 'd_1' then move to next step.
3. If $d_1 \leq c_1$ Pass the same sample for the second inspection for the same sample of size 'n' otherwise ($d_1 > c_1$) reject the lot.
4. Count the No. of defectives in second inspection for the same sample, d_2 then move to next step.
5. If $d_2 \leq c_2$ accept the lot otherwise ($d_2 > c_2$) reject the lot.

4.1. Operating Characteristics Function of DISSP

The OC function of DISSP (n, c_1, and c_2) based on Bivariate Poisson distribution is given by,

The operating Characteristics function for the Single Sampling Plan of first Inspection is

$$P_{a1}(p) = P(d_1 \leq c_1) = \sum_{r=0}^{c1} \frac{e^{-x} x^0}{0!} \quad (1)$$

The operating Characteristics function for the Single Sampling Plan of second Inspection is

$$P_{a2}(p) = P(d_2 \leq c_2) = \sum_{r=0}^{c2} \frac{e^{-y} y^r}{r!} \quad (2)$$

In this plan, when c_1 and c_2 the OC function of Double Inspection Single Sampling Plan is given by

$$P_a(p) = P(d_1 = c_{1,}\ d_2 \leq c_2) \quad (3)$$

$$P_a(p) = P(d_1 = c_1) * P(d_2 \leq c_2) \quad (4)$$

After applying equation (2) and (3) in the equation (4), on simplification, when c_1& c_2

$$P_a(p) = e^{-2np}(1 + np) \quad (5)$$

$$\mathrm{Pa(p)} = \left(\sum_{k=0}^{c1} \frac{e^{-np} \quad np^k}{k!}\right) \left(\sum_{k=0}^{c2} \frac{e^{-np} \quad np^k}{k!}\right) \quad (6)$$

$$\mathrm{Pa}(p) = \mathrm{Pa}_1 * \mathrm{Pa}_2 \quad (7)$$

4.2. Average Outgoing Quality of DISP

Waiver [12] defines AOQ as "The expected quality of outgoing product following the use of an acceptance sampling plan for a given value of incoming product quality". Average Outgoing Quality of DISP is,

$$AOQ = p * Pa(p) \quad (9)$$

4.3. Average Total Inspection of DISP

$$ATI = n\,(Pa(p)) + N(1 - Pa(p)) \quad (10)$$

4.4. Illustration

In this technological world usage of the electronic gadgets increase day by day like Smart watch, Smart Bags, wireless devices and etc... Particularly usage of smart watches is increasing nowadays and branded watches are very small in size and Price wise it's very high. Because of the demand, manufacture produce very large number of items, and they concentrate their quality. The following are the major quality characteristics of smart watch inspection. Sensor, Pulse Reader, Audio Device, Screen, Buttons, Straps...etc.

In DISSP two inspectors check two different quality Characteristics, c1= Checking quality of the display and c2 = Checking the performance of the Sensor, both the quality characteristics are independent. Table 1 shows the acceptance probabilities of the first test of the sample with size n = 50 and acceptance number c1 = 1 and the acceptance probability of the second test of the sample with size n = 50 and acceptance number $c_2 = 2$. Probability of accepting double checks Single sample design size n = 50, $c_1 = 1$, and $c_2 = 2$. Table 1 also shows the average initial quality and Average Total Inspection of the DISSP.

Table 1. Locates the values for plotting curves like, OC, AOQ and ATI

P	SSP-1	SSP-2	Pap	AOQ	ATI
0.01	0.9098	0.9856	0.8967	0.0090	148.1292
0.02	0.7358	0.9197	0.6767	0.0135	357.1574
0.03	0.5578	0.8088	0.4512	0.0135	571.3645
0.04	0.4060	0.6767	0.2747	0.0110	739.0021
0.05	0.2873	0.5438	0.1562	0.0078	851.5757
0.06	0.1991	0.4232	0.0843	0.0051	919.9363
0.07	0.1359	0.3208	0.0436	0.0031	958.5806
0.08	0.0916	0.2381	0.0218	0.0017	979.2852
0.09	0.0611	0.1736	0.0106	0.0010	989.9247
0.1	0.0404	0.1247	0.0050	0.0005	995.2126

Figure 1. OC curves of single sampling plan 1 (n=50, c=1), single sampling plan 2 (n=50, c=2) and DISSP (n=50, c_1=1 and c_2=2). We can see that the slope of the operation line of the double inspection plan using one sample is steeper than that of the other two samples (SSP-1 and SSP-2) OC Curves. Figure 2 shows the Average Outgoing Quality curve and Figure 3 shows the Average Total Inspection Curve for the proposed plan.

The tables presented in DISSP are exact for single sampling plan are exact for situations involving non conformities, since this work adopted the bivariate Poisson model. The sample plans created from these tables are not necessarily less than or equal to the indicated risks, but in certain situations the values will be apparent. Due to these large differences in sample size, the specified risk must be met exactly. The plans found in these tables should be used as a starting point for finding a suitable plan.

5. Designing of DISSP

Table 2 is used to determine a DISSP for given sample size n, Pa(p) and p. The values on np that are determined by using the parameter, acceptance constants c_1, c_2 and Pa(p) in this Table.

With the given values of n, p, and Pa(p) one can find DISSP using Table 2 as follows.

1. Compute the value of np using the given values of n and p.
2. With computed values of np, entering into Table 2 in the column headed Pa(p) by np which is equal to or just greater than the computed np, the acceptance numbers c_1 and c_2 are determined from Table 2 of the corresponding np values.

For example, if one fixes n=50, Pa(p)=0.95 and p=0.006, one obtains DISSP as follows,

1. np= 50*0.006=0.3.
2. in the column headed by Pa(p)=0.95, find the value just greater than or equal to this value is np=0.33.
3. The corresponding to this np value the acceptance numbers c_1 and c_2 are 1 and 2 respectively.
4. Now the desired DISSP parameters are n=50. c_1=1 and c_2=2.

Selection of DISSP indexed by AQL and LQL, Table 3 is used to select a DISSP for given AQL (p_1) LQL (p_2). Table 3 assumes producer risk (α) = 0.05 and 0.01, and Consumers risk (β) = 0.01, 0.05 and 0.10. Against given fixed values of operating ratio p_2/p_1 Table 3 gives the acceptance numbers c_1 and c_2 and the value of np_1. With the given values of p_1, p_2, α and β, one can find DISSP from Table 3 as follows.

1. Compute the operating ratio p_2/p_1.
2. With the computed value of p_2/p_1 enter
3. Table 3, in the column headed with α = 0.05 and β =0.01, one obtains the p_2/p_1 which is very close to this computed ratio.
4. The acceptance numbers c_1 and c_2 are obtained from Table 3.
5. The sample size n is obtained as $n=np_1/p_1$ where np_1 values are given the column heading corresponding to the acceptance numbers obtained in Step 3.

For example, if one fixes p_1= 0.005, α=0.05 p_2=0.04 and β=0.01, one obtains a DISSP as follows.

1. Compute p_2/p_1 = 0.04/0.005= 8,
2. Using Table 3 under column headed with α=0.05 and β=0.01, one can find the values of the ratio very close to 8, the value is 8.66.
3. The corresponding values of acceptance numbers for the first and second inspection are c_1=1, c_2=2 respectively and np_1=0.05.
4. The sample size $n=np_1/p_1$= 0.05/0.006 =8.33, which is nearest to 8.

6. Operating Characteristics Curve for DISSP

K. Dumicic et al. [5] have studied an OC Curve of an Acceptance Sampling Plan". The OC curve for a DISSP can be constructed using Table 2. This can be done by dividing each entry for the given values, by the values of sample size n. The result of each division is the number of non conformities per unit for which the probability of acceptance is shown in the column heading.

For example with n=50, c_1=1 and c_2=2 division of each entry in the row of Table 2, by n=50 leads to the value given in the following table for plotting the OC curve of DISSP (n=50, c_1=1 and c_2=2).

Table 2. Locates the values of np

Pa(p)	**P**
0.99	0.003
0.95	0.007
0.90	0.007
0.75	0.017
0.50	0.028
0.25	0.042
0.10	0.057
0.05	0.068
0.01	0.091

7. Constructions of Tables

Based on the Operating Characteristics Function of DISSP

$$P_a(p) = P_{a1}(p) * P_{a2}(p) \quad (8)$$

Where,

$Pa_1(p)$= Probability of acceptance for the First Inspection (n, c_1)

Pa_2 (p)= Probability of acceptance for the Second Inspection (n, c_2)

For given values of c_1 c_2 and Pa(p), equation (4) can be solved for np with computer search technique using C^{++} programming and values of np are tabulated in Table 2. Using these values of np, operating ratios $p_2 / p_1 = np_2 / np_1$ are calculated and given in Table 3 for assumed values of α (0.05 and 0.01) and β (0.01, 0.05 and 0.10).

8. Merits and Purpose of This Plan

In other words, DISSP method shows Maximum acceptance in minimum size of sample. In this plan, we inspect two different and important quality characteristics of the similar product, this proposed method was suitable for costliest and mass production situation.

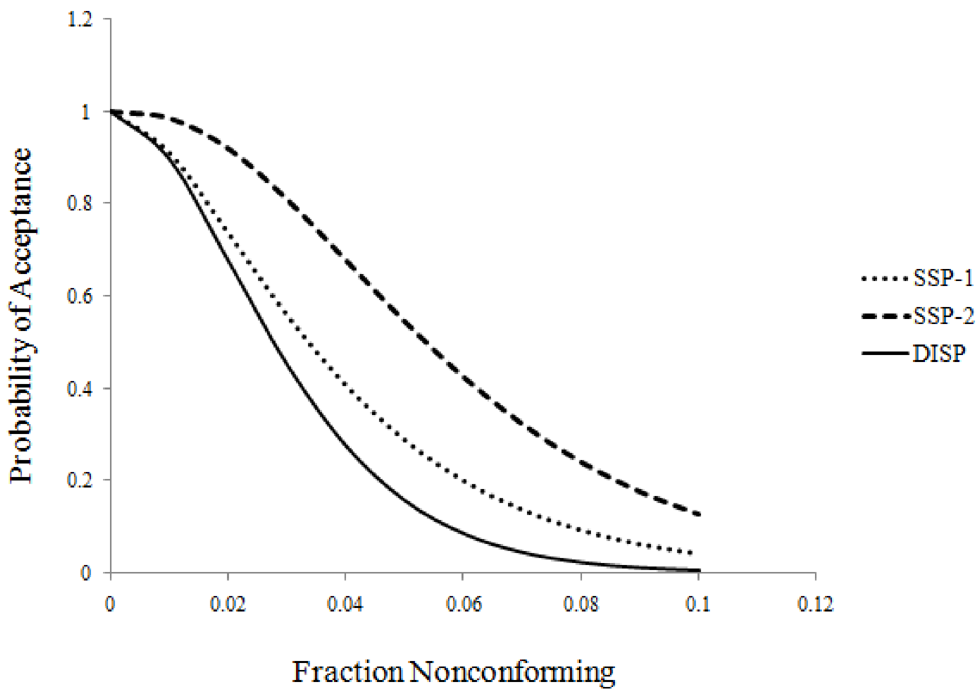

Figure 1. Operating Characteristics curves

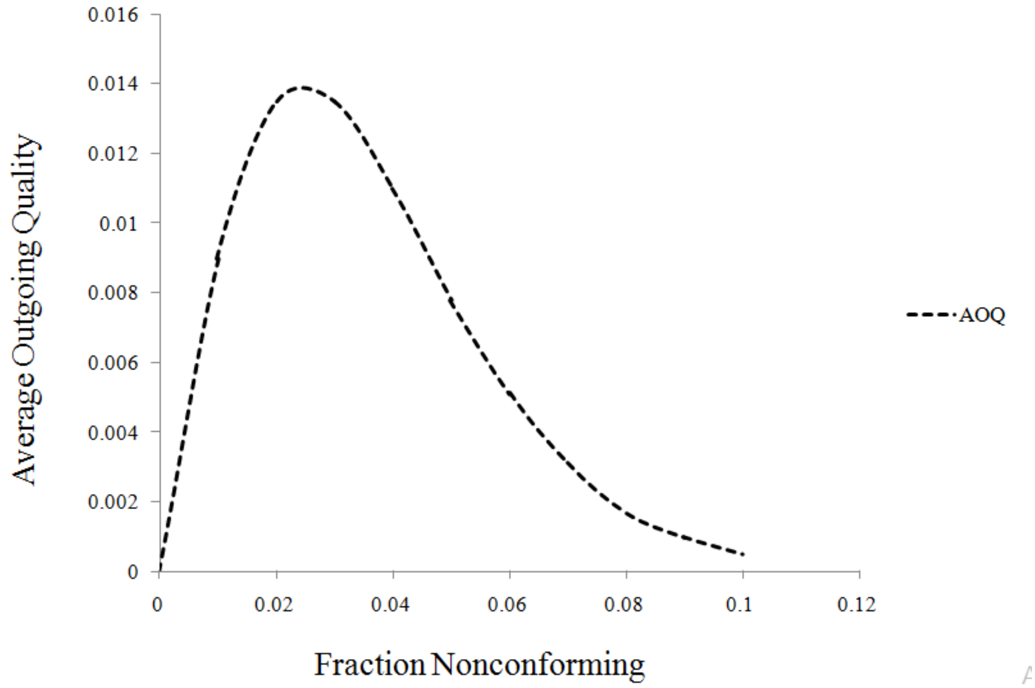

Figure 2. Average Outgoing Quality Curve

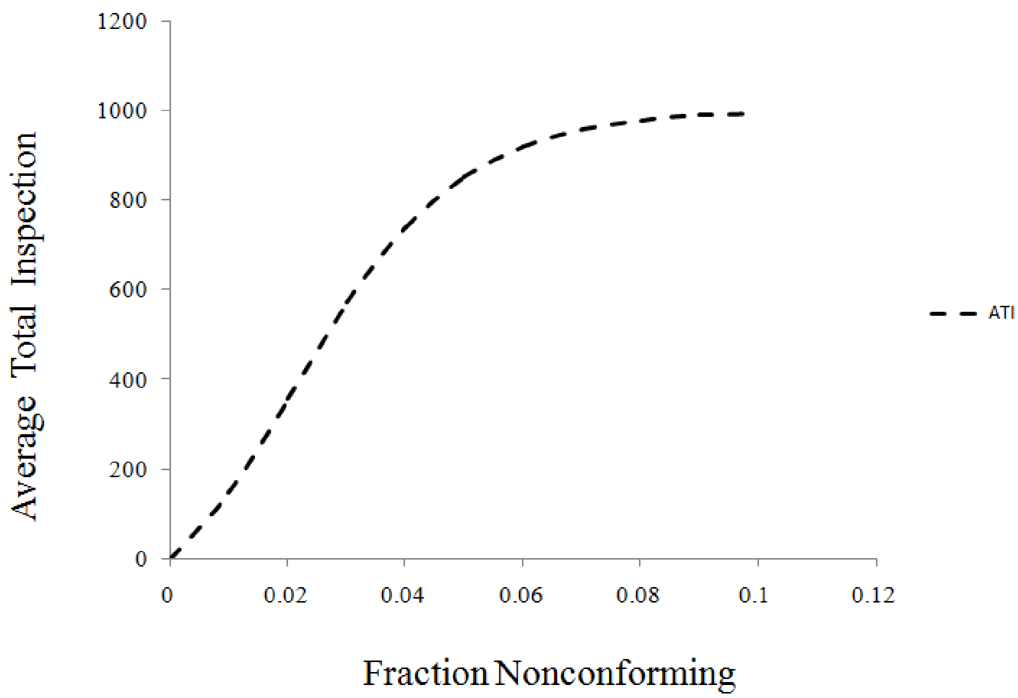

Figure 3. Average Total Inspection curve

Table 2. Probability of Acceptance Pa for DISSP for different acceptance numbers

Acceptance numbers		Probability of Acceptance Pa(p)								
c_1	c_2	0.99	0.95	0.90	0.75	0.50	0.25	0.10	0.05	0.01
0	0	0.01	0.05	0.05	0.14	0.034	0.63	1.15	1.49	2.33
0	1	0.01	0.05	0.1	0.25	0.57	1.05	1.63	2.05	3.33
0	2	0.01	0.05	0.1	0.28	0.66	1.24	1.93	2.42	3.48
0	3	0.01	0.05	0.1	0.28	0.68	1.33	2.12	2.66	3.84
0	4	0.01	0.05	0.1	0.28	0.69	1.37	2.22	2.82	4.11
0	5	0.01	0.05	0.1	0.28	0.69	1.38	2.27	2.91	4.3
0	6	0.01	0.05	0.1	0.28	0.69	1.38	2.29	2.96	4.43
1	0	0.01	0.05	0.1	0.25	0.57	1.05	1.63	2.05	3.3
1	1	0.1	0.24	0.24	0.63	1.07	1.67	2.36	2.84	3.89
1	2	0.15	0.33	0.33	0.84	1.38	2.08	2.86	3.39	4.54
1	3	0.15	0.35	0.35	1.51	1.55	2.35	3.22	3.81	5.05
1	4	0.15	0.35	0.35	0.95	1.63	2.52	3.48	4.12	5.46
1	5	0.15	0.35	0.35	0.96	1.66	2.62	3.66	4.35	5.79
1	6	0.15	0.35	0.35	0.96	1.67	2.66	3.77	4.51	6.04
2	0	0.01	0.05	0.05	0.28	0.66	1.24	1.93	2.42	3.48
2	1	0.15	0.33	0.33	0.63	1.38	2.08	2.86	2.84	4.54
2	2	0.33	0.62	0.62	1.26	1.88	2.67	3.52	4.11	5.32
2	3	0.42	0.76	0.76	1.51	2.23	3.1	4.03	4.65	5.95
2	4	0.43	0.8	0.8	1.64	2.24	3.41	4.42	5.08	6.47
2	5	0.43	0.81	0.81	1.7	2.57	3.62	4.7	5.43	6.9
2	6	0.43	0.81	0.81	1.72	2.63	3.76	4.94	5.7	7.26
3	0	0.01	0.05	0.05	0.28	0.68	1.33	2.12	2.66	3.84
3	1	0.15	0.35	0.35	1.51	1.55	2.35	3.22	3.81	5.05
3	2	0.42	0.76	0.76	1.51	2.23	3.1	3.52	4.65	5.95
3	3	0.67	1.09	1.09	1.95	2.73	3.67	4.65	5.31	6.68
3	4	0.79	1.27	1.27	2.23	3.09	4.11	5.16	5.85	7.29
3	5	0.81	1.34	1.34	2.4	3.34	4.4	5.57	6.3	7.82
3	6	0.82	1.36	1.36	2.48	3.5	4.69	5.89	6.67	8.26
4	0	0.01	0.05	0.05	0.28	0.69	1.37	2.22	2.82	4.11
4	1	0.15	0.35	0.35	0.95	1.63	2.52	3.48	4.12	5.46
4	2	0.43	0.8	0.8	1.64	1.07	2.24	4.42	5.08	6.47
4	3	0.79	1.27	1.27	2.23	3.09	4.11	5.16	5.85	7.29
4	4	1.07	1.63	1.63	2.67	3.59	4.67	5.7	6.5	7.99
4	5	1.22	1.83	2.22	2.98	3.99	5.11	6.28	7.04	8.6
4	6	1.26	1.93	1.93	3.18	4.24	5.47	6.7	7.1	9.12

Table 2. Continued

Acceptance numbers		Probability of Acceptance Pa(p)								
c_1	c_2	0.99	0.95	0.90	0.75	0.50	0.25	0.10	0.05	0.01
5	0	0.01	0.05	0.1	0.28	0.69	1.38	2.27	2.91	4.3
5	1	0.15	0.35	0.35	0.96	1.66	2.62	3.66	4.35	5.79
5	2	0.43	0.81	0.81	1.7	2.57	3.62	4.7	5.43	6.9
5	3	0.81	1.34	1.34	2.4	3.34	4.4	5.57	6.3	7.82
5	4	1.22	1.83	2.22	2.98	3.99	5.11	6.28	7.04	8.6
5	5	1.53	2.2	2.63	3.43	4.47	5.67	6.88	7.66	9.2
5	6	1.7	2.43	2.89	3.75	4.86	6.12	7.38	8.2	9.87
6	0	0.01	0.05	0.1	0.28	0.69	1.38	2.29	2.96	4.43
6	1	0.15	0.35	0.35	0.96	1.67	2.66	3.77	4.51	6.04
6	2	0.43	0.81	0.81	1.72	2.63	3.76	4.94	5.7	7.26
6	3	0.82	1.36	1.36	2.48	3.5	4.69	5.89	6.67	8.26
6	4	1.26	1.93	1.93	3.18	4.24	5.47	6.7	7.1	9.12
6	5	1.7	2.43	2.89	3.75	4.86	6.12	7.38	8.2	9.87
6	6	2.04	2.82	3.3	4.21	5.36	2.5	7.97	8.82	10.5

Table 3. Values of operating ratios for DISSP

		Values of p_2/p_1					Values of p_2/p_1			
c_1	c_2	α=0.05	α=0.05	α=0.05	np_1		α=0.01	α=0.01	α=0.01	np_2
		β=0.10	β=0.05	β=0.01			β=0.10	β=0.05	β=0.01	
0	0	23.00	29.80	46.60	0.05		3.40	63.00	115.00	0.01
0	1	32.60	41.00	66.60	0.05		57.00	105.00	163.00	0.01
0	2	38.60	48.40	69.60	0.05		66.00	124.00	193.00	0.01
0	3	42.40	53.22	76.82	0.05		68.00	133.00	212.00	0.01
0	4	44.40	56.42	82.20	0.05		69.00	137.00	222.00	0.01
0	5	45.44	58.21	86.00	0.05		69.00	138.00	227.00	0.01
0	6	45.80	59.20	88.60	0.05		69.00	138.00	229.00	0.01
1	0	32.60	41.00	66.00	0.05		57.00	105.00	163.00	0.01
1	1	9.83	11.83	16.21	0.24		10.70	16.70	23.60	0.10
1	2	8.67	10.27	13.76	0.33		9.20	13.87	22.36	0.15
1	3	9.20	10.89	14.43	0.35		10.33	15.67	21.47	0.15
1	4	9.94	11.77	15.60	0.35		10.87	16.80	23.20	0.15
1	5	10.46	12.43	16.54	0.35		11.07	17.47	24.40	0.15
1	6	10.77	12.89	17.26	0.35		11.13	17.73	25.13	0.15
2	0	38.60	48.40	69.60	0.05		66.00	124.00	193.00	0.01
2	1	8.67	8.61	13.76	0.33		9.20	13.87	19.07	0.15
2	2	5.68	6.63	8.58	0.62		5.70	8.09	10.67	0.33
2	3	5.30	6.12	7.83	0.76		5.31	7.38	9.60	0.42
2	4	5.53	6.35	8.09	0.80		5.21	7.93	10.28	0.43
2	5	5.80	6.70	8.52	0.81		5.98	8.42	10.93	0.43
2	6	6.10	7.04	8.96	0.81		6.12	8.74	11.49	0.43

Table 3. Continued,

		Values of p_2/p_1					Values of p_2/p_1			
c_1	c_2	**α=0.05**	**α=0.05**	**α=0.05**	**np_1**		**α=0.01**	**α=0.01**	**α=0.01**	**np_2**
		β=0.10	**β=0.05**	**β=0.01**			**β=0.10**	**β=0.05**	**β=0.01**	
3	0	42.40	53.20	76.80	0.05		68.00	133.00	212.00	0.01
3	1	9.20	10.89	14.43	0.35		10.33	15.67	21.47	0.15
3	2	4.63	6.12	7.83	0.76		5.31	7.38	8.38	0.42
3	3	4.27	4.87	6.13	1.09		4.08	5.48	6.94	0.67
3	4	4.06	4.61	5.74	1.27		3.91	5.20	6.53	0.79
3	5	4.16	4.70	5.84	1.34		4.12	5.43	6.88	0.81
3	6	4.33	4.90	6.07	1.36		4.27	5.72	7.18	0.82
4	0	44.40	56.40	82.20	0.05		69.00	137.00	222.00	0.01
4	1	9.94	11.77	15.60	0.35		10.87	16.80	23.20	0.15
4	2	5.53	6.35	8.09	0.80		2.49	5.21	10.28	0.43
4	3	4.06	4.61	5.74	1.27		3.91	5.20	6.53	0.79
4	4	3.50	3.99	4.90	1.63		3.36	4.36	5.33	1.07
4	5	3.43	3.85	4.70	1.83		3.27	4.19	5.15	1.22
4	6	3.47	3.68	4.73	1.93		3.37	4.34	5.32	1.26
5	0	45.40	58.20	86.00	0.05		69.00	138.00	227.00	0.01
5	1	10.46	12.43	16.54	0.35		11.07	17.47	24.40	0.15
5	2	5.80	6.70	8.52	0.81		5.98	8.42	10.93	0.43
5	3	4.16	4.70	5.84	1.34		4.12	5.43	6.88	0.81
5	4	3.43	3.85	4.70	1.83		3.27	4.19	5.15	1.22
5	5	3.13	3.48	4.18	2.20		2.92	3.71	4.50	1.53
5	6	3.04	3.37	4.06	2.43		2.86	3.60	4.34	1.70
6	0	45.80	59.20	88.60	0.05		69.00	138.00	229.00	0.01
6	1	10.77	12.89	17.26	0.35		11.13	17.73	25.13	0.15
6	2	6.10	7.04	8.96	0.81		6.12	8.74	11.49	0.43
6	3	4.33	4.90	6.07	1.36		4.27	5.72	7.18	0.82
6	4	3.47	3.68	4.73	1.93		3.37	4.34	5.32	1.26
6	5	3.04	3.37	4.06	2.43		2.86	3.60	4.34	1.70
6	6	2.83	3.13	3.72	2.82		2.63	1.23	3.91	2.04

9. Conclusions

The construction of DISSP from the given table was discussed based on the 3 criteria sets of sample size and OC curve based on one Point shows when the bivariate poisson model was assumed for the construction by these values given are valid approximation under the poisson model the values always will be close but in cases where more exact plans with risk no greater than those specified. This proposed plan is suitable when there is a possibility of costliest, mass production and Human intervention are much involved, with aim to produce best quality products. The OC function for DISSP n, c_1, c_2 under Bivariate Poisson distribution. This plan will provide protection to both producer and consumer risks. The proposed plan can apply for Foods Processing Units, Electronic Gadgets Manufacturing companies and Jewell ornament, etc.

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