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Bayesian Acceptance Sampling Plans Through Numerical Methods

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Abstract : *This paper is concerned with the set of Tables for the selection of Bayesian Single Sampling Plan (BSSP) Plan presents a new procedure for BSSP indexed through Acceptable and Limiting Quality Levels with the application of (Linear interpolation Method, Secant Method , Muller's Method , Modified Muller's Method) four Numerical method alogorithm. Tables and Procedures are also provided for the selection of the parameters for the plan.*
Key words : *Bayesian Single Sampling , Linear Interpolation Method , Secant Method, Muller's Method, Modified Muller's Method, Acceptable and Limiting Quality Levels.*

I. INTRODUCTION

Bayesian Statistics is directed towards the use of sample information. thomas Bayes (1702-1761) was the first to use prior information in inductive inference and the approach to statistics, which formally seeks to utilize prior information, is called Bayesian analysis. Suppose a product in a series is supplying a product, due to random fluctuations these lots will differ in quality even though the process is stable and in control. These fluctuations can be separated in to within lot (sampling) variations of individual units and between lot (sampling and process) variations.

Bayesian Approach

Bayesian Acceptance Sampling Approach is associated with the utilization of prior process history for the selection of distributions (viz., Gamma, Poisson, Beta Binomial) to describe the random fluctuations involved in Acceptance Sampling. Bayesian sampling plans requires the user to specify explicitly the distribution of defectives from lot to lot. The prior distribution is the expected distribution of a lot quality on which the sampling plan is going to operate. The distribution is called prior because it is formulated prior to the taking of samples. The combination of prior knowledge, represented with the prior distribution, and the empirical knowledge based on the sample leads to the decision on the lot.

- ❖ It consists of minimizing average (expected) costs, including inspection, acceptance and rejection costs.
- ❖ Bayesian statistics is useful to sampling issues because
- ❖ It takes into account prior information in the sampling set up
- ❖ It can update information through the Bayes formula to modify/adapt the sampling stringency according to the latest results
- ❖ It removes uncertainty on parameter of interest when decision making.

In Bayesian inference, the conjugate prior for the rate parameter p of the Poisson distribution is the Gamma distribution . Let

$$p \sim \text{Gamma}(s,t)$$

denote that p is distributed according to the Gamma density w parameterized in terms of a shape parameter p and an inverse scale parameter t.

$$\text{Gamma (or) w (p; s,t)} = e^{-pt}p^{s-1}t^{s} \,/\, \Gamma(s),\ s,t > 0,\ p > 0$$

$$= 0 \qquad \text{Otherwise}$$

Then , given the same sample of n measured values $k_i$as before, and a prior of Gamma (s,t), the posterior distribution is

$$p \sim \text{Gamma}\ (s+\sum_{i=1}^{n} k_i\, , t+n)$$

The posterior mean E[p] approaches the maximum likelihood estimate $p^{\wedge}_{MLE}$ in the limit as s⟶0,t→ 0.The posterior predictive distribution of additional data is a Gamma Poisson distribution (i.e., negative binomial) distribution.

Bayesian Single Sampling Plan

A single sampling plan is characterized by sample size n and the acceptance number c. Sampling inspection in which the decision to accept or not to accept is based on the inspection of a single sample size n.

Operating Procedure

Select a random sample of size n and count the number of non-conforming units d. If there is c or less non-conforming units, the lot is accepted, otherwise the lot is rejected. Thus the plan is characterized by two parameters viz., the sample size n and the acceptance number c.

The OC function of the Single Sampling Plan is given as

$$P_a(p) = P(d \leq c, n)$$

Bayesian Single Sampling Plan (BSSP)

The operating characteristic function of Single Sampling Plan is

$$P_a(p) = P(d \leq c, n)$$

The single sampling plan is characterized with sample size n and the acceptance number c. The probability of acceptance of SSP based on Poisson Model is provided as

$$P(n, c/p) = \sum_{x=0}^{c} e^{-np} np^x / x!$$

Using the past history of inspection, it is observed that p follows Gamma prior distribution with density function,

$$w(p) = e^{-pt} p^{s-i} t^s \, / \, \Gamma(\mathrm{s}), \qquad \mathrm{s,t} > 0, \; p > 0$$

Thus the average probability of acceptance is given as

$$\bar{P} = \int_0^{\infty} P(n, c/p) w(p) dp$$

$$= \sum_{x=0}^{c} (n^x t^s \, \Gamma(\mathrm{s} + x)) / (x! \, \Gamma(\mathrm{s}) (\mathrm{n} + \mathrm{t})^{\mathrm{s}+x}$$

Which can also be written as

$$\bar{P} = \sum_{x=0}^{c} (s + x - 1_{C_{s-1}} (s/(s + n\mu))^s \, (n\eta/(s + n\mu))^x$$

Where $\mu = s/t$, is the expectation of Gamma distribution and approximately the mean value of product quality.

II. LINEAR INTERPOLATION METHOD ALGORITHM

The operating characteristic function of Single Sampling Plan is

$$P_a(p) = P(d \leq c, n)$$

Using the Past history of inspection, it is observed that p follows Gamma prior distribution with density function,

$$w(p) = e^{-pt} p^{s-i} t^s \, / \, \Gamma(\mathrm{s}), \qquad \mathrm{s,t} > 0, \; p > 0$$

Thus the average probability of acceptance for Bayesian Single Sampling plan is given as

$$\overline{P} = \int_0^\infty P(n, c/p)w(p)dp$$

$$= \sum_{x=0}^{c} (s + x - 1_{C_{s-1}} (s/(s + n\mu))^s \, (n\eta/(s + n\mu))^x$$

Let us assume

$$f(x) = \sum_{x=0}^{c} (s + x - 1_{C_{s-1}} (s/(s + n\mu))^s \, (n\eta/(s + n\mu))^x$$

Now the values of proportion defectives $(n\mu)$ has been found out for different values of Probability of acceptance $P_a(p) = \bar{P} = 0.99, 0.95, 0.75, 0.50, 0.10, 0.05, 0.01$

Therefore $f(x)$ now becomes

$$f(x) = \sum_{x=0}^{c} (s + x - 1_{C_{s-1}} (s/(s + n\mu))^s \, (n\eta/(s + n\mu))^x - \bar{P}$$

Step: 1 Select two initial values x_1 and x_2 such that $f(x_1)$ and $f(x_2)$ are of opposite signs.
Step: 2 Set $f_1 = f(x_1)$ and $f_2 = f(x_2)$
Step: 3 Set

$$x_3 = x_2 - \frac{f_2(x_2 - x_1)}{f_2 - f_1}$$

Step: 4 Calculate $f(x_3)$ and set $f_3 = f(x_3)$
Step: 5

a. If $f_3 = 0$ or if the desired precision is met, x_3 is taken as the required root value.Then go to Step 7.
b. If $f_3 \neq 0$ and if the desired precision is not met, then go to step 6.

Step: 6

a. If f_3 is of opposite sign to f_1 , then reset $x_2 = x_1$.
b. If f_3 is of same sign as that of f_1 , then reset $x_1 = x_3$. Go to step 2.

Step: 7 Stop.

SECANT METHOD ALGORITHM:

Step: 1 Select tow initial values x_2 , x_0 and x_1
Step: 2 Set $f_1 = f(x_1)$ and $f_2 = f(x_2)$
Step: 3 Set

$$x_3 = x_2 - \frac{f_2(x_2 - x_1)}{f_2 - f_1}$$

Step: 4 Calculate $f(x_3)$ and set $f_3 = f(x_3)$
Step: 5

a. If $f_3 = 0$ or if the desired precision is met, x_3 is taken as the required root value.Then go to Step 7.
b. If $f_3 \neq 0$ and if the desired precision is not met, then go to step 6.

Step: 6 Reset $x_2 = x_3, x_1 = x_2$
Step: 7 Stop.

MULLER'S METHOD ALGORITHM

Step: 1 Select two initial values x_2 , x_0 and x_1

Step: 2 Calculate $f(x_2)$, $f(x_0)$ and $f(x_1)$

Set $f_1 = f(x_1)$, $f_0 = f(x_0)$ and $f_2 = f(x_2)$

Calculate $f(x_0)$ and set $f_0 = f(x_0), c = f_0$

Step: 3 Calculate $h_1 = x_1 - x_0, h = x_0 - x_2, \lambda = {}^{h_2}/_{h_1}$

Step: 4 Calculate

$$a = \frac{\lambda f_1 - f_0(1+\lambda) + f_2}{\lambda {h_1}^2 (1+\lambda)}$$

$$b = \frac{f_1 - f_0 - a{h_1}^2}{h_1}$$

Step: 5 Calculate the value of root

$$x = x_0 - \frac{2c}{b + \sqrt{b^2 - 4ac}} \qquad if \quad b > 0$$

$$x = x_0 - \frac{2c}{b - \sqrt{b^2 - 4ac}} \qquad if \quad b < 0$$

$$x = x_0 - \left(\pm\sqrt{\frac{c}{a}}\right) \qquad if \quad b = 0$$

Step: 6 Calculate $f(x)$

a. If $f(x) = 0$ or if the desired precision is met, x is taken as the required root value. Then go to Step 9.

b. If $f(x) \neq 0$ and the desired precision are not met, then go to step 7.

Step: 7

a. If $x > x_0$, then reset: $x_2 = x_0$, $x_0 = x$, $x_1 = x_1$

b. If $x < x_0$, then reset: $x_2 = x_2$, $x_0 = x$, $x_1 = x_1$

Go to Step 2.

Step: 8 Stop.

III. MODIFIED MULLER'S METHOD ALGORITHM

Step: 1 Start with two initial values x_1 and x_2 such that $f(x_1)$ and $f(x_2)$ are of opposite signs. Set $f_1 = f(x_1)$, and $f_2 = f(x_2)$

Step: 2 Set x

$$x_0 = x_1 - \frac{f_1(x_1 - x_2)}{f_1 - f_2}$$

Step: 3 Calculate $f(x_0)$ and set $f_0 = f(x_0), c = f_0$

Step: 4 Calculate $h_1 = x_1 - x_0, h = x_0 - x_2, \lambda = {}^{h_2}/_{h_1}$

Step: 5 Calculate

$$a = \frac{\lambda f_1 - f_0(1+\lambda) + f_2}{\lambda {h_1}^2 (1+\lambda)}$$

$$b = \frac{f_1 - f_0 - a{h_1}^2}{h_1}$$

Step: 6 Calculate the value of root

$$x = x_0 - \frac{2c}{b + \sqrt{b^2 - 4ac}} \qquad if \quad b > 0$$

$$x = x_0 - \frac{2c}{b - \sqrt{b^2 - 4ac}} \qquad if \quad b < 0$$

$$x = x_0 - \left(\pm\sqrt{\frac{c}{a}}\right) \qquad if \quad b = 0$$

Step: 7 Calculate $f(x)$

a. If $f(x) = 0$ or if the desired precision is met, x is taken as the required root value.Then go to Step 9.

b. If $f(x) \neq 0$ and the desired precision are not met, then go to step 8.

Step: 8

a. If $x > x_0$, then reset: $x_2 = x_0$, $x_0 = x$, $x_1 = x_1$

b. If $x < x_0$, then reset: $x_2 = x_2$, $x_0 = x$, $x_1 = x_1$

Go to Step 3.

Step: 9 Stop.

Selection of parameters for Bayesian Single Sampling plan

For example, suppose one want to design a Bayesian single sampling plan from given n=150, p=0.02 and Pa(P)=0.90. In this case np=3. Select from Table 6 in the column given by Pa(P)=0.10 that value which is equal or just less than 3. One obtains the value of 3.112, which is associated with c=0. Thus, the sampling plan is given by (n=150, c=0,s=6). The number of iteration required by all the methods are same. Therefore one can use any one of the given methods for the calculation of parameters.

Parametric values for Bayesian Single Sampling Plan involving Linear Interpolation Method

Prior distribution parameter	**LINEAR INTERPOLATION METHOD (For c =1)** < − − − − − − − − −**Probability of Acceptance**− − − − − − − − − −>						
S	0.99 ↓	0.95 ↓	0.75 ↓	0.5 ↓	0.1 ↓	0.05 ↓	0.01 ↓
	Proportion defectives for given probability of acceptance &No.of iterations						
1	0.1111 (6)	0.2880 (6)	1.0000 (2)	2.4142 (6)	18.4868 (9)	38.4923 (10)	198.4987 (15)
2	0.1252 (6)	0.3131 (6)	0.9689 (5)	2.0000 (6)	8.2145 (9)	12.7765 (10)	31.9540 (13)
3	0.1315 (6)	0.3245 (6)	0.9631 (4)	1.8838 (6)	6.3615 (8)	9.0674 (9)	18.2966 (12)
4	6.0000 (6)	0.3311 (6)	0.9613 (4)	1.8293 (6)	5.6129 (8)	7.6757 (9)	14.0122 (12)
5	0.1375 (6)	0.3353 (6)	0.9606 (4)	1.7976 (6)	5.2107 (8)	6.9561 (9)	11.9887 (11)
6	0.1391 (6)	0.3383 (6)	0.9603 (4)	1.7770 (6)	4.9602 (7)	6.5183 (9)	10.8239 (11)
7	0.1404 (6)	0.3405 (6)	0.9602 (4)	1.7624 (6)	4.7894 (7)	6.2245 (9)	10.0708 (11)
8	0.1413 (6)	0.3422 (6)	0.9602 (4)	1.7515 (6)	4.6655 (7)	6.0138 (9)	9.5452 (11)
9	0.1421 (6)	0.3436 (6)	0.9602 (4)	1.7432 (6)	4.5715 (7)	5.8555 (9)	9.1581 (11)

Parametric values for Bayesian Single Sampling Plan involving Secant Method

Prior distribution parameter	**SECANT METHOD (For c =1)** **< − − − − − − − − −Probability of Acceptance− − − − − − − − − − >**						
S	0.99 ↓	0.95 ↓	0.75 ↓	0.5 ↓	0.1 ↓	0.05 ↓	0.01 ↓
	Proportion defectives for given probability of acceptance &No.of iterations						
1	0.1111 (5)	0.2880 (5)	1.0000 (1)	2.4142 (5)	18.4868 (9)	38.4923 (10)	198.4987 (15)
2	0.1252 (5)	0.3131 (5)	0.9689 (4)	2.0000 (5)	8.2145 (9)	12.7765 (10)	31.9540 (13)
3	0.1315 (5)	0.3245 (5)	0.9631 (3)	1.8838 (5)	6.3615 (8)	9.0674 (9)	18.2966 (12)
4	6.0000 (5)	0.3311 (5)	0.9613 (3)	1.8293 (5)	5.6129 (8)	7.6757 (9)	14.0122 (12)
5	0.1375 (5)	0.3353 (5)	0.9606 (3)	1.7976 (5)	5.2107 (8)	6.9561 (9)	11.9887 (11)
6	0.1391 (5)	0.3383 (5)	0.9603 (3)	1.7770 (5)	4.9602 (7)	6.5183 (9)	10.8239 (11)
7	0.1404 (5)	0.3405 (5)	0.9602 (3)	1.7624 (5)	4.7894 (7)	6.2245 (9)	10.0708 (11)
8	0.1413 (5)	0.3422 (5)	0.9602 (3)	1.7515 (5)	4.6655 (7)	6.0138 (9)	9.5452 (11)
9	0.1421 (5)	0.3436 (5)	0.9602 (3)	1.7432 (5)	4.5715 (7)	5.8555 (9)	9.1581 (11)

Parametric values for Bayesian Single Sampling Plan involving Muller's Method

Prior distribution parameter	**MULLER'S METHOD (For c =1)** < − − − − − − − − −**Probability of Acceptance**− − − − − − − − − −>						
S	0.99	0.95	0.75	0.5	0.1	0.05	0.01
	Proportion defectives for given probability of acceptance &No.of iterations						
1	0.1111 (3)	0.2880 (5)	1.0000 (1)	2.4142 (5)	18.4868 (5)	38.4923 (5)	198.4987 (15)
2	0.1252 (3)	0.3131 (4)	0.9689 (4)	2.0000 (5)	8.2145 (4)	12.7765 (5)	31.9540 (5)
3	0.1315 (3)	0.3245 (5)	0.9631 (3)	1.8838 (5)	6.3615 (4)	9.0674 (5)	18.2966 (5)
4	6.0000 (3)	0.3311 (4)	0.9613 (3)	1.8293 (5)	5.6129 (4)	7.6757 (5)	14.0122 (5)
5	0.1375 (4)	0.3353 (5)	0.9606 (3)	1.7976 (5)	5.2107 (4)	6.9561 (5)	11.9887 (5)
6	0.1391 (4)	0.3383 (4)	0.9603 (3)	1.7770 (5)	4.9602 (4)	6.5183 (5)	10.8239 (5)
7	0.1404 (4)	0.3405 (4)	0.9602 (3)	1.7624 (5)	4.7894 (4)	6.2245 (5)	10.0708 (5)
8	0.1413 (4)	0.3422 (5)	0.9602 (3)	1.7515 (5)	4.6655 (4)	6.0138 (5)	9.5452 (5)
9	0.1421 (4)	0.3436 (5)	0.9602 (3)	1.7432 (5)	4.5715 (4)	5.8555 (5)	9.1581 (5)

Parametric values for Bayesian Single Sampling Plan involving Modified Muller's Method

Prior distribution parameter	**MODIFIED MULLER'S METHOD (For c =1)** < − − − − − − − − −**Probability of Acceptance**− − − − − − − − − −>						
S	0.99	0.95	0.75	0.5	0.1	0.05	0.01
	Proportion defectives for given probability of acceptance &No.of iterations						
1	0.1111 (2)	0.2880 (5)	1.0000 (1)	2.4142 (5)	18.4868 (9)	38.4923 (10)	198.4987 (5)
2	0.1252 (2)	0.3131 (5)	0.9689 (4)	2.0000 (5)	8.2145 (9)	12.7765 (10)	31.9540 (5)
3	0.1315 (5)	0.3245 (5)	0.9631 (3)	1.8838 (5)	6.3615 (8)	9.0674 (9)	18.2966 (5)
4	6.0000 (2)	0.3311 (5)	0.9613 (3)	1.8293 (5)	5.6129 (8)	7.6757 (9)	14.0122 (5)
5	0.1375 (2)	0.3353 (5)	0.9606 (3)	1.7976 (5)	5.2107 (8)	6.9561 (9)	11.9887 (5)
6	0.1391 (2)	0.3383 (5)	0.9603 (3)	1.7770 (5)	4.9602 (7)	6.5183 (9)	10.8239 (5)
7	0.1404 (5)	0.3405 (5)	0.9602 (3)	1.7624 (5)	4.7894 (7)	6.2245 (9)	10.0708 (11)
8	0.1413 (2)	0.3422 (5)	0.9602 (3)	1.7515 (5)	4.6655 (7)	6.0138 (9)	9.5452 (5)
9	0.1421 (2)	0.3436 (5)	0.9602 (3)	1.7432 (5)	4.5715 (7)	5.8555 (9)	9.1581 (5)

Proportion defective values of Bayesian Single Sampling Plan (for c = 0)

Modified Muller's Method						Mullers Method					Secant Method		
c	s	Iteration number	$\bar{P}$=0.99		c	S	Iteration Number	$\bar{P}$=0.99		c	s	Iteration number	$\bar{P}$=0.99
	1	3	0.01010			1	3	0.010101			1	3	0.010101
	2	3	0.01008			2	3	0.010076			2	3	0.010076
	3	3	0.01007			3	3	0.010067			3	3	0.010067
	4	3	0.01006			4	3	0.010063			4	3	0.010063
0	5	3	0.01006		0	5	3	0.010060		0	5	3	0.010060
	6	3	0.01006			6	3	0.010059			6	3	0.010059
	7	3	0.01006			7	3	0.010058			7	3	0.010058
	8	3	0.01006			8	3	0.010057			8	3	0.010057
	9	3	0.01006			9	3	0.010056			9	3	0.010056
c	s	Iteration number	$\bar{P}$=0.95		c	S	Iteration Number	$\bar{P}$=0.95		c	s	Iteration number	$\bar{P}$=0.95
	1	3	0.52630			1	3	0.5263			1	3	0.52630
	2	4	0.05196			2	4	0.0520			2	4	0.05196
	3	4	0.05173			3	4	0.0517			3	4	0.05173
	4	4	0.05162			4	4	0.0516			4	4	0.05162
0	5	4	0.05156		0	5	4	0.0516		0	5	4	0.05156
	6	4	0.05151			6	4	0.0515			6	4	0.05151
	7	4	0.05148			7	4	0.0515			7	4	0.05148
	8	4	0.05146			8	4	0.0515			8	4	0.05146
	9	4	0.05144			9	4	0.0514			9	4	0.05144
c	s	Iteration number	$\bar{P}$=0.75		c	S	Iteration Number	$\bar{P}$=0.75		c	s	Iteration number	$\bar{P}$=0.75
	1	6	0.33333			1	6	0.33333			1	6	0.33333
	2	5	0.30940			2	5	0.30940			2	5	0.30940
	3	4	0.30193			3	4	0.30193			3	4	0.30193
	4	4	0.29828			4	4	0.29828			4	4	0.29828
0	5	4	0.29612		0	5	4	0.29612		0	5	4	0.29612
	6	4	0.29469			6	4	0.29469			6	4	0.29469
	7	4	0.29368			7	4	0.29368			7	4	0.29368
	8	4	0.29292			8	4	0.29292			8	4	0.29292
	9	4	0.29233			9	4	0.29233			9	4	0.29233

Proportion defective values of Bayesian Single Sampling Plan (for c = 0)

Modified Muller's Method						Mullers Method					Secant Method		
c	s	Iteration number	$\bar{P}$=0.50		c	S	Iteration number	$\bar{P}$=0.50		c	S	Iteration number	$\bar{P}$=0.50
	1	11	1.00000			1	11	1.00000			1	11	1.00000
	2	10	0.82843			2	11	0.82843			2	10	0.82843
	3	10	0.77976			3	11	0.77976			3	10	0.77976
0	4	10	0.75683		0	4	11	0.75683		0	4	10	0.75683
	5	10	0.74349			5	11	0.74349			5	10	0.74349
	6	10	0.73477			6	11	0.73477			6	10	0.73477

	7	10	0.72863			7	11	0.72863			7	10	0.72863
	8	10	0.72406			8	11	0.72406			8	10	0.72406
	9	10	0.72054			9	11	0.72054			9	10	0.72054
c	s	Iteration number	$\bar{P}$=0.10		c	S	Iteration number	$\bar{P}$=0.10		c	S	Iteration number	$\bar{P}$=0.10
	1	67	9.000045			1	57	9.000045			1	67	9.000045
	2	40	4.324569			2	46	4.324569			2	40	4.324569
	3	32	3.463314			3	32	3.463314			3	32	3.463314
	4	29	3.113124			4	29	3.113124			4	29	3.113124
0	5	27	2.924471		0	5	27	2.924471		0	5	27	2.924471
	6	25	2.806802			6	25	2.806802			6	25	2.806802
	7	24	2.726474			7	24	2.726474			7	24	2.726474
	8	23	2.668178			8	23	2.668178			8	23	2.668178
	9	22	2.623952			9	22	2.623952			9	22	2.623952
c	s	Iteration number	$\bar{P}$=0.10		c	S	Iteration number	$\bar{P}$=0.10		c	S	Iteration number	$\bar{P}$=0.10
	2	68	6.94439			2	68	6.94439			2	68	6.94439
	3	62	5.14328			3	62	5.14328			3	62	5.14328
	4	55	4.45899			4	55	4.45899			4	55	4.45899
0	5	50	4.10284		0	5	50	4.10284		0	5	50	4.10284
	6	48	4.43034			6	48	4.43034			6	48	4.43034
	7	45	3.73890			7	45	3.73890			7	45	3.73890
	8	44	3.63374			8	44	3.63374			8	44	3.63374
	9	43	3.55457			9	43	3.55457			9	43	3.55457

IV. CONCLUSION

Designing of Bayesian Single Sampling Plan(BSSP) indexed through Acceptable and Limiting Quality Levels using Linear Interpolation Method , Secant Method Muller's Method, Modified Muller's Method in obtaining the proportion defectives (nμ) for (BSSP) in this paper. The work presented in this paper relates to the new procedure for the construction and selection of Bayesian Single Sampling Plan. The results presented in this paper are mainly related with proposing new procedure and necessary tables for ready made selection of sampling system through quality levels involving producer and consumer quality levels. Tables are provided which are tailor made, handy and ready – made uses to the industrial shop – floor conditions. These tables are useful for both producer and consumer for obtaining good quality products with less inspection cost.

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