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RESEARCH ARTICLE

SELECTION OF BAYESIAN DOUBLE SAMPLING PLAN BASED ON BETA PRIOR DISTRIBUTION INDEX THROUGH QUALITY REGION

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ABSTRACT

This paper is concerned with the set of tables for the selection of Bayesian Double Sampling Plan (DSP-(0,1)) on the basis of different combinations of entry parameters. Double Sampling Plan involving Producer's and consumer's risks and Probabilistic Quality Region , Indifference Quality Region for specified AQL and LQL. Beta distributions are considered as prior distribution. Comparison is made with conventional Double Sampling Plan.

INTRODUCTION

Bayesian acceptance sampling using sampling procedure to determine whether to accept or reject a product or process. It has been a common quality control technique that used in industry and particularly in military for contracts and procurement of products. It is usually done as products that leave the factory or in some cases even within the factory. Most often a producer supplies number of items to consumer and decision to accept or reject the lot is made through determining the number of defective items in a sample from that lot. The lot is accepted, if the number of defectives falls below the acceptance number or otherwise the lot is rejected. Acceptance sampling by attributes each item is tested and classified as conforming or non-conforming. A sampling is taken and contains too many non-conforming items, then the batch is rejected, otherwise it is accepted. For this method to be effective, batches containing some non-conforming items must be acceptable. If the only acceptable percentage of non-conforming items is zero, this can only be achieved through examine every items and removing the item which are non-conforming. This is known as 100% inspection. Effective acceptance sampling involves effective selection and the application of specific rules for lot inspection. The acceptance sampling plans applied on a lot-by-lot basis become an element in the overall approach to maximize quality at minimum cost. Since different sampling plans may be statistically valid at different times during the process, therefore all sampling plans should be periodically reviewed.

Bayesian acceptance sampling approach is associated with the utilization of prior process history for the selection of distribution (viz., gamma Poisson , beta binomial) to describe the random fluctuations involved in acceptance sampling, Bayesian sampling plan requires the user to specify explicitly the distribution of defective from lotto 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.

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A complete statistical model for Bayesian sampling inspection contains three components:

1. The prior distribution (i.e) the expected distribution of submitted lots according to quality.
2. The cost of sampling inspection, acceptance and rejection.
3. A class of sampling plans that usually defined by means of a restriction designed to give a protection against accepting lot of poor quality.

Risk-based sampling plans are traditional in nature, drawing upon producer and consumer type of risks as depicted by the OC curve. Economically based sampling plans explicitly consider certain factors as cost of inspection, accepting a non-conforming units and rejection a conforming unit, in an attempt to design a cost-effective plan. Bayesian plan design procedures take into account the past history of similar lots submitted previously for the inspection purposes. Non-Bayesian plan design methodology is not explicitly based upon the past history.

To improve the quality for any product and services, it is customary to modernize the quality practices and simultaneously reduce the cost for inspection and quality improvement. As a result of increasing customer quality requirements and development for new product technology many existing quality assurance practices and techniques need to be modified.

The need for such statistical and analytical techniques in quality assurance is rapidly increasing owing to stiff competition in industry towards product quality improvement. This paper introduces a method for selection of Bayesian Chain Sampling Plan based on range of quality instead of point wish description of quality by invoking a Novel approach called quality interval sampling (QIS) plan. This method seems to be versatile and can be adopted in the elementary production process where the stipulated quality level is advisable to fix at later stage and provides a new concept for selection of BDSP –(0,1) plan involving quality levels.

The sampling plan provides both vendor and buyer decision rules for the product acceptance to meet the present product quality requirement. Due to rapid advancement of manufacturing technology. Suppliers require their products to be of high quality with very low fraction defectives often measured in parts per million. Unfortunately, traditional methods in some particular situations fail to find out a minute defect in the product. In order to overcome such problems quality interval sampling (QIS)plan is introduced. This paper designs the parameters for the plan indexed with quality regions involving QIS.

Dodge (1955) has derived Chain Sampling inspection Plans. Case and Keats (1982) have examined the relationship between defectives in the sample and defectives in the remaining lot for each of the five prior distributions, they observe that the use of a binomial prior renders sampling useless and inappropriate. These results serve to make the designers and users of Bayesian sampling plans more aware of the consequence associated with selection of particular prior distribution. Calvin (1984) has presented in a clear and concise treatment by means of 'how and when to perform Bayesian acceptance sampling'. These procedure are suited to the sampling of lots from process or assembly operations, which contain assignable causes. These causes may be unknown and awaiting isolation, known but irremovable due to the state of the art limitations, or known but uneconomical to remove. He has considered the Bayesian sampling in which primary concern is with the process average function non conforming p_1 with lot fraction non-conforming p and its limitations being discussed.

Hald (1960) has derived optimal solutions for the cost function k(n,c) in the cases where the prior distribution is rectangular , polya and binomial. Tables are given for optimum n,c and k(n,c) for various values of the parameters, which is an important result on Bayesian acceptance sampling (BAS). Hald(1965) has given a rather system of single sampling attribute plans obtained by minimizing average cost, under the assumptions that the cost linear in the fraction defective p. Wortham and Baker (1976) have given Multiple Deferred State Sampling Plan inspection. Soundararajan(1978a) procedures and tables for construction and selection of Chain Sampling Plans (ChSP-1). Varest (1981) A Procedure of Construct Multiple Deferred State Sampling Plans. Raju (1984) Contribution to the study of Chain Sampling Plans. Soundararajan and Vijayaraghavan (1989) have designing Multiple deferred state sampling (MDS-1(0,2)) plans involving minimum risks. Subramani and Govindaraju (1990) have Selection of Multiple Deferred State MDS-1 Sampling Plan for given Acceptable and Limiting Quality Levels involving Minimum Risks. Suresh and Ramkumar (1996) have Selection of a Sampling Plan indexed with a Maximum Allowable Average Outgoing Quality. Suresh and Latha (2001) have discussed Bayesian Single Sampling Plan for a gamma prior distribution. Suresh and Latha (2002) discussed the Construction and Evaluation of Performance Measures of Bayesian Chain Sampling Plan using Gamma Distribution as the prior distribution. Latha and Jayabharathi (2012) have studied the selection of Bayesian Chain Sampling attributes Plan based on geometric distribution. Suresh and Sangeetha (2010) have studied the selection of Repetitive Deferred Sampling Plan with Quality Regions. Latha and Arivazhagan (2015) have studied the selection of Multiple Deferred State Sampling plan based on Beta Prior Distribution. Latha and Arivazhagan (2015) have studied the Bayesian Chain Sampling Plan using Beta Prior Distribution.

This paper designs the parameters of the plan indexed with AQL, LQL and α, β and IQL, PQR and IQR for specified s and n_1, n_2 the parameter of the prior distribution with numerical illustrations are also provided.

Double Sampling Plans DSP-(0,1)

The Operating Procedure of Double Sampling Plan with c_1= 0, c_2=1 designated as DSP-(0,1) Plan is as follows,

1. Draw a random sample of size n_1 from each lot and observe the number of nonconforming units d_1.
2. If $d_1=0$, accept the lot ; if $d_1>1$, Reject the lot; if $d_1=1$, draw a second random sample of size n_2 and observe the number of non conforming units d_2. If $d_2=0$, accept the lot ; if $d_2\geq 1$, rejected the lot. Thus the DSP –(0,1) plan has two parameters n_1 and n_2.,

Bayesian Average Probability of Acceptance

The oc expression for $P_a(p)$ to the double sampling plan was Presented by Dodge and Roming (1959) as

$$P_a(p) = P(d_1 \leq c_1; n_1) + \sum_{d_1=c+1}^{c_2} P(d_1; n_1)P(d_2 \leq c_2 - d_1; n_2)$$

The Binomial Model of the OC function of DSP-(0,1) plan is given by, $P_a(p) = (1-p)^{n_1} + n_1 p(1-p)^{n_1-1}(1-p)^{n_2}$

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

The past history its observe that the process average p the Beta prior distribution. The parameter s and t with density function,

$$f(p) = \frac{p^{s-1}(1-p)^{t-1}}{\beta(s,t)}, 0 < p < 1,\ s,t > 0, q = 1-p \quad (2)$$

Where $\mu = \frac{s}{s+t}$, Under the proposed Double Sampling Plans, the Probability of Acceptance of Double Sampling Plan of type DSP-(0,1) plan based on the Beta Binomial Distribution is given by, $\bar{P} = \int_0^1 p_a(p)f(p)dp$

$$\bar{P} = \int_0^1 (1-p)^{n_1} + n_1 p(1 - p)^{n_1+n_2-1} \left(\frac{p^{s-1}(1-p)^{t-1}}{\beta(s,t)}\right) dp$$

$$\bar{P} = \frac{1}{\beta(s,t)} \{\beta(s, n_1+t) + n_1\beta(s+1, n_1+n_2+t-1)\}$$

$$\bar{P} = \frac{\Gamma_{s+t}}{\Gamma_s\Gamma_t} \frac{\Gamma_s\Gamma_{n_1+t}}{\Gamma_{s+t+n_1}} + \frac{n_1\Gamma_{s+t}}{\Gamma_s\Gamma_t} \quad (3)$$

Table 1 Certain μ values for specified values of P(μ) BDSP-(0,1)

			Probability of Acceptance						
s	**n_1**	**n_2**	**0.99**	**0.95**	**0.90**	**0.50**	**0.10**	**0.05**	**0.01**
1	100	100	0.000646	0.001686	0.002722	0.014482	0.103201	0.193695	0.55381
	100	50	0.000788	0.002045	0.003286	0.017052	0.117866	0.217773	0.58956
	50	100	0.001012	0.002678	0.004371	0.024402	0.168767	0.298445	0.68792
	50	50	0.001293	0.003372	0.005437	0.028586	0.187254	0.324756	0.71305
	25	20	0.002781	0.007214	0.011581	0.058734	0.326525	0.502790	0.83926
	20	25	0.003007	0.007844	0.012647	0.065282	0.355550	0.535490	0.85634
2	100	100	0.000727	0.001828	0.002856	0.012016	0.049751	0.076373	0.17729
	100	50	0.000888	0.002222	0.003458	0.014204	0.056985	0.086734	0.19784
	50	100	0.001136	0.002889	0.004557	0.020203	0.086736	0.132337	0.29230
	50	50	0.001455	0.003657	0.005709	0.023846	0.095980	0.144491	0.31214
	25	20	0.003132	0.007838	0.012192	0.049632	0.186286	0.269501	0.51304
	20	25	0.003383	0.008505	0.013279	0.055149	0.209266	0.301160	0.55832
3	100	100	0.000763	0.001893	0.002922	0.011309	0.039175	0.055855	0.11039
	100	50	0.000933	0.002303	0.003542	0.013394	0.044784	0.063219	0.12282
	50	100	0.001192	0.002985	0.004648	0.018970	0.069476	0.099540	0.19410
	50	50	0.001529	0.003787	0.005841	0.022477	0.076404	0.107732	0.20543
	25	20	0.003290	0.008121	0.012486	0.046966	0.151327	0.207980	0.36902
	20	25	0.003553	0.008805	0.013584	0.052140	0.171546	0.235958	0.41432

Table 2 Values of μ_2/μ_1 tabulated against s and n_1, n_2 for given α and β for Bayesian Double Sampling Plan

s	***n_1***	***n_2***	***μ_2/μ_1 for α=0.05 β=0.10***	***μ_2/μ_1 for α=0.05 β=0.05***	***μ_2/μ_1 for α=0.05 β=0.01***	***μ_2/μ_1 for α=0.01 β=0.10***	***μ_2/μ_1 for α=0.01 β=0.05***	***μ_2/μ_1 for α=0.01 β=0.01***	***μ_2/μ_1 for α=0.10 β=0.10***	***μ_2/μ_1 for α=0.10 β=0.05***	***μ_2/μ_1 for α=0.10 β=0.01***
1	100	100	61.25056	71.15907	328.47570	159.75390	299.83750	857.29100	37.91367	71.15907	203.45700
	100	50	57.63619	106.49050	288.29340	149.57610	276.36170	748.17260	35.86914	66.27298	179.41570
	50	100	63.01979	111.44320	256.87830	166.82350	295.00820	679.9980	38.61062	68.27843	157.38270
	50	50	55.53203	96.30961	211.46200	144.82130	251.16470	551.46950	34.43942	59.72854	131.14290
	25	20	45.26268	69.69642	116.33770	117.41280	180.79470	301.78350	28.19489	43.41508	72.46870
	20	25	45.32764	68.26747	109.17130	118.24080	178.08110	284.78220	28.11339	42.34127	67.71092
2	100	100	27.21608	41.77954	96.98304	68.43329	105.05230	243.85830	17.41982	26.74125	62.07458
	100	50	25.64120	39.02718	89.02088	64.17230	97.67342	222.79280	16.47918	25.08213	57.21226
	50	100	30.02285	45.80720	101.17690	76.35211	116.49380	257.30630	19.03357	29.04038	64.14308
	50	50	26.24423	39.50864	85.34945	65.94778	99.27924	214.47020	16.81074	25.30725	54.67057
	25	20	23.76825	34.38565	65.45881	59.48399	86.05582	163.82160	15.27886	22.10402	42.07867
	20	25	24.60621	35.41142	65.64918	61.85811	89.02158	165.03690	15.75905	22.67925	42.04502
3	100	100	20.69499	29.50628	58.31577	51.31917	73.16928	144.61070	13.40783	19.11647	37.78150
	100	50	19.44501	27.44907	53.32766	48.01051	67.77283	131.66810	12.64483	17.84976	34.67826
	50	100	23.27569	33.34785	65.02730	58.30838	83.54035	162.90120	14.94883	21.41769	41.76385
	50	50	20.17427	28.44635	54.24324	49.98626	70.48217	134.39970	13.08008	18.44331	35.16884
	25	20	18.63300	25.60873	45.43770	46.00024	63.22157	112.17440	12.11964	16.65692	29.55446
	20	25	19.48191	26.79697	47.05294	48.28881	66.42027	116.62770	12.62881	17.37067	30.50126

Hence the above equation is mixed distribution of Beta Binomial distribution.

Construction of Table

$\bar{P}$ is reduced and μ_0 is the point of control, The above equation (3) can be reduced to
Now s=1,

$$\bar{P} = \frac{(1-\mu)}{(n_1\mu+1-\mu)} + \frac{n_1\mu(1-\mu)}{(n_1\mu+n_2\mu+1-\mu)(n_1\mu+n_2\mu+1-2\mu)}$$

Now s=2, $\bar{P}$ as

$$= \frac{(2-2\mu)(2-\mu)}{(n_1\mu+2-2\mu)(n_1\mu+2-\mu)}$$

$$+ \frac{2n_1\mu(2-2\mu)(2-\mu)}{(n_1\mu+n_2\mu+2-3\mu)(n_1\mu+n_2\mu+2-2\mu)(n_1\mu+n_2\mu+2-\mu)}$$

Now s=3,

$$\bar{P} = \frac{(3-3\mu)(3-2\mu)(3-\mu)}{(n_1\mu+3-3\mu)(n_1\mu+3-2\mu)(n_1\mu+3-\mu)}$$

$$\bar{P} = \frac{(3-3\mu)(3-2\mu)(3-\mu)}{(n_1\mu+3-3\mu)(n_1\mu+3-2\mu)(n_1\mu+3-\mu)}$$

Designing Plans for given AQL, LQL, α and β

Tables 1 and 2 are used for selecting a Bayesian Double Sampling Plan for specified AQL and LQL, α ,β by the following steps.

The steps utilized for selecting Bayesian Double Sampling Plan (BDSP-(0,1)) are as follows:

1. To design a plan for given (AQL, 1-α) and (LQL, β) first calculate the operating ratio μ_2/μ_1
2. For a fixed n_1, n_2 locate the tabular value of μ_2/μ_1 which is equal to or just less than the desired μ_2/μ_1 in the column of desired α, β.
3. Corresponding to the located value of μ_2/μ_1 the value of s and n_1, n_2 can be obtained.

Example 1 For s=1, n_1=100, n_2=50, and $\bar{P} = 0.50$ the corresponding Indifference Quality Level (IQL) value μ_0=0.017052. And For s=3, n_1=50, n_2=50, and AQL value μ_1= 0.003787 and LQL values μ_2=0.076404.

Table 3 Values of PQR and IQR, $\mu_2/\mu_1$for specified values s,n_1,n_2

s	n_1	n_2	μ_1	μ_0	μ_2	d_2	d_0	*T*	μ_2/μ_1
1	100	100	0.001686	0.014482	0.103201	0.101515	0.012796	7.933339	61.21056
	100	50	0.002045	0.017052	0.117866	0.115821	0.015007	7.717747	57.63619
	50	100	0.002678	0.024402	0.168767	0.166089	0.021724	7.645415	63.01979
	50	50	0.003372	0.028586	0.187254	0.183882	0.025214	7.292853	55.53203
	25	20	0.007214	0.058734	0.326525	0.319311	0.051520	6.197807	45.26268
	20	25	0.007844	0.065282	0.355550	0.347706	0.057438	6.053588	45.32764
2	100	100	0.001828	0.012016	0.049751	0.047923	0.010188	4.703867	27.21608
	100	50	0.002222	0.014204	0.056985	0.054763	0.011981	4.570749	25.64120
	50	100	0.002889	0.020203	0.086736	0.083847	0.017314	4.842728	30.02285
	50	50	0.003657	0.023846	0.095980	0.092323	0.020189	4.572923	26.24423
	25	20	0.007838	0.049632	0.186286	0.178448	0.041794	4.269683	23.76825
	20	25	0.008505	0.055149	0.209266	0.200761	0.046644	4.304111	24.60621
3	100	100	0.001893	0.011309	0.039175	0.037282	0.009416	3.959325	20.69499
	100	50	0.002303	0.013394	0.044784	0.042481	0.011091	3.830323	19.44501
	50	100	0.002985	0.018970	0.069476	0.066491	0.015985	4.159542	23.27569
	50	50	0.003787	0.022477	0.076404	0.072617	0.018690	3.885319	20.17427
	25	20	0.008121	0.046966	0.151327	0.143206	0.038845	3.686594	18.63300
	20	25	0.008805	0.052140	0.171546	0.162741	0.043334	3.755460	19.48190

From Table 1 for the given variation Average Probability of Acceptance of the above equations. The average product quality level μ using Newton's approximation method is obtained. The above examples, we can understand that when s and n_1, n_2 are increased, the average product quality is decreased.

Example 2 Suppose the value for μ_1 is assumed as 0.0027 and value for μ_2 is assumed as 0.30 then the operating ratio is calculate as 111.11111. Now the integer approximately equal to this calculated operating ratio and their corresponding parametric values are observed from the table2. The actual values s=1, n_1=50, n_2=100 μ_1=0.002678 and μ_2=0.298445 at (α=0.05 and β=0.05).

Designing of Quality interval Bayesian Double Sampling Plan (BDSP-(0,1))

Probabilistic Quality Region (PQR)

It is an interval of quality ($\mu_1 < \mu < \mu_2$) in which product is accepted with a minimum probability 0.10 and maximum probability 0.95, Probability Quality Range denoted as the $d_2 = (\mu_2 - \mu_1)$ is derived from the average Probability of acceptance

$$\bar{P}(\mu_1 < \mu < \mu_2) = \frac{\Gamma_{s+t}}{\Gamma_s\Gamma_t}\frac{\Gamma_s\Gamma_{n_1+t}}{\Gamma_{s+t+n_1}} + \frac{n_1}{\Gamma_s\Gamma_t}\frac{\Gamma_{s+1}\Gamma_{n_1+n_2+t-1}}{\Gamma_{s+t+n_1+n_2}}$$

Where $\mu = \frac{s}{s+t}$, is the expectation of beta distribution and approximately the mean values of product quality.

Indifference Quality Region (IQR)

It is an interval of quality ($\mu_1 < \mu < \mu_0$) in which product is accepted with a minimum probability 0.50 and maximum probability 0.95. Indifference Quality Range denoted as the $d_0 = (\mu_o - \mu_1)$ is derived from the average Probability of acceptance

$$\bar{P}(\mu_1 < \mu < \mu_0) = \frac{\Gamma_{s+t}}{\Gamma_s \Gamma_t} \frac{\Gamma_s \Gamma_{n_1+t}}{\Gamma_{s+t+n_1}} + \frac{n_1 \Gamma_{s+t}}{\Gamma_s \Gamma_t} \frac{\Gamma_{s+1} \Gamma_{n_1+n_2+t-1}}{\Gamma_{s+t+n_1+n_2}}$$

Where $\mu = \frac{s}{s+t}$, is the expectation of beta distribution and approximately the mean values of product quality.

Selection of the Sampling Plan

Table 3, gives unique values of T for different values of s and n1, n2. Here Operating Ratio $T = \frac{\mu_2 - \mu_1}{\mu_0 - \mu_1} = \frac{d_2}{d_0}$, Where $d_2 = (\mu_2 - \mu_1)$ and $d_0 = (\mu_0 - \mu_1)$ is used to characterize the sampling plan. For any given values of PQR(d_2) and IQR(d_0) one can find the ratio $T = \frac{d_2}{d_0}$, Find the value in the Table 3, under the column T which is equal to or just less than the specified ratio, corresponding s and n_1, n_2 values are noted. From this ratio one can determine the parameters for the BDSP-(0,1) Plan.

In the similar way, the above equations are equated to the average probability of acceptance 0.95 and 0.10, AQL(μ_1) and IQL(μ_2) are obtained μ_2/μ_1 in Table 3.

Example 3. Given μ_1= 0.00783 compute the values of PQR and IQR then compute T. Select the respective values from Table 3. The nearest values of PQR and IQR corresponding to s=2, n_1=25, n_2=20 and μ_1=0.007838 are d_2= 0.178448 and d_0= 0.041794, Then T= 4.269683. Hence the required plan has parameters n_1=25, n_2=20, s=2, through Quality Interval.

CONCLUSION

Bayesian Acceptance Sampling is the technique, which deals with the procedure in which decision to accept or reject lots or process based on their examination of past history or knowledge of samples. There are many way to determine an appropriate sampling plan. However all of them are either settled on a non-economic basis or do not take into consideration the produce's and consumer's quality and risk requirements. Using the Bayesian sampling attribute plan without a cost function for a prior distribution can reduce the sample size. The work presented in this paper mainly related to procedure for designing Bayesian Chain Sampling plan for Acceptable quality level, producer's and consumer's risks, indifference quality levels, indifference and probabilistic quality regions. The Risks and Quality Region for specified AQL and LQL sampling plan possesses wider potential applicable in industry ensuring higher standard of quality attainment for product or process. Thus quality level and quality region are good measure for defining and designing for acceptance sampling plan which are tailor-made, handy and ready-made uses to industrial shop-floor situations.

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