Designing of Generalized Two Plan System with Repetitive Deferred Sampling Plan as Reference Plan Using Minimum Risks

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Research Article

Abstract: This paper presents a new procedure and tables for minimum sum of risk of a Generalized Two Plan system of type (n, c_N, c_T) with Repetitive Deferred Sampling Plan as reference plan indexed through Acceptable Quality Level (AQL) and Limiting Quality Level (LQL). Tables are constructed by considering various quality levels, and illustrations are also provided for ready-made selection of plan parameters.

Keywords: Acceptable Quality Level (AQL), Limiting Quality Level (LQL), Minimum Risks, Multiple Deferred Sampling plan, Operating Characteristic Curve, Repetitive Deferred Sampling Plan.

1. Introduction

Acceptance sampling is a statistical tool used to make decisions concerning whether or not a lot of products should be released for consumer use. An acceptance sampling plan is a statement regarding the required sample size for product inspection and the associated acceptance or rejection criteria for sentencing individual lots. The criteria used for measuring the performance of an acceptance sampling plan, is usually based on the operating characteristic (OC) curve which quantifies the risks for producers and consumers. The OC curves plots the probability of accepting the lot versus the lot fraction nonconforming, which displays the discriminatory power of the sampling plan. The basic acceptance sampling plan called the single-sampling plan is widely used in industry to inspect items due to its easiness of implementation. A single sampling attribute inspection plan calls for acceptance of a lot under consideration. If the number of non-conforming units found in a random sample of size n is less than or equal to the acceptance number. Whenever a sampling plan for costly or destructive testing is required, it is common to force the OC curve to pass through a point, say, (LQL, β). In this paper Generalized Two Plan System with Repetitive Deferred Sampling plan as reference plan has been proposed. Dodge (1959) proposed a new sampling inspection system namely two-plan system. The two-plan system has a normal as well as a tightened plan which has a tighter OC curve compared with that of the normal plan. A sampling system consists of two or more sampling plans and rules for switching between them to achieve the advantageous features of each. In general any sampling system of sampling inspection involving only normal and tightened inspections will be referred to as a two-plan system. The tightened inspection can be used when the quality of a product deteriorated and normal inspection is used when the quality is found to be good. Dodge(1965), Hald and Thyregod (1966) and Stephens and Larson(1967) have investigated the two-plan systems using different switching criteria to achieve the desired discrimination on the operating ratio (OC) curve and MIL-STD-105D (1963) systems using the Markov chain approach. Romboski(1969) has investigated the properties of a particular type such a two-plan system namely QS system which was originally proposed by Dodge(1967). Thus the generalized two-plan system is very useful to find performance measures of a desired sampling system by substituting numbers for s, m, and d. Kuralmani(1992) has designed two-plan switching system involving acceptable and limiting quality levels. The procedure with a pair of plans gives an overall OC curve that generally lies in between the OC curve of the normal and tightened plans in a Two-Plan switching system. This system is largely incorporated in MIL-STD-105E (1989) which forms an integrated sampling inspection system guaranteeing the consumer that the outgoing quality will be better than the specified AQL and at the same time assuring the producer that the risk of rejection will be smaller for products of AQL quality or better ones. The Repetitive Deferred Sampling plan has been developed by Shankar and Mohapatra(1991) and this plan is essentially an extension of the Multiple Deferred Sampling plan MDS-(c_1, c_2) due to Rambert Vaerst(1981). In this plan the acceptance or rejection of a lot in deferred state is dependent on the inspection results of the preceding or succeeding lots under Repetitive Group Sampling (RGS) inspection. So, RGS is a particular case of RDS plan. Further Wortham and Baker (1976) have developed Multiple Deferred State Sampling (MDS) plans and also provided tables for construction of plans. Suresh (1993) has proposed procedures to select Multiple Deferred State Plan of type MDS and MDS-1 indexed through producer and consumer quality levels considering filter and incentive effects.

Lilly Christina (1995) has given the procedure for the selection of RDS plan with given acceptable quality levels and also compared RDS plan with RGS plan with respect to operating ratio(OR) and ASN curve. Suresh and Saminathan (2010) have studied the selection of Repetitive Deferred Sampling Plan through acceptable and limiting quality levels. Golub(1953) has developed a method of designing a single sampling plan when the sample size is fixed and has given an expression for c such that the sum of two risks namely producer's risk (α) and consumer's risk (β) is minimum. Minimizing $\alpha + \beta$ is same as maximizing $(1-\alpha) + (1-\beta)$. The Golub's approach for single sampling plan has been extended by Soundararajan(1981) under poisson model and hyper geometric model. Soundararajan(1978a,b)constructed the tables for the selection of Chsp-1 plans under poisson model and also given for i which minimizes the sum of producer's and consumer's risk for specified AQL and LQL when sample size is fixed. Soundararajan and Govindaraju (1982) have also studied the Chsp-1 plan involving minimum sum of producer's and consumer's risk. Subramani(1991) has studied the selection of single sampling plans for given p_1, p_2, α, and β involving minimum sum of risk. He also studied attribute double sampling plan, Chsp (0,1), Multiple Deferred sampling plan of type MDS(c_1,c_2) and MDS-1(c_1,c_2), RGS plan, and Link sampling plan involving minimum sum of producer's and consumer's risk. Raju (1984) has given a set of tables for finding i values indexed through AQL and LQL for fixed sample size minimizing $\alpha + \beta$ with and without weight for Chsp-1 plan. Raju (1984) has also followed Golub's approach for designing Multiple Deferred state sampling plan of type MDS-1 (c_1, c_2). Govindaraju and Subramani(1990) have studied the selection of single sampling attribute plan involving the minimum sum of risks without fixing the sample size poisson model. Soundararajan and Vijayaraghavan (1989b) have applied Golub's approach for designing Multiple Deferred State Sampling MDS-1(0,2) plans involving minimum risks. Sivasankari(2004) has designed the special type double sampling plan involving minimum sum of risk and Two-Plan System TPS (c_N, c_T, n) involving minimum sum of risks. Chintha Zacharias (2006) has studied the selection of Two-plan system TPS (n,kn;c) using minimum sum of risks. In acceptance sampling, the producer and consumer play a dominant role and hence one allows certain level of risks for producer and consumer, namely α=0.05 and β= 0.10. Further this approach results in the rounded values of p_2/p_1. The expression for the sum of producer's and consumer's risk.

$$\alpha+\beta=[1-P_a(p_1)]+P_a(p_2) \tag{1}$$

If the operating ratio p_2/p_1 and np_1 are known, then np_2 can be calculated as

$$np_2=(p_2/p_1)(np_1) \tag{2}$$

2. Generalized Two-Plan System

Generalized Two-Plan System which is analogous of Dodge (1959) two-plan acceptance sampling system. Dodge (1965), Stephens and Larson (1967), Calvin(1977), Hobbs(1987)etc have discussed two-plan system in detail in various research papers. All the above discussed switching rules can be viewed as a unique system of rules and can be generalized. Kuralmani(1992) has introduced the switching procedure for such a generalized two-plan system, and its OC and ASN functions. The selection of single sampling two-plan system with equal sample sizes but with different acceptance numbers designated as TPS (n,c_N,c_T).

2.1 Operating Procedure

Switching rules for generalized Two-plan Systems are:

Normal to Tightened

When normal inspection is in effect, tightened inspection shall be instituted when's' out of 'm' consecutive lots or batches have been rejected on original inspection (s≤m).

Tightened to Normal

When tightened inspection is in effect, normal inspection shall be instituted when'd' consecutive lots or batches have been considered acceptable on original inspection.

A number of important measures of performance are to be determined and used in the evaluation of OC function which will be discussed.

P_N = the proportion of lots expected to be accepted under normal inspection.

P_T = the proportion of lots expected to be accepted under tightened inspection.

I_N = the expected proportion of lots inspected on normal inspection.

I_T = the expected proportion of lots inspected on tightened inspection.

Dodge (1959) has provided a performance measure with a composite of function for the probability of acceptance,

$$P_a(p) = I_N P_N + I_T P_T \tag{3}$$

The methods for deriving various measures of performance for the Generalized Two- Plan System are also studied.

All probabilities can now be evaluated using the condition that the sum of all probabilities equals to one,

i.e. $I_N + I_T = 1$ (4)

one can get,

$$I_N = \frac{\mu}{\mu+\tau} \quad (5)$$

$$I_T = \frac{\tau}{\mu+\tau} \quad (6)$$

Where,

$$\mu = \frac{1+(1-a)^{s-2}(2a-a^{m-s+2}-1)}{a(1-a^{m-s+1})(1-a)^{s-1}} \quad (7)$$

= the average number of lots inspected using the normal plan before going to tightened inspection.

$$\text{and } \tau = \frac{1-b^d}{(1-b)b^d} \quad (8)$$

= the average number of lots inspected using the normal plan before going to tightened inspection.

Here, a as P_N and b as P_T, the composite OC and ASN functions are, respectively, obtained as

$$Pa(p) = \frac{\mu P_N + \tau P_T}{\mu+\tau} \quad (9)$$

Where,

P_N = Probability of acceptance under the normal inspection.

$P_N = p(d \le c_N / n, p)$

P_T = Probability of acceptance under the tightened inspection.

$P_T = p(d \le c_T / n, p)$

Note that where μ and τ are the average number of lots inspected using normal inspection before going to tightened inspection and average number of lots inspected using tightened inspection before going to normal inspection respectively.

3. Conditions for RDS Plan

1. Production is steady so that result of past, current and future lots are broadly indicative of a continuing process.
2. Lots are submitted substantially in the order of their production.
3. A fixed sample size, n from each lot is assumed.
4. Inspection is by attributes with quality defined as fraction non-conforming.

3.1 Operating Procedure for RDS Plan

1. Draw a random sample of size n from the lot and determine the number of defectives (d) found therein.
2. Accept the lot if $d \le c_1$. Reject the lot if $d > c_2$.
3. If $c_1 \le d < c_2$, accept the lot provided 'i' proceeding or succeeding lots are accepted under RDS inspection plan, otherwise reject the lot.

Here c_1 and c_2 are acceptance numbers such that $c_1 < c_2$, when i=1 this plan reduces to RDS plan.

3.2 Operating Characteristic for RDS Plan

The operating characteristic function $P_a(p)$ for Repetitive Deferred Sampling Plan is derived by Shankar and Mohapatra (1991) using the Poisson Model as,

$$P_a(p) = \frac{p_a(1-p_c)^i + p_c p_a{}^i}{(1-p_c)^i} \quad (10)$$

where

$$p_a = p[d \le c_1] = \sum_{r=0}^{c_1} \frac{e^{-x}(x)^r}{r!} \quad (11)$$

$$p_c = p[c_1 < d \le c_2] = \sum_{r=0}^{c_2} \frac{e^{-x}(x)^r}{r!} - \sum_{r=0}^{c_1} \frac{e^{-x}(x)^r}{r!} \quad (12)$$

also x=np.

Thus the RDS plan is characterized with parameters namely n, c_1, c_2 and the acceptance criterion i.

4. Selection of Minimum Risk for RDS Plan

Table 1 is used to select a minimum risks generalized two-plan system for given p_1 and p_2. For the system of table, the producer's and consumer's risks will be at most 10% each. Against the fixed value of the operating ratio p_2/p_1. Table 1 give the acceptance number c_N (normal acceptance number), c_T (tightened acceptance number) and the associated producer's and consumer's risks in the body of the table against the product of sample size and Acceptable Quality Level (np_1). The following procedure is used for selecting the system for given p_1, p_2, α, β.

1. Computing the operating ratio p_2/p_1.
2. With the computed value of p_2/p_1, enter Table 1 in the row headed by p_2/p_1 which is equal to or just smaller than the computed ratio.
3. The normal acceptance number c_N, and the tightened acceptance number c_T, are obtained when one proceeds from left to right in the row identified in step 2 such that the tabulated producer's and consumer's risks are equal to just less than the desired values.
4. The sample size n is obtained as $n = np_1/p_1$. Where np_1 values are given in the column heading corresponding to the acceptance numbers obtained in step 3.

For example, if one fixes $p_1 = 0.02$, $p_2 = 0.56$ and $\alpha = 0.05$ and $\beta = 0.10$, from table 1, one obtains a Two-Plan system TPS (n; c_N, c_T) with Repetitive Deferred Sampling (RDS) plan as reference plan involving minimum sum of risks as follows,

1. $p_2/p_1 = 28$
2. Tabulated $p_2/p_1 = 28.0$

3. Corresponding to $c_N = 0$, $c_T = 1$, given in the body of the table, one obtains $\alpha = 0.03$, $\beta = 0.041$ against the desired value of $\alpha = 0.05$, $\beta = 0.10$.
4. $n = np_1/p_1 = 0.4/0.02 = 20$.

5. Construction of Tables

The expression for the OC function of Generalized Two Plan system with Repetitive Deferred Sampling (RDS) Plan as reference plan is given by,

$$P_a(p) = \frac{\mu P_N + \tau P_T}{\mu + \tau} \tag{13}$$

$$P_N = \frac{p_a(1-p_c)^i + p_c p_a{}^i}{(1-p_c)^i} \tag{14}$$

where

$$p_a = p[d \le u_1] = \sum_{r=0}^{u_1} \frac{e^{-x}(x)^r}{r!}$$

$$p_c = p[u_1 < d \le u_2] = \sum_{r=0}^{u_2} \frac{e^{-x}(x)^r}{r!} - \sum_{r=0}^{u_1} \frac{e^{-x}(x)^r}{r!}$$

$$P_T = \frac{p_a(1-p_c)^i + p_c p_a{}^i}{(1-p_c)^i} \tag{15}$$

$$p_a = p[d \le v_1] = \sum_{r=0}^{v_1} \frac{e^{-x}(x)^r}{r!}$$

$$p_c = p[v_1 < d \le v_2] = \sum_{r=0}^{v_2} \frac{e^{-x}(x)^r}{r!} - \sum_{r=0}^{v_1} \frac{e^{-x}(x)^r}{r!}$$

where $x=np$ is the OC function of RDS plan as reference plan. The expression for the sum of producer's and consumer's risk is given as,

$$\alpha + \beta = [1-P_a(p_1)] + P_a(p_2)$$

For fixed np_1 the value of np_2 is calculated from equation $np_2 = (p_2/p_1)(np_1)$ and is used in equation $\alpha + \beta = [1-P_a(p_1)] + P_a(p_2)$. The parameters c_N, c_T corresponding to the minimum $[1-P_a(p_1)]+P_a(p_2)$ are obtained by searching for $c_N = 0(0.03)20$, $c_T = 1(0.041)0.40$ with the help of a computer program. The values in table 1 gives producer and consumer risks which are obtained corresponding to the values of u_1, u_2, v_1, v_2, s, m, d, c_N, c_T and i for which the sum of risks is minimum.

6. Conclusion

In acceptance sampling, the producer and consumer plays a dominant role and hence one allows certain level of risks for producer and consumer, namely α=0.05 and β= 0.10. In practice it is desirable to design any sampling plan with the associated quality levels which concern to producer and consumer. Generalized Two-Plan System and Repetitive Deferred Sampling Plan have wide potential applicability in industries to ensure higher standard of quality attainment and increased customer satisfaction. Here the selection procedures are considered in this paper using the quality levels associated with minimum sum of producer's and consumer's risks without specifying the sample size rather than the fixed risks. Tables are provided in this paper are tailor-made which are useful to the shop floor condition.

Table 1: Parametric Values for Two Plan System with Repetitive Deferred Sampling Plan using Minimum Sum of Risks

np_1 / OR	0.150	0.200	0.250	0.300	0.350	0.400	0.450	0.500	0.550	0.650	0.700
44.9	1,0 1,.5	1,0 1,.7	1,0 1,.8	1,0 2,0	1,0 2,.2	1,0 2,.3	1,0 2,.5	1,0 2,.7	1,0 2,.8	1,0 3,.2	1,0 3,.3
44.8	1,0 2,.2	1,0 2,.4	1,0 2,.5	1,0 2,.7	1,0 2,.8	1,0 2,.9	1,0 3,.1	1,0 3,.2	1,0 3,.4	1,0 3,.6	1,0 3,.8
44.4	1,0 2,.2	1,0 2,.2	1,0 2,.3	1,0 2,.4	1,0 2,.5	1,0 2,.5	1,0 2,.6	1,0 2,.7	1,0 2,.8	1,0 2,.9	1,0 3,0
43.7	1,0 4,.3	1,0 4,.4	1,0 4,.5	1,0 4,.6	1,0 4,.7	1,0 4,.8	1,0 4,.9	1,0 3,2	1,0 5,.1	1,0 5,.4	1,0 5,.5
42.8	1,0 4,.8	1,0 4,.9	1,0 5,0	1,0 5,.1	1,0 5,.2	1,0 5,.3	1,0 5,.4	1,0 5,.5	1,0 5,.6	1,0 5,.8	1,0 5,.9
41.6	2,0 2,.2	2,0 2,.2	2,0 2,.2	2,0 2,.2	2,0 2,.3	2,0 2,.3	2,0 2,.3	2,0 2,.3	2,0 2,.4	2,0 2,.4	2,0 2,.4
40.2	1,0 3,.6	1,0 3,.6	1,0 3,.7	1,0 3,.7	1,0 3,.7	1,0 3,.7	1,0 3,.8	1,0 3,.8	1,0 3,.8	1,0 3,.9	1,0 3,.9
38.6	1,0 3,.9	1,0 3,.9	1,0 3,.9	1,0 3,.9	1,0 2,2	1,0 2,2	1,0 2,2	1,0 2,2	1,0 4,.1	1,0 4,.1	1,0 4,.1
36.8	3,0 4,.5	3,0 4,.5	3,0 4,.6	3,0 4,.6	3,0 4,.6	3,0 4,.6	3,0 4,.6	3,0 4,.7	3,0 4,.7	3,0 4,.7	3,0 4,.7
34.8	1,0 4,.8	1,0 4,.8	1,0 4,.8	1,0 4,.8	1,0 4,.8	1,0 4,.8	1,0 4,.9	1,0 4,.9	1,0 4,.9	1,0 4,.9	1,0 4,.9
32.7	1,0 5,.8	1,0 5,.8	1,0 5,.8	1,0 5,.8	1,0 5,.8	1,0 5,.8	1,0 5,.9	1,0 5,.9	1,0 5,.9	1,0 5,.9	1,0 5,.9
30.4	2,0 6,.3	2,0 6,.3	2,0 6,.3	2,0 6,.3	2,0 6,.3	2,0 6,.4	2,0 6,.4	2,0 6,.4	2,0 6,.4	2,0 6,.4	2,0 6,.5

28.0	1,0 3,4	1,0 3,4	1,0 3,4	1,0 3,4	1,0 3,4	1,0 3,4.1	1,0 3,4.1	1,0 7,.1	1,0 7,.1	1,0 7,.1	1,0 7,.2
25.6	1,0 4,5	1,0 4,5	1,0 4,5	1,0 4,5	1,0 4,5	1,0 4,5	1,0 9,.1	1,0 4,5.1	1,0 4,5.1	1,0 4,5.1	1,0 4,5.1
23.2	3,0 2,3.4	3,0 2,3.4	3,0 2,3.4	3,0 2,3.4	3,0 2,3.4	3,0 2,3.4	3,0 2,3.4	3,0 2,3.4	3,0 2,3.4	3,0 2,3.5	3,0 2,3.5
20.8	1,0 3,4.7	1,0 3,4.7	1,0 3,4.7	1,0 3,4.7	1,0 3,4.7	1,0 3,4.7	1,0 3,4.7	1,0 3,4.7	1,0 3,4.7	1,0 3,4.8	1,0 3,4.8
18.5	1,0 4,4.4	1,0 4,4.4	1,0 4,4.4	1,0 4,4.4	1,0 4,4.4	1,0 2,6.4	1,0 2,6.4	1,0 1,7.4	1,0 4,4.4	1,0 4,4.5	1,0 4,4.5
15.8	1,0 2,1.6	1,0 2,1.6	1,0 2,1.6	1,0 2,1.6	1,0 2,1.6	1,0 3,.6	1,0 3,.6	1,0 3,.6	1,0 3,.6	1,0 3,.6	1,0 3,.6
12.4	2,0 2,2.9	2,0 2,2.9	2,0 2,2.9	2,0 2,2.9	2,0 2,2.9	2,0 4,.9	2,0 4,.9	2,0 4,.9	2,0 4,.9	2,0 4,.9	2,0 4,.9
10.7	1,0 4,5.4	1,0 4,5.4	1,0 4,5.4	1,0 4,5.4	1,0 4,5.4	1,0 4,5.4	1,0 4,5.4	1,0 4,5.4	1,0 4,5.4	1,0 4,5.4	1,0 4,5.4
8.5	1,0 5,6.1	1,0 5,6.1	1,0 5,6.1	1,0 5,6.1	1,0 5,6.1	1,0 5,6.1	1,0 5,6.1	1,0 11,.1	1,0 11,.1	1,0 11,.1	1,0 11,.1
7.2	1,0 6,6.4	1,0 4,8.4	1,0 4,8.4	1,0 6,6.4	1,0 6,6.4	1,0 2,10.4	1,0 4,8.4	1,0 10,2.4	1,0 12,.4	1,0 8,4.4	1,0 5,7.4
6.3	3,0 3,3.9	3,0 3,3.9	3,0 2,4.9	3,0 .9,6	3,0 2,4.9	3,0 3.4,3.5	3,0 6,.9	3,0 2,4.9	3,0 3,3.9	3,0 2,4.9	3,0 6,.9

Key

C_N	C_T
α%	β%

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