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An Analysis on Performance Measures of Repetitive Deferred- Link Sampling Plan (RD-LSP)

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Abstract

This paper mainly deals the designing of Repetitive Deferred – Link Sampling Plan (RD-LSP) through AQL and LQL with their Operating Characteristic Curve. The tables are constructed for various combinations of Acceptable Quality Level (AQL), Indifference Quality Level (IQL), Limiting Quality Level (LQL) and their Operating Ratios. Illustrations are also provided for readymade selection of plan parameters.

Keywords: Acceptable Quality Level (AQL), Indifference Quality Level (IQL), Limiting Quality Level (LQL), Operating ratio, Repetitive Deferred Link Sampling Plan.

Introduction

Acceptance sampling was mainly designed to make a decision whether to accept or reject a lot on the basis of information provided by the sample taken from the particular lot. Acceptance sampling plan may be classified by attributes and variables. Acceptance sampling plan for attributes means that items will be judged as defective / bad or non-defective / good. Further, a sampling plan may be either type i. Acceptance-Rejection type or ii. Acceptance-Rectification type. In an acceptance –rejection sampling inspection plan lots are either accepted or rejected on the basis of the sample. In an Acceptance- rectification sampling plan if we do not accept on the basis of the sample, we take recourse to 100% inspection and in either case replace all defectives by non-defectives.

Repetitive Deferred Sampling (RDS) Plan

Rambert Vaerst (1981) developed the procedure of Multiple Deferred Sampling plan MDS- (c_1,c_2)[1]. Shankar and Mohapatra (1991)extended MDS, in which the acceptance of a lot in deferred state depends on the inspection results of the preceding or succeeding lots under Repetitive Group Sampling (RGS) plan[2]. This plan is designated as Repetitive Deferred Sampling (RDS) plan. Lilly Christina (1995) has given a methodology for the selection of RDS plan with given acceptable quality levels[3]. Further Suresh and Jayalakshmi (2005) gave a procedure for the selection of RDS plan through acceptable and limiting quality levels[4].

Situations for using RDS Plan: i. In a steady production process, the results of past, current and future lots are approximately suggests whether the process is a continuing process or not. ii. Lots are submitted considerably in the order of their production. iii. Each lot has an assumed fixed sample size, n. iv. Attribute characteristics were considered for inspection and the quality is defined as proportion defective.

Operating Procedure for RDS Plan: i. A random sample of size n is drawn from the lot. Count the number of defectives (d) found in the lot. Let c_1 be the first acceptance number and c_2 be the second acceptance number. ii. The lot is accepted if $d \le c_1$, and rejected if $d \ge c_2$. iii. If $c_1 < d < c_2$, accept the lot provided i preceding or succeeding lots are accepted under RGS inspection plan, otherwise reject the lot. iv. Here c_1 and c_2 are acceptance numbers such that $c_1 < c_2$. RDS plan reduces to RGS for i=1. v. The operating characteristics curve is obtained for RDS plan by having the OC function to determine $P_a(p)$ values is given below

$$P_a(P) = \frac{P_a(1-P_c)^i + P_c P_a{}^i}{(1-P_c)^i} \tag{1}$$

When k=0; $P_a = P[d \le c_1] = \sum_{d=0}^{c_1} \frac{e^{-np}\ np^d}{d!}$

$$P_c = P[c_1 < d < c_2] = \sum_{d=0}^{c_2} \frac{e^{-np}\, np^d}{d} - \sum_{r=0}^{c_1} \frac{e^{-np}\, np^d}{d}$$

Link Sampling Plan

The link sampling for attributes was proposed by Harish Chandra and Srivenkataramana[5]. The Link sampling plan procedure was established to reduce the sample size and consequent cost of the decision process using sample information from related lots. The Link sampling plan was proposed as an alternative to the usual double sampling plan. Further, Ravi shanker has derived the MAPD for link sampling plan[6]. Subramani has optimized the link sampling plan using minimum sum of risk[7]. Kuralmani has given a procedure for selection of link sampling plan through acceptable and limiting quality levels[8].

Condition for application of link sampling plan: i. The product being inspected comprises a series of successive lots produced by an essentially continuous process. ii. Lots are submitted substantially in the order of their production. iii. There is confidence in the supplier to the extent that the lots are expected to be essentially the same quality. iv. Lot size should not be too small.

These conditions are the same as those needed for any other conditional sampling procedures.

Operating procedure for link sampling plan: i. Select a random sample of size n from the lot i (i > 1), and find d_i, the number of defectives in this sample. Let c_1 and c_2 be the acceptance numbers. ii. The lot i is accepted when $d_i \leq c_1$ and the lot i is rejected when $d_i > c_2$. iii. If $c_1 < d_i \leq c_2$, then defer the decision until the sample result of lot i+1 is obtained. Take $D_i = d_{i-1}+d_i+d_{i+1}$. iv. If $D_i \leq c_2$, then accept the lot i. v. If $D_i > c_2$, then reject the lot i.

The operating characteristic function P_a (p) for link sampling plan is derived by Harish Chandra and Srivenkataramana as,

$$p_a(p) = \sum_{i=0}^{c_1} \frac{e^{-np}(np)^i}{i!} + \sum_{i=c_1+1}^{c_2} \frac{e^{-np}(np)^i}{i!} * \sum_{j=0}^{c_2-i} \frac{e^{-2np}(2np)^j}{j!} \quad (2)$$

Repetitive Deferred–Link Sampling Plan (RD-LSP)

Repetitive Deferred – Link Sampling Plan by attributes is a sampling inspection procedure, which is employed for making a decision about an isolated lot of finished products. The plan is specified by four parameters, namely, the sample size n, lot number i, and the acceptance numbers c_1 and c_2. The proposed plan has the following operating procedure.

Operating Procedure for RD-LSP

Step 1: Draw a random sample of size n from the determined lot size N and designate the lot number as (i) and also determine the number of defectives d_i.
Step 2: If $d_i \leq c_1$, then accept the lot (i) and if $d_i > c_2$, then reject the lot (i).
Step 3: If $c_1 < d_i < c_2$ then, defer the decision and go to next step.
Step 4: Draw a random sample n from lots i-1 and i+1 and determine the number of defectives say d_{i-1} and d_{i+1} and take $D_i=d_{i-1}+d_i+d_{i+1}$. Let 'D_i' be a compound defectives of RD-LSP.
Step 5: If $D_i \leq c_2$, then accept the lot 'i' and if $D_i > c_2$, then reject the lot 'i'.

The flow chart for RD-LSP as follows,

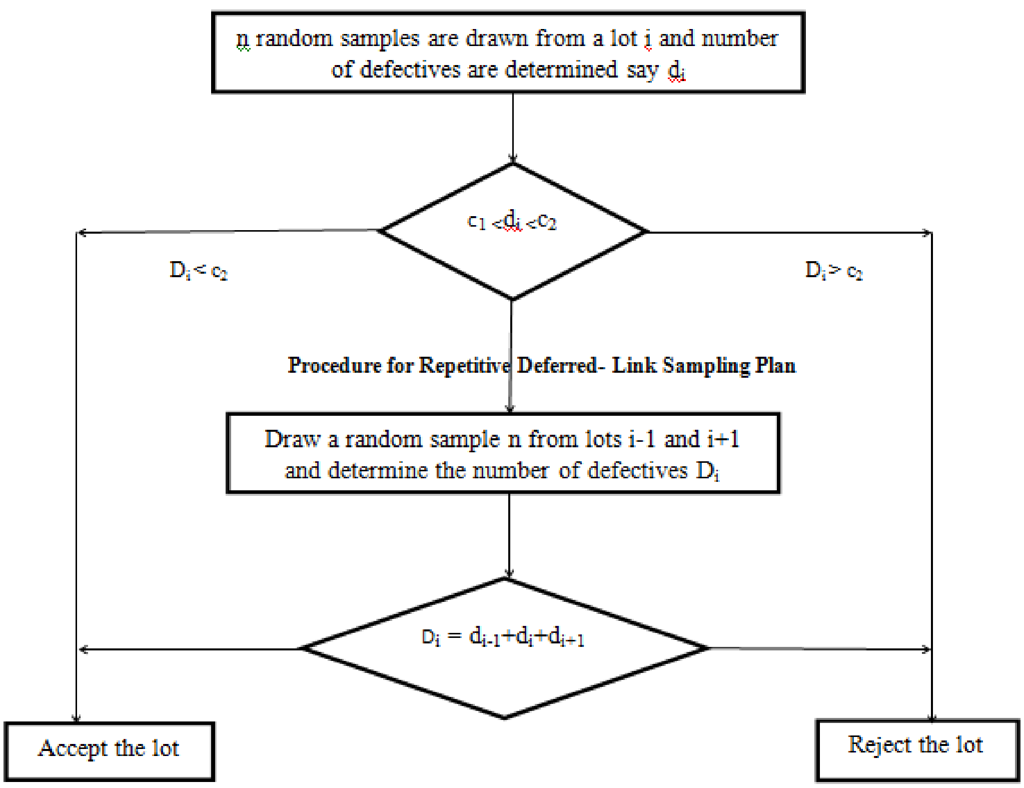

Figure-1
Procedure for Repetitive Deferred- Link Sampling Plan

Operating Characteristic Function: The performance of RD-LSP can be studied from its operating characteristic (OC) curve, which is resulted by plotting probability of acceptance P_a (p) of the lot against the proportion defectives p. The operating characteristic function P_a (p) for RD-LSP is defined as follows,

$$P_a(p) = \frac{P_a(1-P_c)^i + P_c P_a^i}{(1-P_c)^i} \qquad (3)$$

where $P_a = \sum \frac{e^{-np}(np)^i}{i!}$

$$P_c = \sum_{i=c_i+1}^{c_2} \frac{e^{-np}(np)^i}{i!} * \sum_{j=0}^{c_2-i} \frac{e^{-2np}(2np)^j}{j!}$$

Designing plans for given AQL, LQL, α AND β: Tables-1 and 2 are used to design Repetitive Deferred –Link Sampling Plan (c_1=0, c_2=1) for given AQL,

LQL, α and β**.** The steps utilize for selecting Repetitive Deferred –Link Sampling Plan (RD-LSP) are as follows: i. For given (AQL,1-α), (LQL,1-β) calculate the corresponding Operation Ratio np_2/np_1. ii. Find the value in Ttable-2 under the column for the appropriate α and β, which is closer to the desired ratio. iii. Corresponding to the ratio value note the values of c_1, c_2, and i. iv. The sample size can be obtained as np_1/p_1 where np_1 can be obtained against the located value ratio.

Illustration-1: Given p_1 = 0.005, c_1 = 1, c_2 = 2 and i = 1 the value of np_1 is selected from table 1 as 0.4450 and the corresponding sample size n_1 is computed as $n_1 = np_1/p_1$ = 0.4450/0.005, n_1 = 89 and the given p_2 = 0.044, c_1 = 1, c_2 = 2 and i = 1 the value of np_2 is selected from table 1 as 3.8850 and corresponding n_2 is computed as $n_2 = np_2/p_2$ = 3.8850/0.044 = 88 and n_1 = 89, n_2 = 88; Hence the parameters of Repetitive Deferred - Link Sampling Plan using Poisson Distribution indexed through Acceptable and Limiting Quality Levels is (89, 1, 2, 1).

Illustration-2: Given p_1 = 0.03, c_1 = 3, c_2 = 5 and i = 3 the value of np_1 is selected from table 1 as 1.4550 and the corresponding sample size n_1 is computed as $n_1 = np_1/p_1$ = 1.4450/0.03, n_1 = 48.5 ≈ 49 and the given p_2 = 0.092, c_1 = 3, c_2 = 5 and i = 3 the value of np_2 is selected from table 1 as 6.6800 and corresponding n_2 is computed as $n_2 = np_2/p_2$ = 6.6800/0.092 = 72.61 ≈ 73 and n_1 = 49, n_2 = 73; Hence the parameters of Repetitive Deferred - Link Sampling Plan using Poisson Distribution indexed through Acceptable and Limiting Quality Levels is (73, 3, 5, 3).

Table-1
Unity values and Operating ratio values for RD-LAP when i = 1

c_1	c_2	Probability of acceptance							OR (p_2/p_1)		
		0.99	0.95	0.90	0.50	0.10	0.05	0.01	α= 0.99 β= 0.01	α= 0.95 β= 0.05	α=0.90 β=0.10
0	1	0.0650	0.0150	0.2250	0.7700	2.3000	2.9950	4.6050	62.47	153.33	10.22
0	2	0.1700	0.3100	0.4100	0.9550	2.3250	3.0000	4.6050	27.09	7.50	5.67
0	3	0.2150	0.3800	0.4950	1.0750	2.3700	3.0150	4.6050	21.44	6.74	4.78
1	2	0.2300	0.4450	0.6150	1.6900	3.8850	4.7400	6.6350	28.85	8.73	6.32
1	3	0.3650	0.6100	0.7800	1.7650	3.8900	4.7400	6.6350	25.04	6.38	4.98
1	4	0.4250	0.6950	0.8750	1.8450	3.8950	4.7450	6.6350	18.18	6.57	4.45
2	3	0.5000	0.8650	0.9950	2.6750	5.3200	6.2950	8.0450	16.81	6.15	5.35
2	4	0.6300	1.1350	1.2500	2.6950	5.3200	6.2950	8.0450	13.34	5.35	4.26
2	5	0.6950	1.0750	1.3300	2.7250	5.3200	6.2950	8.0450	12.09	4.95	3.93
3	4	0.8600	1.3850	1.7550	3.6700	6.6800	7.7500	10.0450	11.68	4.82	3.81
3	5	0.9600	1.4650	1.8100	3.6700	6.6800	7.7500	10.0450	10.46	4.55	3.69
4	5	1.4300	1.9700	2.4350	4.6700	7.9900	9.100	11.6000	8.11	4.06	3.28

Table-2
Unity values and Operating ratio values for RD-LAP when i = 2

c_1	c_2	Probability of acceptance							OR (p_2/p_1)		
		0.99	**0.95**	**0.90**	**0.50**	**0.10**	**0.05**	**0.01**	**α= 0.99 β= 0.01**	**α= 0.95 β= 0.05**	**α=0.90 β=0.10**
0	1	0.0600	0.1450	0.2100	0.7350	2.3000	2.9950	4.6050	67.68	20.66	10.95
0	2	0.1650	0.2900	0.3750	0.8650	2.3050	3.1000	4.6050	24.63	10.69	7.95
0	3	0.2050	0.3550	0.4600	0.9600	2.3100	2.9950	4.6050	22.51	8.44	5.02
1	2	0.1100	0.2800	0.4450	1.6550	3.8850	4.7400	6.6300	20.28	18.15	4.98
1	3	0.3600	0.5950	0.7750	1.7250	3.8850	4.7450	6.6350	18.43	16.92	8.73
1	4	0.4200	0.6700	0.8400	1.7500	3.8900	4.7400	6.6350	15.79	13.18	5.01
2	3	0.5000	0.8650	1.1300	2.6750	5.3200	6.300	8.0450	16.81	8.60	4.63
2	4	0.6250	0.9850	1.2350	2.6850	5.3200	6.2950	8.0450	13.45	7.28	4.70
2	5	0.6900	1.0600	1.3100	2.700	5.3200	6.2950	8.0450	12.18	6.34	4.31
3	4	0.8600	1.3850	1.7500	3.6750	6.6800	7.7500	10.0450	11.68	5.59	3.82
3	5	0.9600	1.4600	1.8050	3.6700	6.6800	7.7500	10.0450	10.46	5.31	3.70
4	5	1.4250	1.9750	2.4250	4.6500	7.9850	9.1200	11.5950	8.14	4.62	3.29

Table-3
Unity values and Operating ratio values for RD-LAP when i = 3

c_1	c_2	Probability of acceptance							OR (p_2/p_1)		
		0.99	**0.95**	**0.90**	**0.50**	**0.10**	**0.05**	**0.01**	**α= 0.99 β= 0.01**	**α= 0.95 β= 0.05**	**α=0.90 β=0.10**
0	1	0.0600	0.1400	0.2000	0.7150	2.3050	2.9990	4.6100	76.83	21.42	11.53
0	2	0.1600	0.2750	0.3500	0.8100	2.3050	3.0150	4.6050	28.78	10.96	6.58
0	3	0.1950	0.3400	0.4200	0.8850	2.3100	3.0150	4.6050	23.68	8.87	5.50
1	2	0.2300	0.4350	0.6000	0.1680	3.8850	4.7400	6.6580	28.63	10.89	6.48
1	3	0.3600	0.5850	0.7400	1.7050	3.8850	4.7400	6.6250	18.40	8.11	5.25
1	4	0.4250	0.6500	0.8150	1.7350	3.8900	4.7400	6.6350	15.61	7.29	4.77
2	3	0.5000	0.8600	1.1300	2.6700	5.3200	6.2950	8.0450	16.81	7.32	4.71
2	4	0.6250	0.9750	1.2250	2.6750	5.3200	6.2950	8.0450	13.45	6.46	4.34
2	5	0.6850	1.0500	1.2900	2.6850	5.3200	6.2950	8.0450	12.27	5.95	4.12
3	4	0.8600	1.3850	1.7500	3.6750	6.6800	7.7500	10.0450	11.68	5.59	3.82
3	5	0.9600	1.4600	1.80	3.6700	6.6800	7.7500	10.0450	10.46	5.33	3.71
4	5	1.4050	1.9750	2.4300	4.6500	7.9850	9.0950	11.5750	8.24	4.61	3.28

Construction of Tables: Assuming that the sample size is less than 10% of the lot size, the probability of accepting a lot of quality, p for RD-LSP is approximated by Poisson distribution and its operating characteristic function $P_a(p)$ is given as follows,

$$P_a(p) = \frac{P_a(1-P_c)^i + P_c P_a^i}{(1-P_c)^i} \quad (4)$$

where; $P_a = \sum \frac{e^{-np}(np)^i}{i!}$;

$$P_c = \sum_{i=c_i+1}^{c_2} \frac{e^{-np}(np)^i}{i!} * \sum_{j=0}^{c_2-i} \frac{e^{-2np}(2np)^j}{j!}$$

The plan parameters are determined for some specified sets of quality levels. The unity values for the proposed plan are calculated using equation (4) for various combinations of (i, c_1, c_2) and are tabulated in Tables-1, 2 and 3. The values for i are 1,2 and 3 and $P_a(p)$ are 0.99, 0.95, 0.90, 0.50, 0.10, 0.05 and 0.01. The values for acceptance numbers are considered with the condition $c_1 < c_2$. Further, the operating ratio values are calculated corresponding to (α= 0.99, β= 0.01), (α= 0.95, β= 0.05) and (α= 0.90, β= 0.10) and listed along with the unity value tables.

Conclusion

This paper mainly reveals an idea of designing a new sampling plan called Repetitive Deferred –Link Sampling Plan (RD-LSP). Also, the construction and selection of RD-LSP through incoming and outgoing quality levels and its corresponding operating ratio has been studied and tabulated. The study can also be extended for various other sampling plans to develop various sampling methodologies. The emphasis of this paper is mainly related with new sampling procedure and the necessary tables have been provided here. They are tailor-made, handy and ready-made to be used in the conditions of industries. Theses tables are useful for both producer and consumer for obtaining good quality products with less inspection costs.

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