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RELIABILITY BASED MIXED SAMPLING PLAN USING CONDITIONAL REPETITIVE GROUP SAMPLING PLAN INDEXED THROUGH MAPD AND AQL

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Introduction

In almost all production processes, the producer must rely on outside sources for both raw material and components. Suppose that the production manager of a personal computer manufacturing company purchases large lots of electronic components from an outside vendor, and then the components are assembled in the making of a computer. Each component can be classified as either good unit or defective according to some specifications. Every time a lot of components arrive from the vendor, the manager faces a problem. How can the manager be sure that the lot contains a small number of defectives, or no defectives at all. Inspecting every component, that is, 100% inspection is expensive. Moreover, the effort required is often so overwhelming that it is inevitable for the inspection personnel and will have inspection fatigue which may cause a defective component which is classified as a good one or vice versa. The 100% inspection approach is clearly not feasible if the inspection procedure is destructive. On the other hand, if no inspection is done, and if the incoming lot contains a large number of defective components, many defective parts are bound to be produced. It is expensive to trouble-shoot the problems and rework the defective parts at the later stages of the production process.

ANSI/ASQC Standard A2 (1987) defines acceptance sampling as the methodology that deals with procedures by which decision to accept the lot or not to accept the lot are based on the results of the inspection of samples.
According to Dodge (1969) the general areas of acceptance sampling are

1. Lot-by- Lot acceptance sampling by the method of attributes, in which each unit in a sample is inspected on a go-not-go basis for one or more characteristics.
2. Lot-by-Lot sampling by the method of variables, in which each unit in a sample is measured for a single characteristics, such as weight or strength
3. Continuous sampling of a flow of units by the method of attributes and
4. Special purpose plans

In designing a sampling plan one has to accomplish a number of different purposes. According to Hamaker, the important factors are

- To strike a proper balance between the consumers requirements, the producer’s capabilities and inspections capacity.
- To separate bad lots from good
- Simplicity of procedures and administration
- Economy in number of observations
- To reduce the risk of wrong decisions with increasing lot size
- To use accumulated sample data as a valuable source of information
- To exert pressure on the producer or supplier when the quality of the lots received is unreliable or not up to the standard and
- To reduce sampling when the quality is reliable and satisfactory.

Statement of the Problem

The construction of sampling plans is an important aspect in acceptance sampling which is used in product control. It has two types

1. Acceptance sampling by Variables
2. Acceptance sampling by Attributes

Many authors studied the construction and selection of sampling plans by variables and attributes separately. Bowker and Goode (1952) studied Sampling inspection by variables, Schilling (1982) studied acceptance sampling in quality control, Radhakrishnan (2002) made contribution to the study on selection of certain acceptance sampling plans. Devaarul (2003) and Sampath Kumar (2008) studied variable - attribute mixed sampling plan and explained their advantages over variable and attribute sampling plans.

Latha (1988) and Devabharathi (1990) studied mixed acceptance sampling plans. Oliver and Springer (1972) and Latha (2002) studied Bayesian attribute acceptance plans. The concept of Reliability is more important in life testing procedure and is very much applied in all major industries of developing and developed countries. A sampling plan involving Reliability concepts is much more essential. In this paper, an attempt is made to construct the sampling plans based on all the above aspects to get Reliability based mixed sampling plans indexed through various parameters suggested by different authors.

Objectives of the Study

The following are the important objectives of the study

- To construct and select the Reliability based mixed sampling plans indexed through AQL, and MAPD.
- To compare the plans constructed through MAPD and AQL.
- The Reliability based mixed sampling plans are constructed for the basic plans using Conditional Repetitive Group Sampling Plan.

Limitations of the Study

The study has the following limitations.

1. The baseline distribution assumed in the construction of sampling plan is Poisson.
2. The life testing procedure till a specified time under given environmental conditions may not be feasible and practicable in some companies or products.
3. Assessing the probability of acceptance in the first stage is possible but cumbersome.

Scope of the Study

The Reliability based Mixed sampling plans has been developed to reduce the sample size, test duration, etc., These mixed plans will be very useful to practitioners because they provide Economic sample size, which in turn minimizes inspection cost, data recordings, inspector error and so on. Reliability based mixed sampling plans differs from the ordinary double sampling procedure in the sense that only acceptance can take place as a result of the application of the variables plan to the first sample. If acceptance is not indicated, a second sample is drawn; acceptance or rejection is then being determined on an attributes basis. The Reliability based mixed sampling plans achieves reduction in sample size associated with a variables plan. In rejecting lots, it is also often decided as psychological or legal advantage to show actual defectives to the producer, a feature which can be had only by rejecting on an attributes basis. Truncated and non-normal distributions cannot be rejected for poor variables results alone, but only on the basis of defective or nonconforming units found in the attributes sample. Furthermore, with regard to acceptance-rejection decisions, the effect of changes in shape of distribution can be minimized by accepting only on variables evidence so good as to be practically beyond question for most distributions which might reasonably be presented to the plans. Thus, Reliability based mixed sampling plans provide a worthwhile alternative to variables plans used.

Conditional Repetitive Group Sampling Plan as Attribute Plan

This section deals with the construction of Reliability based mixed sampling Plans (RMSPs) having Conditional Repetitive Group Sampling (CRGS) plan as attribute plan. The plans are constructed using MAPD. The plan indexed through MAPD is compared with the plan indexed through AQL. Tables are constructed for easy selection of the plans. Illustrations with explanations are also provided.

Formulation of RMSPs having CRGS Plan as Attribute Plan

The development of RMSPs and the subsequent discussions are limited only to the lower specification limit. By symmetry a parallel discussion can be made use for upper specification limits. It is suggested that the RMSPs with CRGS plan as attribute plan in the case of single sided specification (L), Standard Deviation (σ) known can be formulated by the four parameters n_1, n_2, k", c_1 and c_2. If Standard deviation is unknown the unbiased estimate of 'σ' namely 's' can be substituted. By giving the values for the parameters an independent plan for single sided specification, standard deviation known would be carried out as follows:

Procedure: Independent Plan

Step 1: Determine the parameters of the RMSPs n_1, n_2, k", c_1 and c_2 with reference to OC curves.

Step 2: Take a random sample of size n_1 from the lot assumed to be large.

Step 3: If the sample order statistic $\hat{«} \geq A' = L + k'' ±$, accept the lot.

Step 4: If the sample order statistic $\hat{«} < A' = L + k'' ±$,take a second sample of size n_2.

Step 5: Inspect and find the number of defectives 'd' in the second sample.

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(i) If $d \le c_1$, accept the lot.
(ii) If $d > c_2$, reject the lot.
(iii) If $c_1 < d \le c_2$, utilize the information of the next preceding 'i' successive lots (i.e.,) the current lot is accepted if the preceding 'i' successive lots result shows $d \le c_1$ in the sample, otherwise reject the lot.

Construction of RMSPs having CRGS Plan as Attribute Plan Indexed through MAPD

In this section the RMSPs indexed through MAPD is constructed. A point on the OC curve can be fixed such that the probability of acceptance of fraction defective p_* is β_*. The general procedure given in Section 2.14, is used for constructing the RMSPs having CRGS plan as attribute plan indexed through MAPD (p_*) [for $\beta_*'' = (\beta_* - \beta_*') / (1- \beta_*')$].

Construction of Tables

The probability of acceptance for CRGS plan under Poisson model is given by

$$P_a(p) = \frac{\sum_{r=0}^{c_1} \frac{e^{-n_2 p}(n_2 p)^r}{r!}}{1-[\sum_{r=0}^{c_1} \frac{e^{-n_2 p}(n_2 p)^r}{r!}\{\sum_{r=0}^{c_2} \frac{e^{-n_2 p}(n_2 p)^r}{r!} - \sum_{r=0}^{c_1} \frac{e^{-n_2 p}(n_2 p)^r}{r!}\}]}$$

The inflection point (p_*) is obtained by using $d^2P_a(p)/dp^2 = 0$ and $d^3P_a(p)/dp^3 \neq 0$. The relative slope of the OC curve h_* is given by $h_* = \left[\frac{-p}{p_a(p)}\right]\frac{dp_a(p)}{dp}$ at $p = p_*$. The inflection tangent of the OC curve cuts the 'p' axis at $p_t = p_* + (p_*/h_*)$. The values of n_2p_*, h_*, n_2p_t and $R = p_t/p_*$ are calculated for an arbitrary value $\beta_*' = 0.45$ using visual basic program and are presented in Table 1.

Table 1: Various characteristics of RMSPs when $\beta_*' = 0.45$

c_1	c_2	n_2p_1	β_*	β_*''	n_2p_*	h_*	n_2p_t	$R=p_t/p_*$
0	1	0.264	0.7565	0.5573	0.766	0.8715	1.6449	2.15
0	3	0.313	0.7256	0.5011	0.954	1.0825	1.8353	1.92
1	2	0.819	0.6918	0.4396	2.050	1.5475	3.3747	1.65
1	4	1.002	0.6644	0.3898	2.363	1.9512	3.5740	1.51
2	3	1.453	0.6635	0.3882	3.310	2.0371	4.9344	1.49
2	5	1.757	0.6461	0.3565	3.623	2.4896	5.0783	1.40
3	3	1.679	0.6472	0.3585	4.406	2.1387	6.4661	1.47
3	6	2.538	0.6362	0.3385	4.830	2.9061	6.4920	1.34
4	5	2.843	0.6336	0.3382	5.749	2.7938	7.8068	1.36
4	7	3.332	0.6293	0.3260	6.012	3.2595	7.8565	1.31
4	8	3.417	0.6235	0.3155	6.133	3.4151	7.9288	1.29
5	6	3.577	0.6242	0.3167	6.987	3.1488	9.2059	1.32
5	8	4.136	0.6239	0.3162	7.178	3.5723	9.1873	1.28
5	9	4.248	0.6191	0.3075	7.300	3.7410	9.2513	1.27
6	7	4.331	0.6167	0.3031	8.187	3.4572	10.5551	1.29
6	8	4.710	0.6207	0.3104	8.231	3.6534	10.4840	1.27
6	9	4.949	0.6195	0.3082	8.334	3.8576	10.4944	1.26

Table 2: Second stage sample size and variable factor with $\beta_*^{'}$ = 0.45 at MAPD.

p_*	R	2.15	1.92	1.65	1.51	1.49	1.40	1.47	1.34	1.36	1.31	1.29	1.32	1.28	1.27	1.29	1.27	1.26
	c_1 / k"	0	0	1	1	2	2	3	3	4	4	4	5	5	5	6	6	6
0.01	0.1467	77,1	95,3	205,2	236,4	331,3	362,5	441,3	483,6	575,5	601,7	613,8	699,6	718,8	730,9	819,7	823,8	833,9
0.02	0.1323	38,1	48,3	103,2	118,4	166,3	181,5	220,3	242,6	287,5	301,7	307,8	349,6	359,8	365,9	409,7	412,8	417,9
0.03	0.1178	26,1	32,3	68,2	79,4	110,3	121,5	147,3	161,6	192,5	200,7	204,8	233,6	239,8	243,9	273,7	274,8	278,9
0.04	0.1034	19,1	24,3	51,2	59,4	83,3	91,5	110,3	121,6	144,5	150,7	153,8	175,6	179,8	183,9	205,7	206,8	208,9
0.05	0.0891	15,1	19,3	41,2	47,4	66,3	72,5	88,3	97,6	115,5	120,7	123,8	140,6	144,8	146,9	164,7	165,8	167,9
0.06	0.0748	13,1	16,3	34,2	39,4	55,3	60,5	73,3	81,6	96,5	100,7	102,8	116,6	120,8	122,9	136,7	137,8	139,9
0.07	0.0605	11,1	14,3	29,2	34,4	47,3	52,5	63,3	69,6	82,5	86,7	88,8	100,6	103,8	104,9	117,7	118,8	119,9
0.08	0.0463	10,1	12,3	26,2	30,4	41,3	45,5	55,3	60,6	72,5	75,7	77,8	87,6	90,8	91,9	102,7	103,8	104,9
0.09	0.0321	9,1	11,3	23,2	26,4	37,3	40,5	49,3	54,6	64,5	67,7	68,8	78,6	80,8	81,9	91,7	91,8	93,9

Key :(n_2,c_2)

Selection of the Plan

Table 1 is used to construct the plans when MAPD (p_*) and tangent intercept (p_t) are given .For any given values of c_1, p_t and p_*, one can find the ratio R = p_t/p_*. Find the value in Table 1 under the column R, which is equal to or just greater than the specified ratio. Corresponding 'c_2' value is noted. From this 'c_1' and 'c_2' value one can determine n_2 using $n_2 = n_2p_*/p_*$.

Table 2 is used to construct the plans when MAPD (p_*), m, n_1, c_1 values are given. For any given values of p_*, c_1, c_2, m and n_1 one can determine n_2 and $k^{''}$.

Example 1: Given the values of p_* = 0.05, p_t = 0.075, c_1 = 1, n_1=10, m=5 and β_*'= 0.45. Find the ratio R = p_t/p_* = 1.50. Using Table5.2.1, corresponding to c_1 = 0, select the value of R equal to or just greater than this ratio. The value of R is 1.51 which is associated with c_1 = 1 and c_2 = 4. It is found from Table 5.2.2 that n_2 = 47 and $k^{''}$= 0.0891 for given p_* and R. The RMSPs for specified p_* = 0.05 is n_1=10, m=5, c_1 = 1, c_2 = 4, n_2 = 47 and $k^{''}$ = 0.0891.

Explanation: In a sample of n_1 =10 specimens selected from a lot of a Biscuit manufacturing company**,** m=5 specimens failed during the life test till time t_0 (specified by the producer/consumer). For a fixed lot quality p_* = 0.050 (50 defectives out of 1000 samples) the value of the parameter $k^{''}$ is obtained as 0.0891. Let $x_{1,10}$, $x_{2,10}$……$x_{5,10}$ denote the progressively censored life times of a random sample of size 10 test specimens. If the sample order statistic $\hat{x}$ ≥ $A^{'}$ = L + 0.0891σ (L= Lower specification limit, σ = Standard deviation are specified by the producer/consumer) then accept the lot else take another sample of size n_2 (=47) from the same lot and put them into life test. Inspect and find the number of defectives'' in the second sample. If d ≤ c_1(=1) accept the lot. If d > c_2 (=4) reject the lot. If c_1 (=1) < d ≤ c_2 (=4) utilize the information of the next preceding 'i' successive lots, otherwise reject the lot and inform the management for further action. Hence the RMSP for a specified p_* = 0.05 is n_1=10, m=5, c_1 = 1, c_2 = 4, n_2 = 47 and $k^{''}$ = 0.0891.

Construction of RMSPs having CRGS as attribute plan indexed through AQL

The general procedure given in Section 2.14 is used for constructing the RMSPs having CRGS as attribute plan indexed through AQL (p_1) [for $\beta_1^{''} = (\beta_1 - \beta_1^{'}) / (1- \beta_1^{'})$]. By assuming the probability of acceptance of the lot as β_1 = 0.95 , $\beta_1^{'}$ = 0.45, m=5, the n_2p_1 and k″ values are calculated for different values of c_1 and c_2 using visual basic program and are presented in Table 3.

Table 3: Second stage sample size and variable factor with $\beta_1^{'}$ = 0.45 at AQL.

p_1	c_1 / k"	0	0	1	1	2	2	3	3	4	4	4	5	5	5	6	6	6
0.001	0.1598	264,1	313,3	819,2	1002,4	1453,3	1757,5	1679,3	2538,6	2843,5	3332,7	3417,8	3577,6	4136,8	4248,9	4331,7	4710,8	4949,9

0.002	0.1583	132,1	157,3	410,2	501,4	727,3	879,5	840,3	1269,6	1422,5	1666,7	1709,8	1789,6	2068,8	2124,9	2166,7	2355,8	2475,9
0.003	0.1569	88,1	104,3	273,2	334,4	484,3	586,5	560,3	846,6	948,5	1111,7	1139,8	1192,6	1379,8	1416,9	1444,7	1570,8	1650,9
0.004	0.1554	66,1	78,3	205,2	251,4	363,3	439,5	420,3	635,6	711,5	833,7	854,8	894,6	1034,8	1062,9	1083,7	1178,8	1237,9
0.005	0.1540	53,1	63,3	164,2	200,4	291,3	351,5	336,3	508,6	569,5	666,7	683,8	715,6	827,8	850,9	866,7	942,8	990,9
0.006	0.1525	44,1	52,3	137,2	167,4	242,3	293,5	280,3	423,6	474,5	555,7	570,8	596,6	689,8	708,9	722,7	785,8	825,9
0.007	0.1511	38,1	45,3	117,2	143,4	208,3	251,5	240,3	363,6	406,5	476,7	488,8	511,6	591,8	607,9	619,7	673,8	707,9
0.008	0.1496	33,1	39,3	102,2	125,4	182,3	220,5	210,3	317,6	355,5	417,7	427,8	447,6	517,8	531,9	541,7	589,8	619,9
0.009	0.1482	29,1	35,3	91,2	111,4	161,3	195,5	187,3	282,6	316,5	370,7	380,8	397,6	460,8	472,9	481,7	523,8	550,9

Key :(n_2,c_2)

Selection of the Plan

Table 3 is used to construct the plans when AQL (p_1), c_1, c_2, and m are given. For any given values of p_1, c_1, c_2 and m one can determine k" and n_2 using $n_2 = n_2 p_1 / p_1$.

Example 2: Given the values of p_1 = 0.008, c_1=0, c_2=1, n_1=10, m=5 and β_1' = 0.45 use Table 5.2.3, and find that n_2 = 33 with k"= 0.1496. The RMSPs for a specified p1 = 0.008 is n_1=10, m=5, c_1= 0, c_2=1, n_2= 33 and k" = 0.1496.

Explanation: In a sample of n_1 =10 specimens selected from a lot of a Biscuit manufacturing company m=5 specimens failed during the life test till time t_0 (specified by the producer/consumer). For a fixed lot quality p_1 = 0.008 (8 defectives out of 1000 samples) the value of the parameter k" is obtained as 0.1496. Let $x_{1,10}$, $x_{2,10}$……$x_{5,10}$ denote the progressively censored life times of a random sample of size 10 test specimens. If the sample order statistic $\hat{«} \geq A' = L + 0.1496\hat{\pm}$ (L= Lower specification limit, $\hat{\pm}$ = Standard deviation are specified by the producer/consumer) then accept the lot else take another sample of size n_2 (= 33) from the same lot and put them into life test. Inspect and find the number of defectives 'd' in the second sample. (i) If $d \leq c_1$(=0) accept the lot.(ii) If $d > c_2$(=1) reject the lot.(iii) If c_1(=0) < d ≤ c_2 (=1) utilize the information of the next preceding 'i' successive lots, otherwise reject the lot and inform the management for further action. Hence the RMSP for a specified p_1 = 0.008 is n_1=10, m=5, c_1= 0, c_2=1, n_2= 33 and k″ = 0.1496.

Comparison of CRGS plan indexed through MAPD and AQL

In this section CRGS plan indexed through MAPD is compared with CRGS plan indexed through AQL. For different combinations of p_* and p_t, the values of n_2 and c_2 are calculated for MAPD and AQL and presented in Table 5.2.4 :

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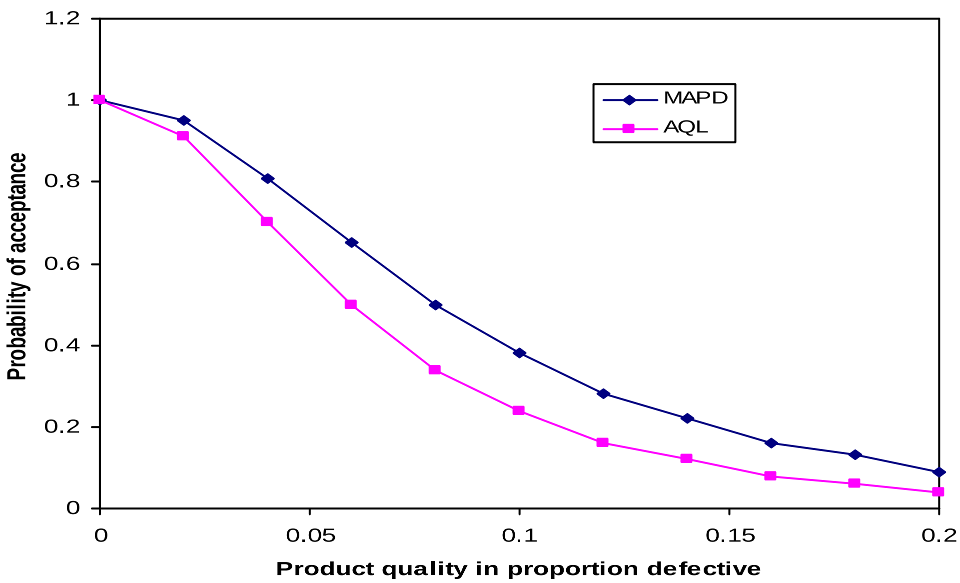
Table 4: Comparison of plans

Given values			Through MAPD		Through AQL	
c_1	p_*	p_t	n_2	c_2	n_2	c_2
0	0.08	0.154	12	3	16	3
1	0.07	0.106	34	4	41	4
2	0.05	0.070	72	5	83	5
3	0.03	0.040	161	6	181	6
4	0.06	0.079	100	7	111	7
5	0.02	0.026	349	6	397	6
6	0.03	0.038	274	8	294	8

It is found from Table 4 that the second sample size (n_2) is relatively less if the plan is constructed through MAPD than AQL and in turn the cost of inspection will be reduced.

Construction of OC Curve

The OC curves of RMSPs with CRGS as attribute plan are constructed for the plans $c_1 = 0$, $c_2 = 3$, $n_2 = 12$ (indexed through MAPD) and $c_1 = 0$, $c_2 = 3$, $n_2 = 16$ (indexed through AQL) are presented in Figure 5.2.1.



Conclusion

It is concluded that the second stage sample size required for CRGS plan indexed through MAPD is less than that of the second stage sample size of the CRGS plan indexed through AQL. Hence the plan indexed through MAPD is better than the plan indexed through AQL using CRGS plan as an attribute plan in the construction of RMSPs, because of lesser sample size and more probability of acceptance.