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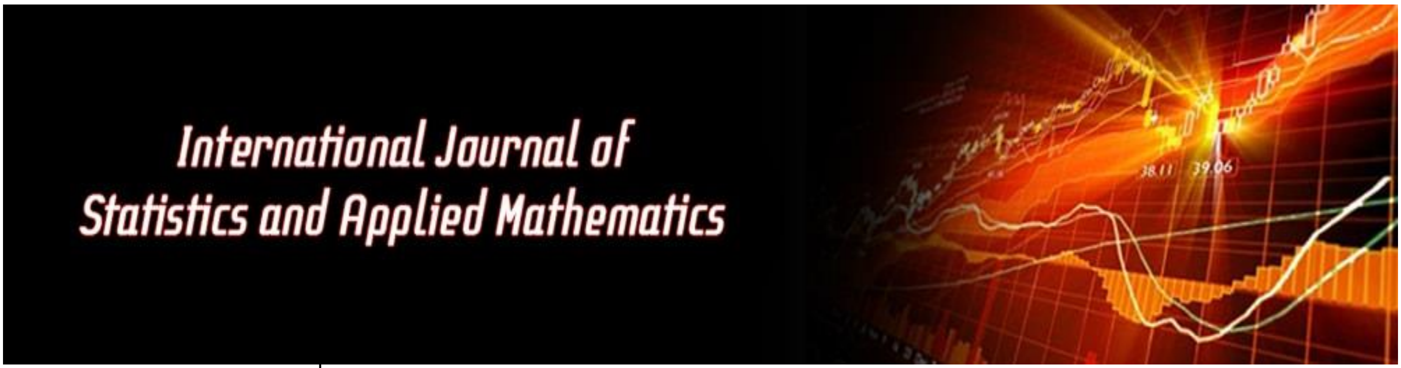

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Design and development of two stages mixed sampling plans with the norm of variance and non-conformities

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Abstract
The mixed sampling plans are two stages sampling plans in which variable and attribute quality characteristics are used in deciding the acceptance or rejection of the lot. In industries variables and attributes together are used to decide about the acceptance of lots.
In industries many products are in measurable dimensions and the quality of the products should not deviate much from the required target. Hence variance of the distributions plays a vital role in the decision making of the lots.
Many quality control practitioners insist that in a mixed sampling inspection the first stage sample should be based on the variance criterion for a target-oriented production to reduce the variance. Hence two stages mixed sampling plans are being developed with a variance criterion. This article presents a new algorithm to make a unique decision on the lot for mixed quality control environment. In this paper the sampling plans are developed by considering variable quality characteristics with variance criteria in the first stage and the second stage is dealt with attribute criteria. New efficiency measures are derived and provided. Designing procedure and Illustrations are given.

Keywords: Mixed sampling, two stages, variable criteria, attribute criteria, designing

1. Introduction

The mixed sampling plans are two stage sampling plans in which variable and attribute quality characteristics are combined in deciding the acceptance or rejection of the lot. Due to modern quality control systems, mixed sampling plans are widely applied in various stages of production. In industries, variable criteria play a vital role in inspection area.

In industries many products are in measurable dimensions and the quality of the products should not deviate much from the required target. Hence variance of the process plays a vital role in the decision making of the lots. In many quality control sections, one has to control both the variability and number of non-conformities. But the literature is not sufficient in this type of mixed environment. Therefore, new mixed sampling plans are being developed to control variance and number of defectives in the first and second stages respectively.

The Operating characteristics function and other related measures of the new mixed sampling plans are derived. A new designing methodology for determining the parameters of the sampling plans are given. Comparisons can be made between two and three stages of mixed sampling plans. Tables are constructed to facilitate easy application of mixed sampling plans in the Quality Control Section of production industries.

In the year 1967, Schilling presented a method for determining the operating characteristics of mixed variables-attributes sampling plans. Savage (1955) [7] has designed mixed variables and attributes sampling plans based on exponential distribution. DevaArul (2004) [1] has developed new algorithm by inculcating the blend of process & product control measures to control the lot quality. Suresh and Deva Arul (2003) [11] have developed Multi-Dimensional Mixed Sampling Plans to control multi-variate quality characteristics. DevaArul. S (2009) [2] has designed new type of mixed sampling system. Suresh and DevaArul (2002) [9, 10] have designed Mixed Chain Sampling Plans to control series of lots. Suresh and DevaArul (2002) [9, 10] have developed new type of mixed sampling plans to reduce the sampling cost. DevaArul and Jemmy Joyce (2010) [3] have developed Mixed Sampling Plans for Second Quality Lots.

John H Curtiss (1947) [6] has studied acceptance Sampling by Variables, with Special Reference to Average or Dispersion. DevaArul and Senthil Kumar (2017) [5] have developed new three stages mixed sampling plan for V-A-V quality characteristics with mean and number of defectives as criteria. DevaArul and Senthil Kumar (2019) [4] have developed new two stages variable sampling plan with mean and variance criteria.

2. Formulation of two stages mixed sampling plans

Let

N: Lot size

n_1: Sample size of the first stage with variance quality characteristics.

n_2: Sample size of the second stage with attribute quality characteristics.

K = Variable factor such that a lot is accepted if $s_1^2 \leq$ k

c = The attributes acceptance number in the second stage

β = P_a = Probability of acceptance

β_1 = Probability of acceptance at AQL

β_1' = Probability of acceptance assigned to first stage

σ^2 = Population variance

P = Fraction defective

3. Algorithm for two stages mixed sampling plans based on variance criteria

Stage 1

Step 1: Draw a random sample of size n_1.

Step 2: Determine s_1^2

Step 3: If $s_1^2 \leq$ k , accept the lot.

Step 4: If $s_1^2 > k$, go to next stage.

Stage 2:

Step 1: Draw another sample of size n_2.

Step 2: Count the number of defectives d.

Step 3: If $\leq c$, accept the lot otherwise reject the lot.

4. Operating Characteristics and Associated Measures of two stages Mixed Plans

4.1 Operating Characteristics function:

The probability of acceptance of mixed sampling plans with variance criterion and number of non-conformities is given below

$$P_a(p) = P_{n_1}[s_1^2 \leq K] + P_{n_1}[s_1^2 > K]\left[\sum_{x=0}^{c} \frac{e^{-n_2 p}{}_{(n_2 p)}x}{x\,!}\right]$$

Proof

The lot will be accepted in the following cases

Case: From the sample of size n_1, if $s_1^2 \leq$ Kthe lot will be accepted

Case: When$s_1^2 > K$, From the sample of size n_2, if $d \leq c$ the lot will be accepted

Case (i) & (ii) are mutually exclusive case.

By the law of addition theorem on probability we get

$$P_a\,(p) = P(i) + P(ii)$$

$$P_a(p) = P_{n_1}[s_1^2 \leq K\,] + P_{n_1}[s_1^2 > K\,]P_{n_2}[d \leq c]$$

Hence,

$$P_a(p) = P_{n_1}[s_1^2 \leq K] + P_{n_1}[s_1^2 > K] \sum_{x=0}^{c} \frac{e^{-n_2 p}{}_{(n_2 p)}x}{x\,!}$$

Similarly, ASN and AOQ are derived and given below.

4.2 Average Sample Number

$$ASN = n_1 + \{n_1 P[s_1^2 > k]\}\{n_2\}$$

4.3 Average Outgoing Quality AOQ

$$AOQ = p * P_a(p)$$

5. Designing and determination of parameters through AQL

Step1: Let the first stage probability acceptance be β_1'

Let the second stage probability acceptance be β_1''

Step2: Determine the sample size n_1 for the known β_1'

Step3: Calculate the acceptance limit k for the existing process average

$$(n-1)k = \sigma_o^2\{\chi^2_{\alpha,n-1}\}$$

$$n - 1 = \frac{\sigma_o^2}{k}\{\chi^2_{\alpha,n-1}\}$$

$$n = 1 + \frac{\sigma_o^2}{k}\{\chi^2_{\alpha,n-1}\}$$

$$k = \frac{\sigma_o^2}{n-1}\{\chi^2_{\alpha,n-1}\}$$

where, $\{\chi^2_{\alpha,n-1}\}$ is the standard chi-square variate with n-1 degrees of freedom.

Here α = 1- β_1' and n = n_1

Step4: Now determine β_1'' the second stage probability of acceptance such that

$$\beta_1'' = \frac{\beta_1 - \beta_1'}{1 - \beta_1'}$$

Step5: Determine the second sample size n_2 and acceptance number "c" such that

$$\sum_{x=0}^{c} \frac{e^{-n_2 p}{}_{(n_2 p)}x}{x\,!} \cong \beta_1''$$

Tables can be constructed using the above designing procedure.

Two Stage Mixed Sampling Plan with Variance Criteria

Table 1: Values of the parameters k and c for the known n1 and n2 @ known AQL and by assuming first stage probability of acceptance at 65% having total probability of acceptance with 95%

AQL	**Known**	**n_1=n_2= 50**			**n_1=n_2= 100**			**n_1=n_2= 150**			**n_1=n_2= 200**		
p1	s^2	k	n_2p_1	c	K	n_2p_1	c	k	n_2p_1	c	k	n_2p_1	c
0.001	10	10.65686	0.05	0	10.4883	0.1	0	10.40721	0.15	0	10.35704	0.2	1
0.002	20	21.31372	0.1	0	20.97659	0.2	1	20.81443	0.3	1	20.71408	0.4	1
0.003	30	31.97058	0.15	0	31.46489	0.3	1	31.22164	0.45	1	31.07112	0.6	1
0.004	40	42.62744	0.2	1	41.95319	0.4	1	41.62885	0.6	1	41.42816	0.8	2
0.005	50	53.28431	0.25	1	52.44148	0.5	1	52.03606	0.75	2	51.7852	1	2
0.006	60	63.94117	0.3	1	62.92978	0.6	1	62.44328	0.9	2	62.14224	1.2	2
0.007	70	74.59803	0.35	1	73.41807	0.7	2	72.85049	1.05	2	72.49928	1.4	3
0.008	80	85.25489	0.4	1	83.90637	0.8	2	83.2577	1.2	2	82.85632	1.6	3
0.009	90	95.91175	0.45	1	94.39467	0.9	2	93.66491	1.35	3	93.21336	1.8	3
0.01	100	106.5686	0.5	1	104.883	1	2	104.0721	1.5	3	103.5704	2	3

6. Example AQL

A production process known to have 0.1% process fraction defective. Determine 2 stage mixed sampling plan for 95% probability of acceptance with 65% first stage probability acceptance with variance criterion.

Solution:

It is given that AQL = 0.1%. From table 1, one can find the required parameters for 95% probability acceptance. For practical reasons if n_1=n_2=100.

From table 1 , when p_1 = 0.001, k=10.488, c=0.

Operating procedure

Stage 1:

Step 1: Draw a random sample of size n_1= 100.

Step 2: Determine s_1^2.

Step 3: If $s_1^2 \leq 10.488$, accept the lot.

Step 4: If $s_1^2 > 10.488$, go to next stage.

Stage 2:

Step 1: Draw another sample of size n_2.= 100.

Step 2: Count the number of defectives d

Step 3: If $d = 0$, accept the lot otherwise reject the lot.

7. Designing and determination of parameters through LQL

Step 1: Let the first stage probability acceptance be β_2'

Let the second stage probability acceptance be β_2''

Step 2: Determine the sample size n_1 for the known β_2'

Step 3: Calculate the acceptance limit K=k_1 for the existing process average LQL= p_2

Step 4: Now determine β_2'' the second stage probability of acceptance such that

$$\beta_2'' = \frac{\beta_2 - \beta_2'}{1 - \beta_2'}$$

Step 5: Determine the second sample size n_2 and acceptance number "c" such that

$$\sum_{x=0}^{c} \frac{e^{-n_2 p}(n_2 p)^x}{x\,!} \cong \beta_2''$$

Tables can be constructed using the above designing procedure.

Two Stage Mixed Sampling Plan with Variance Criteria

Table 2: Values of the parameters k and c for the known n_1 and n_2 @ known LQL and by assuming first stage probability of acceptance be 5% having total probability of acceptance with 10%

LQL	**Known**	**n_1=n_2=**	**50**		**n_1=n_2=**	**100**		**n_1=n_2=**	**150**		**n_1=n_2=**	**200**	
p_2	s^2	k	n_2p_2	c	k	n_2p_2	c	k	n_2p_2	c	k	n_2p_2	c
0.01	10	6.92455	0.5	0	7.78246	1	0	8.17363	1.5	0	8.4101	2	0
0.02	20	13.8491	1	0	15.56492	2	0	16.34725	3	0	16.8202	4	1
0.03	30	20.77366	1.5	0	23.34737	3	0	24.52088	4.5	1	25.2303	6	2
0.04	40	27.69821	2	0	31.12983	4	1	32.69451	6	2	33.6404	8	4
0.05	50	34.62276	2.5	0	38.91229	5	1	40.86814	7.5	3	42.0505	10	5
0.06	60	41.54731	3	0	46.69475	6	2	49.04176	9	4	50.4606	12	7
0.07	70	48.47187	3.5	0	54.4772	7	3	57.21539	10.5	5	58.8707	14	8
0.08	80	55.39642	4	1	62.25966	8	4	65.38902	12	7	67.2808	16	10
0.09	90	62.32097	4.5	1	70.04212	9	4	73.56265	13.5	8	75.6909	18	11
0.1	100	69.24552	5	1	77.82458	10	5	81.73627	15	8	84.101	20	13

8. Example LQL

A production process known to have 3% process average fraction defective. Determine two stages mixed sampling plan for the known LQL with 10% Probability of acceptance.

Solution

It is given that LQL = 3%.

Let the probability of acceptance at LQL in the first stage be 5%. From table 2, one can find the required parameters for 10% total probability acceptance.

For practical reasons if n_1=n_2=200.

From table 2 when p_2 = 0.03, the variable constant k_1=25.2303 and acceptance constant is c=2.

Operating procedure

Stage 1

Step 1: Draw a random sample of size n_1 = 200.

Step 2: Determine s_1^2.

Step 3: If $s_1^2 \leq 25.2303$, accept the lot.

Step 4: If $s_1^2 > 25.2303$, go to next stage.

Stage 2

Step 1: Draw another sample of size n_2.= 200.

Step 2: Count the number of defectives d
Step 3: If $d \leq 2$, accept the lot otherwise reject the lot.

9. Conclusion

In this research article, a new two stage mixed sampling plan with variance criterion is developed. Since the final decision is based on combination of vari-attri criteria the inspection result will lead to exact decision. The new algorithm is made easy to operate in quality control section. Based on the designing procedure tables are constructed to facilitate quality control engineers. It is found that the two stages mixed sampling plan is more sensitive towards deterioration of the quality. Hence this sampling plan pressurizes the producer to maintain the variability in the production processes. From the table (1) one can find that whenever the sample size increases, the acceptance constant k decreases and from table (2), it is found that whenever the sample size increases, k increases for lower probability of acceptance. Customers may be satisfied by this type of inspection since both variance and non-conformities are monitored and controlled.

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