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Construction and Evalution of Performance Measures for One Plan Suspension System

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Abstract

This paper is proposed with acceptance sampling systems when a small sample size is necessary or desirable. Under these conditions, a sampling plan with smaller sample size is not very effective, since discrimination between good and bad quality is not sufficient. Also, the lot-by-lot inspection provides an incentive for the producer to turn out consistently good quality. Hence it is intended to adapt one plan suspension system with single sampling plan as reference plan. When producer and consumer are negotiating for quality limits and sampling plan, it is important especially for the producer to find out the proportion of lots expected to be accepted under the plan when it is in operation.

This paper mainly relates with the procedure for designing one plan suspension system with single sampling plan indexed through relative slopes at acceptable and limiting quality levels. Tables and procedures are also provided for the selection of the parameters for the system with specified quality levels. Numerical illustrations are also provided for the shop floor applications of these procedures.

Subject Classification: 62P30 / 62D05.

Keywords: Suspension system, Reference Quality Level, Single Sampling Plan, Average Outgoing Quality Limit, Maximum Allowable Percent Defective, Maximum Allowable Average Outgoing Quality, Relative Slopes.

Introduction

Cone and Dodge (1962) have first shown that the effectiveness of a small sample lot-by-lot sampling system which can be greatly improved by using cumulative results as a basis for suspending inspection. It requires the producer to correct what is wrong and submit satisfactory written evidence of action taken before the inspection is resumed. The small sample is considered due to small quantity of production or costly/ destructive nature of testing.

Troxell (1972) has applied this suspension principle to acceptance sampling system incorporating a suspension rule to suspend inspection on the basis of unfavorable lot history, when small sampling plans are necessary or desirable. Here suspension rule is seems to be a stopping time random variable and a suspension system is a rule which used with a single sampling plan or a pair of normal and tightened sampling plans. When single plan is used with a suspension rule it is called One Plan (OP) suspension system.

In this paper a new procedure has been presented, that what is the behaviour of submitted lots before suspension occurs if it follows Poisson distribution. Attention is centered primarily on small sample single sampling plan with acceptance number c=0 and c=1. Lilly Christina (1995) has studied the design and analysis of suspension system.

A suspension rule, which is designated as (j, k), $2 \leq j \leq k$, is a rule for suspending inspection based on finding j lot rejections in k or less lots. Specifically, an account is kept for lot dispositions from the present lot to a fixed number of k-1 previous consecutive lots. At any time the present lot increases the total number of lot rejections observed over the fixed span of length k to some predetermined integer j, inspection is suspended; a run of j out of k or less lots is said to have occurred. Given j and k, at least j lots must be inspected before a decision is possible upon beginning of a new process or from the time of the last suspension. Upon restart of inspection after suspension, history starts a new in that all previous dispositions are ignored. The rule then determines uniquely at every lot whether to continue or suspend inspection.

The phrase “lot disposition” always refers to either lot acceptance (A) or lot rejection (R), while the term ‘lot history’ refers to a sequence of lot dispositions e.g.(AARARA….). A one plan suspension system is a combination of a suspension rule and a single lot-by-lot sampling plans. Under OP suspension system, a lot-by-lot sampling plan is used in the usual way to decide whether individual lots shall be accepted or rejected. The sampling inspection procedures being treated here is one involving the sampling of a continuous process with samples taken from each lot or partition of the product. The conditions for application are given below:

Conditions for Application

1. Production is reasonably steady. So that results on current and proceeding lots are broadly indicative of a continuous process.
2. Samples are taken from lot substantially in the order of their production so that observed variations in quality of product reflect process performance.
3. Inspection is performed close to the production source so that inspection information can be made available promptly.
4. Inspection is by attributes, with quality measured in terms of fraction defective p

5. A single sample of size n or double or multiple samples of equal size n is taken from each sampled lot.

Operating Procedure

1. For the product under consideration establish a reference quality level (RQL). This RQL termed as np represents the desired quality at delivery considering the need for service and cost of production.
2. Consider the established RQL, select a suspension system.
3. Apply the suspension rule to the first, second…kth lot, then to each successive group of k lots.
4. If any lot is rejected, declare the lot non-conforming and dispose it in accordance with standard procedures.
5. If for any lot, the suspension rule occurs, declare the current lot non-conforming and also declare the process as non-conforming.
6. When the process is judged non-conforming:
    a. Notify the submitting agency that no additional lots may be submitted for inspection until that agency has furnished evidence, satisfactory to the inspection agency that action has been taken to assure the submission of satisfactory material.
    b. Dispose the current non-conforming lot in accordance with standard procedures.
    c. When satisfactory evidence for corrective action is furnished, start inspection again with the next succeeding lot and with this lot begin accumulation.
    d. If it becomes necessary to refuse lot submission second time, so advice an appropriate higher authority and notify the submitting agency that further submissions will be refused until evidence satisfactory to the higher authority has been approved.

Average Run Length

According to Troxell (1972) the expected time to suspension or average run length of the suspension rule (j, k) designated as ARL (j, k) can be calculated as follows:

First, the expected number of lot rejections until suspension is calculated. Since the rejections are interspaced with lot acceptances, the second step is to find the total expected number of lots inspected, including the rejected lot, between successive lot rejections the ARL equals the sum of the total number of lots inspected until suspension.

ARL (j, k) = Total number of inspected lots between two rejections ×

Expected number of rejections until suspension.

Using this fact, for j=2, the expression is given by a single term and for j=3, the result is best expressed in the form of a continued fraction, which is found by solving for the stationary distribution of a particular Markov chain. For higher rules, a discussion is given indicating the method of solving for the expected number of rejections until suspension.

Troxell (1972) has derived the following results:

i. ARL for the rule (j, j), j ≥2 is

$$\text{ARL (j, j)} = \frac{1-(1-P_a)^j}{P_a(1-P_a)^j}$$

ii. ARL for the rule (j, ∞) is

$$\text{ARL (j, }\infty) = \frac{j}{1-P_a}$$

which is the waiting time for jth occurrence of a lot rejection, or the mean of the negative binomial distribution with parameter j.

iii) ARL for the rule (2, k) is

$$\text{ARL (2, k)} = \frac{(2 - \text{Pa}^{k-1})}{(1 - \text{Pa})(1 - \text{Pa}^{k-1})}, \; k \geq 2$$

For any k such that $j < k < \infty$ and $0 < P_a < 1$

$$\text{ARL (j, j)} > \text{ARL (j, k)} > \text{ARL (j, }\infty)$$

So that the rules (j, j) and (j, ∞) respectively are upper and lower bounds for all rules in the class (j, k). Troxell (1980) has given the new procedure for one plan suspension system using single sampling plan with c= 0. Further tables are provided for solving ARL equations in terms of Probability of acceptance (P_a).

In the literature, when selecting the parameters for a plan, one usually considers a standard quality level with reference to which the plan should operate, and the degree of sharpness of inspection around that quality level. Soundararajan (1975) has used p_*, i.e. the proportion defective corresponding to the inflection point on the OC curve, as the quality standard and h_*, i.e. the point at which the inflection tangent to the OC curve cuts the proportion defective axis, as the degree for sharpness of inspection for the selection of single sampling plan. Pandey (1986) have tabulated Bayesian Single Sampling Plan by attributes with three decision criteria for Discrete Prior Distribution.

Suresh and Ramkumar (1996) have studied the selection of single sampling plan indexed through MAAOQ. Suresh and Saminathan (2007) have given a procedure to define multiple repetitive group sampling plans indexed with MAPD and MAAOQ. Suresh and Jayalakshmi (2007) have suggested new procedures on quick switching system with STDS using specified quality levels.

The proportion non-conforming corresponding to the inflection point on the OC curve as denoted by p_* and interpreted as Maximum Allowable Percent Defective (MAPD) by Mayer (1967) has used as the quality standard along with some other condition for the selection of sampling plans. The relative slope of the OC curve at this point was denoted as h_*, also used to fix the discrimination of the OC curve for any sampling plan. Mandelson (1962) has explained the desirability for a system of sampling plans indexed through Maximum Allowable Percent Defective (MAPD). Suresh and Pradeepa (2007) have proposed procedures to select Bayesian Multiple

Deferred State plan indexed through producer and consumer quality levels considering filter and incentive effects.

Soundararajan and Muthuraj (1985) have tabulated SSP by attribute under the condition with Poisson model indexed through MAPD. Suresh and Srivenkataramana (1996) have proposed procedures to select Single Sampling Plan using Producer and Consumer Quality Levels. Suresh and Jayalakshmi (2008) have explained the desirability for developing quick switching system indexed through maximum allowable percent defective. Suresh and Kaviyarasu (2008) have suggested new procedures on quick switching system with conditional RGS plan using specified quality levels. Radhakrishnan and Sampathkumar (2009) have given the new procedure for construction and comparison of mixed sampling plan using MAPD and MAAOQ.

Selection of One Plan Suspension System

Designing plans for given p_1 and h_1

For any given values of p_1 and h_1, use Table 1 for finding the parameters of One plan system. For given h_1, using Table 1, scan the column headed h_1 which is equal to or just greater than the desired value which provides corresponding value for k and np_1.

Example

For given $p_1 = 0.003$ and $h_1 = 0.055$, using Table 1, under the column headed h_1, one can locate the value which is equal to or just greater than the specified h_1. The values associated to the corresponding h_1 are $np_1 = 0.0263$ and k= 2. Hence $n=np_1 / p_1 = 8.7667 \approx 9$ Thus the One plan suspension system for given p_1 and h_1 has the parameter c=1, k=2 and n=9.

Designing plans for given p_2 and h_2

For any given values of p_2 and h_2, use Table 1 for finding the parameters of One plan system. For given h_2, using Table 1, scan the column headed h_2 which is equal to or just greater than the desired value which locates the corresponding value for k and np_2.

Example

For given $p_2 = 0.006$ and $h_2 = 3.15$, using Table 1, under the column headed h_2, one can locate the value which is equal to or just greater than the specified h_2. The values associated to the corresponding h_2 are $np_2 = 0.2269$ and k=10. Hence $n = np_2 / p_2 = 37.81 \approx 38$. Thus the One plan suspension system for given p_2 and h_2 has the parameter c=1, k=10 and n=38.

Designing plans for given p_* and h_*

For any given values of p_* and h_*, use Table 1 for finding the parameters of One plan system. For given h_*, using Table 1, scan the column headed h_* which is equal to or just greater than the desired value which locates the corresponding value for c, k and np_*.

Example

For given p_* = 0.02 and h_* = 0.15, using Table 1, under the column headed h_*, one can locate the value which is equal to or just greater than the specified h_*. The values associated to the corresponding h_* are np_* = 0.4323 and k=4. Hence n= np_* / p_* = 21.615 ≈ 22. Thus the One plan suspension system for given p_* and h_* has the parameter c=1, k=4 and n=22.

Designing plans for given p_0 and h_0

For any given values of p_0 and h_0, use Table 1 for finding the parameters of One plan system. For given h_0, using Table 1, scan the column headed h_0 which is equal to or just greater than the desired value which locates the corresponding value for k and np_0.

Example

For given p_0 = 0.002 and h_0 = 0.15, using Table 1, under the column headed h_0, one can locate the value which is equal to or just greater than the specified h_0. The values associated to the corresponding h_0 are np_0 = 0.0416 and k=11. Hence n=np_0 / p_0 = 20.8 ≈21. Thus the One plan suspension system for given p_1 and h_1 has the parameter c=1, k=11 and n=21.

Designing plans for given p_1 and K_1

In order to design one plan suspension system with single sampling plan as reference plan for given p_1 and K_1 Table 2 is utilized. The steps utilized for selecting one plan suspension system with single sampling plan as reference plan are as follows.

- Scan the Table 2 with column headed by K_1 and locate the value of K_1 which is just greater than or equal to the given K_1. Locate the corresponding np_1 value.
- The value of k is found against the located K_1 value.
- The sample size is thus determined by np_1/p_1.

Example

For given p_1=0.005 and K_1 = 18 scan the column headed K_1 in Table 2 which is equal to or just greater than the desired value. The value corresponding to K_1 is np_1 = 0.0263 and k=2 then n=5.26≈6. The selected parameters for one plan suspension system with single sampling plan as reference plan are n=6, k=1 and c=1.

Designing plans for given p_2 and K_2

In order to design one plan suspension system with single sampling plan as reference plan for given p_2 and K_2 Table 2 is utilized. The steps utilized for selecting one plan suspension system with single sampling plan as reference plan are as follows.

- Scan the Table 2 with column headed by K_2 and locate the value of K_2 which is just greater than or equal to the given K_2. Locate the corresponding np_2 value.
- The value of k is found against the located K_2 value.
- The sample size is thus determined by np_2/p_2.

Example

For given p_2=0.10 and K_2 = 0.18 scan the column headed K_2 in Table 2 which is equal to or just greater than the desired value. The value corresponding to K_2 is np_2 = 0.6367 and k=5 then n=6.367≈ 7. The selected parameters for one plan suspension system with single sampling plan as reference plan are n=7, k=5 and c=1.

Designing plans for given p_0 and K_0

In order to design one plan suspension system with single sampling plan as reference plan for given p_0 and K_0 Table 2 is utilized. The steps utilized for selecting one plan suspension system with single sampling plan as reference plan are as follows.

- Scan the Table 2 with column headed by K_0 and locate the value of K_0 which is just greater than or equal to the given K_0. Locate the corresponding np_0 value.
- The value of k is found against the located K_0 value.
- The sample size is thus determined by np_0/p_0.

Example

For given p_2=0.05 and K_0 = 0.8 scan the column headed K_0 in Table 2 which is equal to or just greater than the desired value. The value corresponding to K_0 is np_0 = 0.5408 and k=2 then n=10.816≈ 11. The selected parameters for one plan suspension system with single sampling plan as reference plan are n=11, k=2 and c=1.

Designing plans for given p_* and K_*

In order to design one plan suspension system with single sampling plan as reference plan for given p_* and K_* Table 2 is utilized. The steps utilized for selecting one plan suspension system with single sampling plan as reference plan are as follows.

- Scan the Table 2 with column headed by K_* and locate the value of K_* which is just greater than or equal to the given K_*. Locate the corresponding np_* value.
- The value of k is found against the located K_* value.
- The sample size is thus determined by np_*/p_*.

Example

For given p_*=0.65 and K_* = 5.4 scan the column headed K_* in Table 2 which is equal to or just greater than the desired value. The value corresponding to K_* is np_* = 0.5552 and k=3 then n=8.5415≈ 9. The selected parameters for one plan suspension system with single sampling plan as reference plan are n=9, k=3 and c=1.

Construction of Tables

The expression for $P_a(p)$ of One Plan Suspension System with single sampling plan as reference plan is given as,

$$P_A(2,k) = \frac{1 + e^{-np} - e^{-npk}}{2 - e^{-np(k-1)}} \qquad \text{for c=0}$$

$$P_A(2,k) = \frac{1+(1+np)e^{-np} - (1+np)^k e^{-npk}}{2-(1+np)^{k-1} e^{-np(k-1)}} \qquad \text{for c=1}$$

The relative slope of the OC curve is given as

$$h_* = \left[\frac{-p}{P_a(p)} \frac{dP_a(p)}{dp}\right]_{p=p_*}$$

The values of relative slopes at RQL_1 and RQL_2 are h_1 and h_2 values, which are calculated using the np_1 and np_2 values in the formulas. The column K_1, K_2, K_0 are obtained from the equation $K = \frac{p_T}{p}$ where $p=p_1=p_2=p_0$. The values of column h_1, h_2, h_0 are obtained using the relation

$$h_1 = -\left[\frac{p}{P_a(p)} \frac{dP_a(p)}{dp}\right]_{p=p_1}$$

$$h_2 = -\left[\frac{-p}{P_a(p)} \frac{dP_a(p)}{dp}\right]_{p=p_2}$$

$$h_0 = -\left[\frac{-p}{P_a(p)} \frac{dP_a(p)}{dp}\right]_{p=p_0}$$

As the measure of sharpness of inspection for designing the plan indexed by the point of control. The values of h_1 and h_2 the relative slope at the respective levels of RQL_1 and RQL_2 are obtained and tabulated in table 1.

Conclusion

Acceptance Sampling is the technique which deals with the procedures in which decision to accept or reject the lots or process which are based on the examination of samples. The work presented in this paper mainly relates to the new procedures proposed for construction and selection of tables for sampling inspections designed through Relative slopes and Incentive index. The emphasis in the present work is that the relation of sampling plans with procedure is more advantages to the producer and consumer than the procedures adopted through AOQL. The procedure stated here reduces the cost of inspection for the producer and consumer to get high quality good items.

In acceptance sampling the producer and consumer plays a dominant role and hence one allows a certain level of risk for both producer and consumer. It is the usual practice to design any sampling plan with associated quality levels, concern to producer and consumer. Hence the selection procedures are considered in this paper with relative slopes on the OC curve. Tables are provided in this paper which are tailor-made, handy and ready-made use, to shop-floor condition which are also well considered for comparison purposes for the industrial needs.

Table 1: Relative Slopes for One Plan Suspension System with Single Sampling Plan as reference plan (for c = 1).

k	np_1	np_2	np_0	np_*	h_1	h_2	h_o	h_*
2	0.0263	4.3547	0.5408	1.4085	0.0539	2.3623	1.2027	0.8220
3	0.0130	1.6459	0.2337	0.5552	0.0270	6.7167	0.7147	0.1823
4	0.0086	0.9454	0.1483	0.4323	0.0179	6.5329	0.4987	0.1518
5	0.0065	0.6367	0.1086	0.2428	0.0136	5.6987	0.3822	0.0271
6	0.0052	0.4725	0.0857	0.1471	0.0109	4.9525	0.3098	0.0048
7	0.0043	0.3732	0.0707	0.1253	0.0090	4.3522	0.2599	0.0033
8	0.0037	0.3076	0.0602	0.1134	0.0078	3.8747	0.2241	0.0028
9	0.0032	0.2613	0.0524	0.1015	0.0067	3.4888	0.1968	0.0021
10	0.0028	0.2269	0.0464	0.0962	0.0059	3.1691	0.1755	0.0021
11	0.0026	0.2005	0.0416	0.0954	0.0055	2.9045	0.1582	0.0025
12	0.0023	0.1795	0.0377	0.0875	0.0048	2.6780	0.1440	0.0020
13	0.0021	0.1625	0.0345	0.0724	0.0044	2.4854	0.1323	0.0010
14	0.0020	0.1484	0.0318	0.0691	0.0042	2.3173	0.1223	0.0009
15	0.0018	0.1365	0.0295	0.0673	0.0038	2.1688	0.1138	0.0009
16	0.0017	0.1264	0.0275	0.0656	0.0036	2.0395	0.1064	0.0010
17	0.0016	0.1177	0.0257	0.0634	0.0034	1.9252	0.0995	0.0009
18	0.0015	0.1101	0.0242	0.0629	0.0032	1.8222	0.0940	0.0010
19	0.0014	0.1034	0.0228	0.0618	0.0029	1.7288	0.0886	0.0011
20	0.0013	0.0975	0.0216	0.0611	0.0027	1.6459	0.0841	0.0011
21	0.0012	0.0922	0.0205	0.0601	0.0025	1.5690	0.0799	0.0012
22	0.0012	0.0875	0.0195	0.0593	0.0025	1.5013	0.0761	0.0012
23	0.0011	0.0832	0.0186	0.0587	0.0023	1.4367	0.0726	0.0013
24	0.0011	0.0794	0.0178	0.0549	0.0023	1.3818	0.0696	0.0010
25	0.0010	0.0758	0.0170	0.0492	0.0021	1.3250	0.0664	0.0006
26	0.0010	0.0726	0.0163	0.0419	0.0021	1.2766	0.0637	0.0003
27	0.0009	0.0696	0.0157	0.0321	0.0019	1.2290	0.0615	0.0002
28	0.0009	0.0669	0.0151	0.0315	0.0019	1.1876	0.0592	0.0002
29	0.0009	0.0644	0.0146	0.0299	0.0019	1.1488	0.0573	0.0002
30	0.0008	0.0620	0.0141	0.0286	0.0017	1.1088	0.0554	0.0002

Table 2: Incentive index for One Plan Suspension System with Single Sampling Plan as reference plan (for c = 1).

k	np_1	np_2	np_o	np_*	K_1	K_2	K_0	K_*
2	0.0263	4.3547	0.5408	1.4085	18.553	0.4233	0.8315	1.217
3	0.0130	1.6459	0.2337	0.5552	37.037	0.1489	1.3992	5.485
4	0.0086	0.9454	0.1483	0.4323	55.866	0.1531	2.0052	6.588
5	0.0065	0.6367	0.1086	0.2428	73.529	0.1755	2.6164	36.900
6	0.0052	0.4725	0.0857	0.1471	91.743	0.2019	3.2279	208.333

7	0.0043	0.3732	0.0707	0.1253	111.111	0.2298	3.8476	303.030
8	0.0037	0.3076	0.0602	0.1134	128.205	0.2581	4.4623	357.143
9	0.0032	0.2613	0.0524	0.1015	149.254	0.2866	5.0813	476.190
10	0.0028	0.2269	0.0464	0.0962	169.492	0.3155	5.6980	476.190
11	0.0026	0.2005	0.0416	0.0954	181.818	0.3443	6.3211	400.000
12	0.0023	0.1795	0.0377	0.0875	208.333	0.3734	6.9444	500.000
13	0.0021	0.1625	0.0345	0.0724	227.273	0.4023	7.5586	1000.000
14	0.0020	0.1484	0.0318	0.0691	238.095	0.4315	8.1766	1111.111
15	0.0018	0.1365	0.0295	0.0673	263.158	0.4611	8.7873	1111.111
16	0.0017	0.1264	0.0275	0.0656	277.778	0.4903	9.3985	1000.000
17	0.0016	0.1177	0.0257	0.0634	294.118	0.5194	10.0503	1111.111
18	0.0015	0.1101	0.0242	0.0629	312.500	0.5488	10.6383	1000.000
19	0.0014	0.1034	0.0228	0.0618	344.828	0.5784	11.2867	909.091
20	0.0013	0.0975	0.0216	0.0611	370.370	0.6076	11.8906	909.091
21	0.0012	0.0922	0.0205	0.0601	400.000	0.6373	12.5156	833.333
22	0.0012	0.0875	0.0195	0.0593	400.000	0.6661	13.1406	833.333
23	0.0011	0.0832	0.0186	0.0587	434.783	0.6960	13.7741	769.231
24	0.0011	0.0794	0.0178	0.0549	434.783	0.7237	14.3678	1000.000
25	0.0010	0.0758	0.0170	0.0492	476.190	0.7547	15.0602	1666.667
26	0.0010	0.0726	0.0163	0.0419	476.190	0.7833	15.6986	3333.333
27	0.0009	0.0696	0.0157	0.0321	526.316	0.8137	16.2602	5000.000
28	0.0009	0.0669	0.0151	0.0315	526.316	0.8420	16.8919	5000.000
29	0.0009	0.0644	0.0146	0.0299	526.316	0.8705	17.4520	5000.000
30	0.0008	0.0620	0.0141	0.0286	588.235	0.9019	18.0505	5000.000

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