International Journal of Scientific Research in Mathematical and Statistical Sciences
Research Paper
Volume-5, Issue-5, pp.19-24, October (2018)
E-ISSN: 2348-4519

Designing of Modified Tightened 3 Levels Continuous Sampling Plan Indexed through Maximum Allowable Average Outgoing Quality

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Available online at: www.isroset.org

Received: 31/Aug /2018, Accepted:13/Oct/2018, Online: 31/Oct/2018

Abstract— The principal objective of this paper is to propose a novel determination of the quality measures for maximum allowable average outgoing quality in final products in manufacturing industries. In this paper presents a procedure for designing continuous sampling plan - MLP-T-3 indexed through maximum allowable average outgoing quality (MAAOQ). Tables and procedures are also provided for the selection of the parameters for the plan with specified Average outgoing quality level (AOQL), Maximum allowable percent defective (MAPD), MAAOQ and operating ratio. Numerical illustrations are also provided for the shop floor applications of this plan. MAAOQ indexed plan provides a method for designing sampling plan based on quality, instead of AOQL description in operating characteristic (OC) curve about quality.

AMS Subject Classification: 62D05; 62P30.

Keywords*—Skip-lot sampling plan, Quality Region, Final Product, Quality, Manufacturing Industries*

I. INTRODUCTION

Acceptance sampling is simply to accept or reject the lot based on exact theory of sampling is a branch of statistical quality control. The primary objective of acceptance sampling is to design sampling plans depicted by sample size and acceptance number which in turn prescribes a procedure will give a specified risk of accepting lots of given quality[1-2]. This paper is developed based on acceptance sampling procedures for construction and evaluation of MAAOQ designing methodology involving inspection for Continuous sampling plan CSP-MLP-T-3. Assuming the existence of lot fraction non-conforming during the production process and the transition of states between them before and after the product is shipped to the customer [3]. The company samples the received shipment of goods and decides either to accept or reject it as conforming to its standards.

The consequences is discussed when the errors occurs in classifying good units as defective and vice versa made by the inspection personnel [4]. When a supplier's product is rejected at a high rate then the supplier is indirectly helped by the acceptance sampling that improves the quality of production through its encouragement of good quality by a high rate of acceptance [5]. Quantitative measures of quality aid in the establishment of plans for manufacturing loss with linear inspection cost and complaint reductions and serve as a basis for establishing and measuring performances [6].

Review on continuous sampling plan of type MLP-T-3

Chung-Ho Chen (2004) proposed a Modified tightened two level continuous sampling plan designated as minimum average fraction [7], which is included in MIL-STD 1235C (2006) and derived AOQ and AFI functions for the $CSP-M$ plan [8], which is a special case of $MLP-T$ plan with three sampling inspection levels $f_1 = f$, $f_2 = 1/2f$ and $f_3 = 1/4f$.

Gauri Shanker (1994) presented a simplification of the GERT analysis to continuous formulation [9] and Ghosh (2002) minimize the amount of inspection in CSP [10]. Govindaraju (1989) has given basic procedure for CSP [11]. Toranagath (2018) has analyzed Delta Generalized Pre-Continuous Functions [12]. Muthulakshmi (2012) has given stopping rule for CSP [13].

The Modified MLP − T − 3 Procedure as a Markov Chain

Let $[X_m]$, $m = 1, 2, \ldots$, denote a discrete-parameter Markov chain with finite state space (S_j), $j = 1, 2, \ldots, 3i + 10$. The states of the process are defined, in a way similar to Roberts (1965) and Lasater (1970), as follows:

$S1$ = $A0$
= A non-conforming unit is found on 100% inspection.

$Sj+1$ = Cj, $j = 1, 2, \ldots, i$
= j consecutive conforming units found during 100% inspection following its commencement.

$Si+j+1$ = Bj, $j = 1, 2, \ldots, i$
= j consecutive conforming units found during 100% inspection after reverting from sampling inspection at level 2.

$S2i+j+1$ = j consecutive conforming units found during 100% inspection after having a non-conforming unit is found on 100% inspection.

$S3i+2$ = $Id1$
= Sampling inspection at level 1 is in effect and the last inspected unit was found to be nonconforming.

$S3i+3$ = $In1$
= Sampling inspection at level 1 is in effect and the last unit submitted for inspection was conforming.

$S3i+4$ = $N1$
= Sampling inspection at level 1 is in effect and the last unit produced was not inspected.

$S3i+5$ = $Id2$
= Sampling inspection at level 2 is in effect and the last inspected unit was found to be nonconforming.

$S3i+6$ = $In2$
= Sampling inspection at level 2 is in effect and the last unit submitted for inspection was conforming.

$S3i+7$ = $N2$
= Sampling inspection at level 2 is in effect and the last unit produced was not inspected.

$S3i+8$ = $Id3$
= Sampling inspection at level 3 is in effect and the last inspected unit was found to be nonconforming.

$S3i+9$ = $In3$
= Sampling inspection at level 3 is in effect and the last unit submitted for inspection was conforming.

$S3i+10$ = $N3$
= Sampling inspection at level 3 is in effect and the last unit produced was not inspected.

The set of $(3i+10)$ states defined above completely describes the mutually exclusive phases of inspection for the modified $MLP - T - 3$ plan.

OPERATING PROCEDURE

1. The procedure starts with 100% inspection of units in the order of production.
   a) If the first i consecutive units are found non-conforming discontinue 100% inspection and switch to sampling inspection at level 2, where only a pre specified fraction f_2 of the units are inspected.
   b) Otherwise continue 100% inspection until any run of i successive units found non-conforming and then proceed to sampling inspection at level 1, where only a pre-specified fraction f_1 of the units are inspected.
2. If sampling inspection is on level 1, then continue inspection until a non-conforming unit is found. When this occurs revert immediately to 100% inspection and then continue as in (1).
3. If sampling inspection is on level 2 or level 3, then continue the inspection until a non-conforming unit is found. When this occurs revert immediately to 100% inspection and then:
   a) If the first i consecutive units are found conforming then discontinue 100% inspection and switch to sampling inspection at level 3, where a pre-specified fraction f_3 of the units is inspected.
   b) Otherwise continue as in 1(b).
4. Repair all non-conforming units found or replace them with conforming units.

An important feature of the modified $MLP - T - 3$ plan compared with $MLP - T - 3$ plan is that one cannot go from one level of sampling inspection to another without going back to 100% inspection. Nirmala and Suresh (2016-2018) these analytical procedure for various CSPs are given the literature [14 -24, 28]. Snehasri and Apama (2018) has studied the Bastion scheme for securing data under key revelation [25]. Rafia et.al (2017) presented product estimator [26]. Sonia and Munishwar (2017) analyzed Customer behavior analysis [27]. Kumaresan and Habeebullah Sait (2018) studied Model Predictive Control of Shunt Active Filter for Power Quality Improvement in Distribution systems [29].

SELECTION PROCEDURE

The Performance Measures of Modified MLP − T − 3 Plan. If one employs a modified MLP −T −3 plan for a process fraction non-conforming p, the following performance measures are obtained. The average number of units, u, inspected during a screening phase is given in the equation (1). The average number of units passed under the sampling inspection is given by,

$$v = \frac{f_2 f_3 (1-q^i) + f_1 f_3 q^i (1-q^i) + f_1 f_2 q^{2i}}{f_1 f_2 f_3 p} \quad (1)$$

The average fraction of total produced units inspected in the long run is,

$$F = \frac{f_1 f_2 f_3}{f_1 f_2 f_3 (1-q^i) + f_2 f_3 q^i (1-q^i) + f_1 f_3 q^{2i} (1-q^i) + f_1 f_2 q^{3i}} \quad (2)$$

The average outgoing quality is,

$$AOQ(p) = \frac{pq^i [(1-f_1) f_2 f_3 (1-q^i) + f_1 (1-f_2) f_3 q^i (1-q^i) + f_1 f_2 (1-f_3) q^{2i}]}{f_1 f_2 f_3 (1-q^i) + f_2 f_3 q^i (1-q^i) + f_1 f_3 q^{2i} (1-q_i) + f_1 f_2 q^{3i}} \quad (3)$$

The average outgoing quality limit (AOQL), the maximum of the AOQ for all values of p, may be found graphically using the AOQ function given by AOQ (p) equation. The average fraction of the total production accepted on a sampling basis the operating characteristic function is,

$$P_a(p) = \frac{a^i [f_2 f_3 (1-q^i) + f_1 f_3 q^i (1-q^i) + f_1 f_2 q^{2i}}{f_1 f_2 f_3 (1-q^i) + f_2 f_3 q^i (1-q^i) + f_1 f_3 q^{2i} (1-q^i) + f_1 f_2 q^{3i}} \quad (4)$$

FOR SPECIFIED MAAOQ AND MAPD

Table 1 is used to construct the plans when MAPD and MAAOQ are specified. For any given values of MAPD (p_*) and MAAOQ (p_{MAQ}), find the value in Table 1 under the column R_1 which is approximately equal to the calculated value. Then the corresponding value of c and f are noted. From this one can determine the parameters c and f for the continuous sampling plan- MLP-T-3.

FOR SPECIFIED AOQL AND MAPD

Table 1 is used to construct continuous sampling plan- MLP-T-3 for given MAPD and MAAOQ quality levels. For any given values of the i and f one can find the performance measure MAAOQ and various ratios R_1 = MAAOQ / MAPD, R_2 = AOQL / MAPD and R_3 = AQL / MAPD.

NUMERICAL EXAMPLES

1. Given MAPD = 0.64291, and MAAOQ = 0.00083 compute the ratio R_1 which is R_1 = MAAOQ / MAPD = 0.00083 / 0.64291 = 0.00129, R_2 = AOQL / MAPD = 0.46433 / 0.64291 = 0.72223 and R_3 = AQL / MAPD = 0.01825 / 0.64291 = 0.02839 which is associated with i = 2, f_1 = 1/5, f_2 = 1/10 and f_3 = 1/20. Thus i = 2, f_1 =1/5, f_2 =1/10 and f_3 = 1/20 are the parameters selected for continuous sampling plan CSP – MLP-T-3 for a given MAPD of 0.64291 and MAAOQ of 0.00083 defective.
2. Given MAPD = 0.70857 and MAAOQ = 0.03452 compute the ratio R_1 which is R_1 = MAAOQ / MAPD = 0.03452 / 0.70857 = 0.04871, R_2 = AOQL / MAPD = 0.67387 / 0.70857 = 0.95103 and R_3 = AQL / MAPD = 0.36965 / 0.70857 = 0.52168 which is associated with i = 4, f_1 = 2/5, f_2 =1/5 and f_3 = 1/10. Thus i = 4, f_1 = 2/5, f_2 =1/5 and f_3 = 1/10 are the parameters selected for continuous sampling plan CSP – MLP-T-3 for a given MAPD of 0.70857and MAAOQ of 0.03452 defective.

CONVERSION OF PARAMETERS

Table 1 may be used to convert continuous sampling plan-MLP-T-3 from one set of parameters to other familiar sets, which will provide related information on the derived plan. For example, given AOQL = 0.73978 and MAAOQ = 0.08097 the value corresponding to this ratios in MAAOQ / MAPD = 0.08097/ 0.72662 = 0.11143, AOQL / MAPD = 0.73978 / 0.72662 = 1.01811 and AQL / MAPD = 0.62368 / 0.72662 = 0.85834.

CONSTRUCTION OF TABLES

The expression for the OC function of continuous sampling plan- MLP-T-3 is given by,

$$P_a(p) = \frac{a^i [f_2 f_3 (1-q^i) + f_1 f_3 q^i (1-q^i) + f_1 f_2 q^{2i}}{f_1 f_2 f_3 (1-q^i) + f_2 f_3 q^i (1-q^i) + f_1 f_3 q^{2i} (1-q^i) + f_1 f_2 q^{3i}} \quad (5)$$

$$R_1 = MAAOQ / MAPD, R_2 = AOQL / MAPD \;\&\; R_3 = AQL / MAPD \quad (6)$$

The incoming quality MAPD column of Table 1 is constructed by equation 1 is equating the second order derivative of operating characteristic function. The values of AQL, AOQL, MAAOQ, MAPD, R_1, R_2 and R_3 are given.

The inspection is done for the purpose of accepting or rejecting the lot based on certain standards. The process involves the manufacturer inspecting the sample at various stages of production and if the lots are accepted then it is sent to further process, otherwise, it may be rejected or the defectives would be replaced based on the table result.

Consumer's Risk

For a given sampling plan, the probability of accepting a lot, the quality of which has a designated numerical value representing a level, which is generally desired to be rejected.

Producer's Risk

For a given sampling plan, the probability of not accepting a lot, the quality of which has a designated numerical value representing a level, which is generally desired to be accepted.

Table 1: Certain Parametric Values for Continuous sampling plan-MLP-T-3

i	f_1	f_2	f_3	AQL	AOQL
2	1/5	1/10	1/20	0.01825	0.46433
2	2/5	1/5	1/10	0.07932	0.4848
2	1/2	1/4	1/8	0.10668	0.57438
3	1/5	1/10	1/20	0.14155	0.54274
3	1/5	1/10	1/20	0.35256	0.66701
3	2/5	1/5	1/10	0.20821	0.59216
3	2/5	1/5	1/10	0.23679	0.60998
3	1/2	1/4	1/8	0.23679	0.61015
3	1/2	1/4	1/8	0.26977	0.62857
4	1/5	1/10	1/20	0.36965	0.67387
4	1/5	1/10	1/20	0.33653	0.65943
4	1/5	1/10	1/20	0.35256	0.66661
4	2/5	1/5	1/10	0.36965	0.67387
4	2/5	1/5	1/10	0.47465	0.71104
4	2/5	1/5	1/10	0.40736	0.68858
4	1/2	1/4	1/8	0.38679	0.61015
4	1/2	1/4	1/8	0.45062	0.70348
4	1/2	1/4	1/8	0.43923	0.69974
5	1/5	1/10	1/20	0.47465	0.71102
5	1/5	1/10	1/20	0.48991	0.71415
5	1/5	1/10	1/20	0.50046	0.71863
5	1/5	1/10	1/20	0.50819	0.72083
5	2/5	1/5	1/10	0.51409	0.72249
5	2/5	1/5	1/10	0.52252	0.72387
5	2/5	1/5	1/10	0.52824	0.72567
5	2/5	1/5	1/10	0.53239	0.72694
6	1/2	1/4	1/8	0.53552	0.72833
6	1/2	1/4	1/8	0.57169	0.7338
6	1/2	1/4	1/8	0.61891	0.73789
6	1/2	1/4	1/8	0.62368	0.73978

Table 1: Continuation….

i	f_1	f_2	f_3	MAAOQ	MAPD
2	1/5	1/10	1/20	0.00083	0.64291
2	2/5	1/5	1/10	0.00233	0.65286
2	1/2	1/4	1/8	0.03449	0.70858
3	1/5	1/10	1/20	0.00683	0.67326
3	1/5	1/10	1/20	0.03114	0.70691
3	2/5	1/5	1/10	0.01269	0.68798
3	2/5	1/5	1/10	0.01541	0.69279
3	1/2	1/4	1/8	0.01540	0.69281
3	1/2	1/4	1/8	0.01926	0.69526
4	1/5	1/10	1/20	0.03452	0.70857
4	1/5	1/10	1/20	0.02858	0.70523
4	1/5	1/10	1/20	0.03114	0.70691
4	2/5	1/5	1/10	0.03452	0.70857
4	2/5	1/5	1/10	0.05757	0.71590
4	2/5	1/5	1/10	0.04141	0.71189
4	1/2	1/4	1/8	0.01540	0.69281
4	1/2	1/4	1/8	0.05114	0.71380
4	1/2	1/4	1/8	0.04836	0.71273
5	1/5	1/10	1/20	0.05757	0.7159
5	1/5	1/10	1/20	0.06213	0.66271
5	1/5	1/10	1/20	0.06616	0.71793
5	1/5	1/10	1/20	0.06862	0.7185
5	2/5	1/5	1/10	0.07059	0.71892
5	2/5	1/5	1/10	0.07357	0.71949
5	2/5	1/5	1/10	0.07571	0.71988
5	2/5	1/5	1/10	0.07732	0.72016
6	1/2	1/4	1/8	0.07857	0.72037
6	1/2	1/4	1/8	0.07886	0.72204
6	1/2	1/4	1/8	0.07944	0.72583
6	1/2	1/4	1/8	0.08097	0.72662

Table 1: Continuation….

i	f_1	f_2	f_3	R_1	R_2	R_3
2	1/5	1/10	1/20	0.00129	0.72223	0.02839
2	2/5	1/5	1/10	0.00357	0.74258	0.12151
2	1/2	1/4	1/8	0.04867	0.81061	0.15055
3	1/5	1/10	1/20	0.01014	0.80615	0.21024
3	1/5	1/10	1/20	0.04405	0.94355	0.49874
3	2/5	1/5	1/10	0.01845	0.86073	0.30265
3	2/5	1/5	1/10	0.02224	0.88047	0.34180
3	1/2	1/4	1/8	0.02224	0.88071	0.34179
3	1/2	1/4	1/8	0.02770	0.90408	0.38801
4	1/5	1/10	1/20	0.04871	0.95103	0.52168
4	1/5	1/10	1/20	0.04052	0.93505	0.47719
4	1/5	1/10	1/20	0.04405	0.94299	0.49874
4	2/5	1/5	1/10	0.04871	0.95103	0.52168
4	2/5	1/5	1/10	0.08042	0.99316	0.66301
4	2/5	1/5	1/10	0.05817	0.96725	0.57223
4	1/2	1/4	1/8	0.02224	0.88071	0.55830
4	1/2	1/4	1/8	0.07164	0.98555	0.63131
4	1/2	1/4	1/8	0.06786	0.98178	0.61626
5	1/5	1/10	1/20	0.08042	0.99316	0.66301
5	1/5	1/10	1/20	0.09375	1.07763	0.73926
5	1/5	1/10	1/20	0.09216	1.00098	0.69709
5	1/5	1/10	1/20	0.09550	1.00325	0.70731
5	2/5	1/5	1/10	0.09819	1.00497	0.71509
5	2/5	1/5	1/10	0.10226	1.00609	0.72624
5	2/5	1/5	1/10	0.10517	1.00804	0.73380
5	2/5	1/5	1/10	0.10736	1.00942	0.73926
6	1/2	1/4	1/8	0.10907	1.01105	0.74341
6	1/2	1/4	1/8	0.10922	1.01628	0.79177
6	1/2	1/4	1/8	0.10945	1.01661	0.85269
6	1/2	1/4	1/8	0.11143	1.01811	0.85834

CONCLUSION

This work has been considered to design and evaluate the continuous production model for the acceptance sampling plans, schemes and system with the aim to provide the optimum plan minimizing the average cost of an item and inspection time, which minimizes the risk of producer and favors the customer in accepting the satisfactory lot with reasonable cost of an item. The Operating Characteristic (OC) function has been modified for MAAOQ under the conditions of AOQL.

Further, the optimum plan and various designing points are determined under the conditions of continuous production, corresponding to some specified producer's and consumer's risks for different values of parameters. The properties of proposed plan function under the assumptions of linear relationships are studied through empirical study of OC curves.

Finally observed that proposed plan protects the producer by minimizing the risk instead of AQL in OC curve, which in turn the consumer requirement is satisfied by accepting the satisfactory product. This plan proposes wider potential applicability in industry ensuring higher standard of quality attainment for final products.

ACKNOWLEDGEMENTS

The first author is thankful to Ministry of Science and Technology, Department of Science and Technology (DST), Govt. of India, New Delhi for providing Women Scientist-A, DST-WOS-A research project as Principal Investigator for financial support to carry out of this research work and grateful to Bharathiar University, for providing necessary facilities for implementing the Research Project. The second author is thankful to University Grants Commission, New Delhi for providing UGC – OTG for research program and DST-FIST, UGC – SAP programmes.

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