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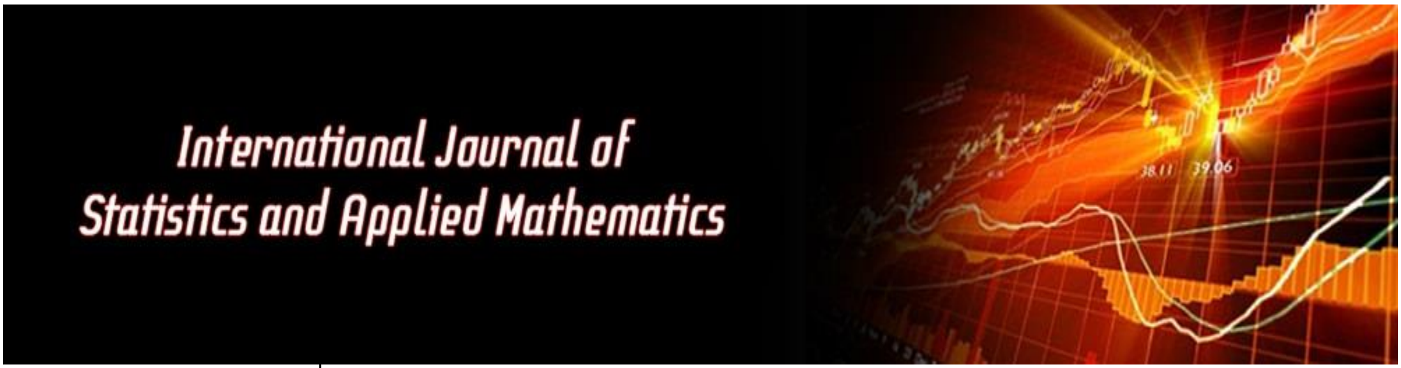

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Design and development of intra lot group acceptance chain sampling plans with an emphasis on zero tolerance non-conformities

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Abstract
In this article a new sampling plan to control product quality known to be Intra Lot Group Acceptance Chain Sampling Plan (ILGAChSP) is developed. Group Acceptance Sampling Plans are widely used in life testing experiments and has applications in research and development centers. In many testing fields, zero defective is expected in every groups or batches. Hence in this paper zero defective is emphasized during testing with an allowance of a non-conformity in a chain of i groups within the same batch of products. If a defective is found then the batch will be accepted only if ‘i’ consecutive chain of groups have zero defective in the current lot. Since ‘i’ chain of groups are tested in the same batch or lot it is termed as Intra Lot Group Acceptance Chain Sampling Plans.

Keywords: intra group chain sampling, efficiency measures, OC function, ASN, AOQ

Introduction
In modern industries acceptance sampling tools and techniques are one of the major components in the field of quality control division. These techniques are employed for incoming or receiving lots of the quality of the product manufactured in the industries.
The advantage of group acceptance sampling plans is it saves the testing time and reduces the cost of inspection if more items are tested in an experiment. Dodge (1955) [9] has found that zero acceptance numbers in certain sampling plans does not discriminate between good and bad lots. Hence he suggested an allowance of one defective in the current lot and with zero defective in the preceding i lots. But in modern industries quality control practitioners insist that when the sampling plan is administered then the first lot should be capable of meeting the consumer requirement. In fact during life testing experiment they need zero tolerance non conformities in each group. If a defective is found then the same experiment is to be conducted for i such groups in the same lot and the lot should be accepted if all the successive chain of groups have zero defective during testing. Hence in order fulfill the need and lacunae, a novel Intra Lot Group Acceptance Chain Sampling Plans are developed. The efficiency measures Operating Characteristic Function, ASN, ATI, AOQ are developed. Designing through standard quality levels leads to the determination of parameters. The motto of this article is to improve the efficiency of sampling algorithm of the Group Acceptance Sampling with Chain sampling procedure for a single lot.

A review on group acceptance sampling plans
Srinivasa Rao G, *et al.* (2020), have developed Group Acceptance Sampling Plans for Resubmitted Lots under Type II Generalized Half Logistic Distribution.
“Resubmitted sampling plan consists of repeat sampling process, once the consumer is not accepted a production lot based on a single acceptance sampling plan then take the second sample of same size for testing; and build a decision removing the first sample results under the provisions of the statutes or contract”.
Muhammad Aslam and Chi-Hyuck Jun (2009) [15], have contributed to GASP for truncated life tests based on the inverse Rayleigh and Log-Logistic distributions. They have compared the results for the two distributions, the inverse Rayleigh and loglogistic distributions when the

consumer's risk and the other plan parameters are specified. The minimum number of groups required is determined by considering the consumer's risk when the true mean equals the specified life ($\mu = \mu_0$).

Srinivasa Rao G (2009) [32], has studied GASP for generalized exponential distribution. The number of groups g required for in the case of the generalized exponential distribution is determined. Muhammad Aslam, *et al*., (2017) [15], have developed Group SkSP-R sampling plan for accelerated life tests with an assumption of Weibull model. They have determined the parameters using non-linear optimization technique. Aiman Fikri Jamaludin, Zakiyah Zain and Nazrina Aziz (2016) [1], have modified Group Chain Sampling Plans for Lifetimes with a Rayleigh Distribution. Optimal number of groups and operating characteristic values are determined for the known consumer's risk, test termination time and mean ratio. Srinivasa Rao Gadde (2019) [30], have studied Group acceptance sampling plans for resubmitted lots under exponentiated Fréchet distribution.

Muhammad Aslam *et al*. (2010) [17], have developed Group Acceptance Sampling Plan of Lifetime Data for Generalized Pareto Distribution. They have compared GASP with the existing sampling plan and found that the mew sampling plan performs better in terms of minimum sample size to reach the decision.

Muhammad Aslam *et al*. (2012) [19] have developed Two-Stage Improved Group Plans for Burr Type XII Distributions. The authors have constructed tables for Burr type XII distribution and log-logistic distribution. Srinivasa Rao B, CH. Srinivas Kumar and K. Rosaiah (2014) [27], have studied Group Acceptance Sampling Plans for Life Tests Based on Half Normal Distribution. They have observed that the minimum number of groups required decreases as the test termination time multiplier increases. Sudamani Ramaswamy and Sutharani (2013) [35], have designed GASP for a Weibull and Gamma Models by minimizing the angle on the OC curve.

Muhammad Aslam, Muhammad Shoaib and Hina Khan (2011) [16], have developed Improved Group Acceptance Sampling Plan for Dagum Distribution under Percentiles Lifetime. They found that if the subgroup size r = 1, then the sampling plan becomes the ordinary single sampling plan.Subba Rao R, A. Naga Durgamamba and R.R.L. Kantam (2014) [33], have developed Hybrid Group Acceptance Sampling Plan Based on Size Biased Lomax Model. The HGASP is as follows: Select the number of testers, r and assign the r items to each predefined groups, g, the required sample size for a lot is n = rg. Pre-fix the acceptance number, c for each group and the experiment time t_0. Accept the lot if at most c failures occurs in each of all groups. Terminate the experiment if more than c failures occur in any group and reject the lot. Muhammad Aslam & Chi-Hyuck Jun (2009), have developed A group acceptance sampling plan for truncated life test having Weibull distribution. Srinivasa Rao B, M. Ch. Priya, and R. R. L. Kantam (2014) [33], have developed sampling plans for linear failure rate distribution.

Harsh Tripathi, Sanku Dey and Mahendra Saha (2020) [11], have developed Double and group acceptance sampling plan for truncated life test based on inverse log-logistic distribution. Balakrishnan N. *et al*. (2006) [3], have contributed to Sampling plans based on Generalized Birnbaum – Saunders distribution. G. Srinivasa Rao, K. Rosaiah, M. Sridhar Babu (2016) [27], have studied GASP using Exponentiated Frhet Model. Muhammad Aslam, P. Jeyadurga, Saminathan Balamurali, and Ali Hussein AL-Marshadi (2019) [18], have studied Time-Truncated Group Plan under a Weibull Distribution based on Neutrosophic Statistics. Neutrosophic statistics fuzzy statistics, in which set values are considered rather than crisp values. Whenever the data may be imprecise, incomplete, and unknown, and exact computation is not possible then the neutrosophic statistics can be used.

Aiman Fikri Jamaludin, Zakiyah Zain and Nazrina Aziz (2016) [2], have Modified Group Chain Sampling Plans for Lifetimes Following a Rayleigh Distribution. "Accept the lot if no defective items are found in the current under inspection sample provided the preceding i samples also contain no defective items. Also accept the lot if no defective items are found in the current under inspection sample provided any one of i preceding samples contains at most one defective item and the rest (i-1) samples have no defective items. Otherwise, reject the lot". The OC function is as follows:

$$P_a(p) = P_{0,n}\,[P_{0,n}{}^{i} + i\,P_{0,n}{}^{i-1}\,P_{1,n}]$$

Nazrina Aziz *et al*. (2020) [22], have compared Group Chain Sampling Plan and Modified Group Chain Sampling Plan Based on Mean Product Lifetime for Rayleigh Distribution. Muhammad Farouk, Nazrina Aziz, Zakiyah Zain (2019) [21], have studied The Two-sided Group Chain Sampling Plan for Pareto Distribution of the second Kind. Rosaiaha K, G S Raob, S V Prasad (2016) [26], have studied Group Acceptance Sampling Plans Based on Truncated Life Tests for Type-II Generalized Log-Logistic Distribution. Radhakrishnan, R and Alagirisamy, K (2011) [23], have constructed group acceptance sampling plan using weighted binomial distribution. Radhakrishnan R and K. Alagirisamy (2012) [24] have given tables for group acceptance sampling plan indexed through indifference quality level and inverse Rayleigh distribution

Sudamani Ramaswamy AR and Priyah Anburajan (2012) [32], have studied GASP Using Inverse Rayleigh and Log-logistic models. Sudamani Ramaswamy AR and S. Jayasri (2014) [36], have studied Time Truncated Group Sampling Plan using Weighted Binomial for Various Distributions. Muhammad Azam *et al*. (2015), have developed two stage group acceptance sampling plan for half normal percentiles.

Dodge HF (1955) [9] has developed chain sampling inspection plans. Clark CR (1960) [5] has developed OC curves for Chain sampling plans. Frishman and Fred (1960) [10] have developed an extended Chain sampling plan. Dodge H. F and Stephens K. S (1964) [10] have given a general family of Chain sampling inspection plans. Dodge HF and Stephens KS (1964) have developed some new chain sampling inspection plans. Soundrarajan V (1978) has given procedure and tables for construction and selection of chain sampling plans. Govindaraju. K and Subramani. K (1992) have designed chain sampling plans for given AQL and LQL. Govindaraju and Lai (1998) have developed modified chain sampling plans for costly or destructive items. Suresh and Devaarul (2002) have developed mixed sampling plans with Chain sampling attribute plan. Radhakrishnan and Sampathkumar (2006) have constructed chain sampling plans using various parameter for ChSP, It is found that there is a research gap to sentence a lot by applying GAS and Chain Sampling Protocol for a single lot. Hence a novel algorithm is developed and the necessary measures of the new plan are derived.

Algorithm of Ilgchsp to sentence a unique lot

Step 1: Let the size of the batches be large and life experiment is conducted with type I censoring with a specified minimum time t_0.

Step 2: Draw a random sample of size $n_j = g * r$ and put them into life test such that 'g' is the number of groups and r items are allocated to each group. Let it be the first sample, j=1.

Step 3: count the number of non-conformities in the first sample comprising of group of items.

Let it be $d_1 + d_2 + \ldots + d_g = \sum d = D$.

Step 3: If each d_j is zero, (i.e) D=0, accept the batch or lot.

Step 4: If D > 1, reject the lot.

Step 5: If D =1, draw 'i' consecutive samples as in step 2 such that group testing is conducted for the chain of groups in the current lot.

Step 6: Accept the batch provided succeeding 'i' consecutive samples from the same lot have zero defective in the batch. Otherwise reject it. The OC function of Intra Lot Group Acceptance Chain sampling plan is

$P_a(p) = (P_{0.r})^{g} + P_{1,n}(P_{0,r})^{ig}$

Where,
$P_{0,r}$= Probability of getting exactly 0 defective in a sample of r units. Such that n=g*r
$P_{1,r}$= Probability of getting exactly 1 defective in a sample of r units.
i = Chaining index of groups in the same lot.
The OC function of Intra Group Chain sampling plan with type B probabilities is,

$P_a(p) = (e^{-np})^{g} + (npe^{-np})^{g}(e^{-np})^{ig}$

i.e

$P_a(p) = (e^{-rgp})^{g} + (rgpe^{-rgp})^{g}(e^{-rgp})^{ig}$

Table 1: OC Function values for known fraction defectives with i=1,g=1

p	n=100 Pa1(p)	n=50 Pa2(p)	n=200 Pa3(p)
0.0001	0.999703663	0.999925458	0.998829
0.002	0.907817859	0.973597598	0.722588
0.003	0.819860911	0.944454928	0.532211
0.004	0.722587777	0.907817859	0.373133
0.005	0.624843422	0.865706401	0.253225
0.006	0.532211341	0.819860911	0.168146
0.007	0.447832894	0.771749856	0.110045
0.008	0.373133054	0.722587777	0.071351
0.009	0.308401026	0.673358919	0.046002
0.01	0.253225059	0.624843422	0.029572
0.011	0.206801708	0.577643939	0.018993
0.012	0.168145723	0.532211341	0.012203
0.013	0.136225542	0.488868673	0.007853
0.014	0.110045491	0.447832894	0.005064
0.015	0.08869125	0.409234223	0.003275
0.016	0.071350981	0.373133054	0.002123
0.017	0.057321018	0.339534544	0.001381
0.018	0.046002352	0.308401026	0.000901
0.019	0.03689207	0.27966245	0.000589
0.02	0.029572498	0.253225059	0.000386

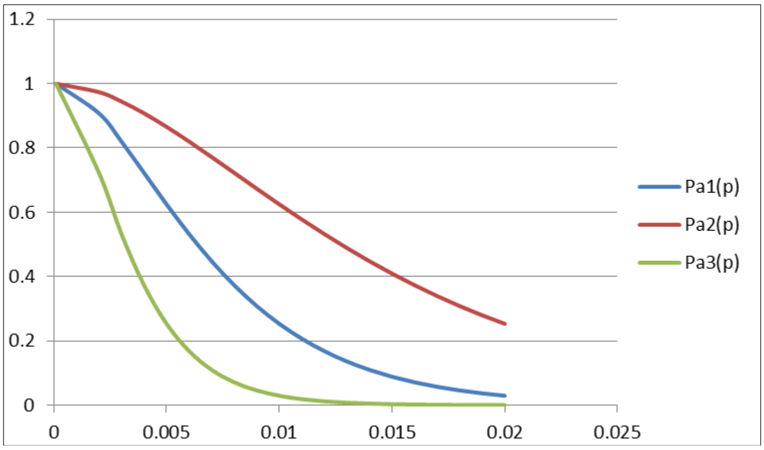

Fig 1: Comparison OF OC Curve

Interpretation

From figure (1), it is found that ILGAChSP well discriminate between good and bad lots. Upto a process average of 0.005, there is good shoulder effect on the OC curve. This gives a confidence to the producer to maintain the quality.

Table 2: Computation of AOQ values

P	$P_a(p)$	AOQ
0.0001	0.998829	0.000079906
0.002	0.722588	0.001156141
0.003	0.532211	0.001277306
0.004	0.373133	0.001194026
0.005	0.253225	0.0010129
0.006	0.168146	0.000807101
0.007	0.110045	0.000616252
0.008	0.071351	0.000456646
0.009	0.046002	0.000331214
0.01	0.029572	0.000236576

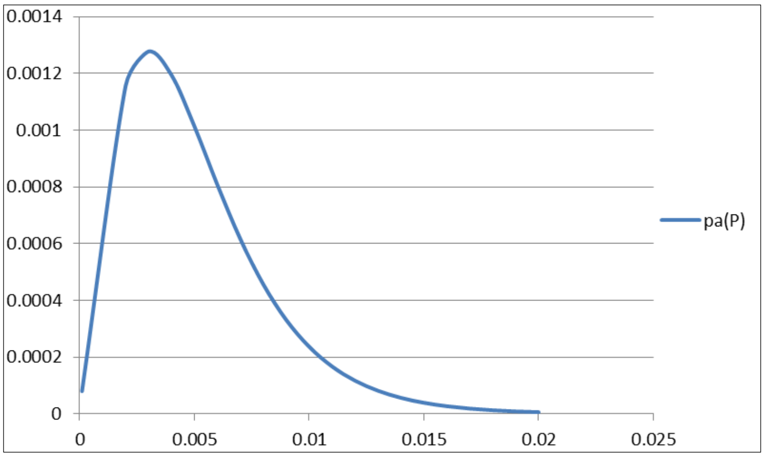

Fig 2: AOQ CURVE

Table 3: Values of np tabulated against i and g for the given values of $P_a(p)$ for IGChSP

i	G	0.99	0.95	0.75	0.50	0.25	0.10	0.05	0.01
1	1	0.0860	0.2066	0.5664	1.0064	1.6606	2.4902	3.1244	4.6487
1	2	0.0600	0.1415	0.3722	0.6369	1.0064	1.4445	1.7622	2.4902
1	3	0.0486	0.1139	0.2940	0.4947	0.7668	1.0800	1.3017	1.7959
1	4	0.0420	0.0978	0.2496	0.4157	0.6369	0.8871	1.0617	1.4445
1	5	0.0374	0.0870	0.2203	0.3642	0.5536	0.7650	0.9113	1.2283
2	1	0.0670	0.1622	0.4559	0.8387	1.4619	2.3246	3.0031	4.6056
2	2	0.0466	0.1106	0.2954	0.5153	0.8387	1.2491	1.5641	2.3246
2	3	0.0378	0.0888	0.2321	0.3960	0.6267	0.9056	1.1121	1.5984
2	4	0.0326	0.0762	0.1965	0.3309	0.5153	0.7321	0.7321	0.8889
2	5	0.0291	0.0677	0.1730	0.2889	0.2889	0.6252	0.7535	1.1498
3	1	0.0569	0.1389	0.4014	0.7671	1.4068	2.3049	2.9961	4.6052
3	2	0.0395	0.0943	0.2561	0.4564	0.7671	1.1846	1.5139	2.3049
3	3	0.0320	0.0756	0.2000	0.3466	0.5612	0.8337	1.0432	1.5498
3	4	0.0276	0.0648	0.1688	0.2878	0.4564	0.6625	0.8170	1.1846
3	5	0.0246	0.0575	0.1483	0.2503	0.3914	0.5598	0.6834	0.9723
4	1	0.0505	0.1241	0.3687	0.7316	1.3916	2.3028	2.9958	4.6052
4	2	0.0350	0.0839	0.2316	0.4217	0.7316	1.1624	1.5016	2.3028
4	3	0.0283	0.0672	0.1799	0.3165	0.5245	0.7996	1.0159	1.5383
4	4	0.0244	0.0575	0.1513	0.2612	0.4217	0.6256	0.7826	1.1624
4	5	0.0218	0.0510	0.1327	0.2262	0.3592	0.5231	0.6467	0.9425

Table 4: Values of p_2/p_1 tabulated against i and g values of α and β and values for IGChSP

i	g	p_2/p_1 for			np_1 for α=0.05	p_2/p_1 for			np_1 for α =0.10
		α=0.05 β =0.10	α=0.05 β =0.05	α=0.05 β =0.01		α=0.01 β = 0.10	α=0.01 β= 0.05	α=0.01 β = 0.01	
10	1	26.4365	34.3947	52.8730	0.0871	67.8620	88.2906	135.7241	0.0339
9	1	25.4155	33.0664	50.8311	0.0906	64.8103	84.3202	129.6207	0.0355
8	1	24.3057	31.6225	48.6115	0.0947	61.5610	80.0927	123.1220	0.0374
7	1	23.0910	30.0420	46.1819	0.0997	58.0781	75.5613	116.1562	0.0396
6	1	21.7496	28.2968	43.4991	0.1059	54.3131	70.6629	108.6262	0.0424
5	1	20.2513	26.3472	40.5021	0.1137	50.1985	65.3091	100.3959	0.0459
10	2	20.0273	26.0559	40.0542	0.0575	49.3383	64.1900	98.6757	0.0233
9	2	19.1827	24.9565	38.3642	0.0600	47.0604	61.2251	94.1178	0.0245
4	1	18.5524	24.1349	37.1010	0.1241	45.6365	59.3689	91.2639	0.0505
8	2	18.2767	23.7762	36.5497	0.0630	44.6450	58.0790	89.2810	0.0258

7	2	17.2994	22.5006	34.5880	0.0666	42.0705	54.7193	84.1145	0.0274
10	3	16.8452	21.9069	33.6748	0.0456	40.7936	53.0516	81.5495	0.0188
3	1	16.5926	21.5688	33.1523	0.1389	40.4942	52.6384	80.9081	0.0569
6	2	16.2405	21.1110	32.4487	0.0710	39.3140	51.1042	78.5499	0.0293
9	3	16.1192	20.9533	32.2064	0.0477	38.9090	50.5778	77.7408	0.0197
8	3	15.3509	19.9363	30.6368	0.0501	36.9307	47.9620	73.7047	0.0208
5	2	15.0913	19.5843	30.0894	0.0765	36.3582	47.1827	72.4916	0.0318

Table 5: Parametric values for IGChSP indexed through AOQL

i	g	np_m	nAOQL	$np_{0.50}$	h_0	AOQL/p_1 for 0.05	np_1 for 0.05
6	1	0.9870	0.1049	1.0064	0.7364	0.9911	0.1059
1	5	0.3284	0.1837	0.6369	1.1790	2.1132	0.0870
1	4	0.3780	0.2094	0.4947	1.1596	2.1413	0.0978
2	5	0.2636	0.1454	0.4157	1.1498	2.1473	0.0677
2	4	0.3054	0.1663	0.3642	1.1264	2.1821	0.0762
1	3	0.4554	0.2487	0.8387	3.3043	2.1835	0.1139
3	5	0.2316	0.1257	0.5153	1.1198	2.1848	0.0575
4	5	0.2125	0.1134	0.3960	1.0911	2.2233	0.0510
3	4	0.2703	0.1443	0.3309	1.0923	2.2273	0.0648
2	3	0.3718	0.1986	0.2889	1.0932	2.2354	0.0888
1	2	0.5992	0.3193	0.7671	1.0908	2.2568	0.1415
5	5	0.2000	0.1049	0.4564	1.0641	2.2625	0.0464
4	4	0.2500	0.1308	0.3466	1.0598	2.2745	0.0575
3	3	0.3333	0.1735	0.2878	1.0530	2.2941	0.0756
6	5	0.1915	0.0987	0.2503	1.0387	2.3024	0.0429
5	4	0.2374	0.1215	0.7316	1.0294	2.3231	0.0523
2	2	0.5000	0.2578	0.4217	1.0402	2.3318	0.1106
7	5	0.1856	0.0939	0.3165	1.0148	2.3429	0.0401

Table 6: Values of np_* and h_* values for IGChSP @ 1-α = 0.95

i	g	np_*	h_*
10	1	0.2624	2.0000
9	1	0.2868	2.0000
8	1	0.3161	2.0000
7	1	0.3520	1.9998
6	1	0.3970	1.9991
5	1	0.4550	1.9955
4	1	0.5326	1.9779
3	1	0.6426	1.9021
1	1	1.1178	1.8552
2	1	0.8121	1.7420
1	2	0.7788	1.0939
10	2	0.2270	0.9977
9	2	0.2450	0.9950
8	2	0.2661	0.9890
7	2	0.2915	0.9762
6	2	0.3224	0.9507
2	2	0.5872	0.9177
5	2	0.3611	0.9079
4	2	0.4117	0.8653

Table 7: Relative slope for acceptable and limiting quality levels for IGChSP

i	g	$np_{0.50}$	h_0	$np_{0.95}$	h_1	$np_{0.10}$	h_2	h_2/h_1	h_2/h_0	h_0/h_1
1	1	1.0064	1.0081	0.2066	0.0925	2.4902	2.7452	29.6812	2.7231	10.8998
1	2	0.6369	1.0908	0.1415	0.0952	1.4445	3.1149	32.7306	2.8555	11.4622
1	3	0.4947	3.3043	0.1139	0.0964	1.0800	3.3043	34.2693	1.0000	34.2693
1	4	0.4157	1.1596	0.0978	0.0972	0.8871	3.4273	35.2640	2.9555	11.9316
1	5	0.3642	1.1790	0.0870	0.0977	0.7650	3.5168	35.9869	2.9829	12.0645
2	1	0.8387	0.9305	0.1622	0.0913	2.3246	2.4040	26.3447	2.5835	10.1972
2	2	0.5153	1.0402	0.1106	0.0943	1.2491	2.7773	29.4468	2.6698	11.0295
2	3	0.3960	1.0932	0.0888	0.0957	0.9056	3.0305	31.6560	2.7721	11.4193
2	4	0.3309	1.1264	0.0762	0.0966	0.7321	3.1971	33.0967	2.8384	11.6603
2	5	0.2889	1.1498	0.0677	0.0972	0.6252	3.3163	34.1194	2.8843	11.8294
3	1	0.7671	0.8600	0.1389	0.0900	2.3049	2.3184	25.7654	2.6959	9.5573
3	2	0.4564	0.9896	0.0943	0.0934	1.1846	2.5367	27.1482	2.5635	10.5903
3	3	0.3466	1.0530	0.0756	0.0950	0.8337	2.7891	29.3508	2.6488	11.0808
3	4	0.2878	1.0923	0.0648	0.0960	0.6625	2.9789	31.0337	2.7273	11.3791
3	5	0.2503	1.1198	0.0575	0.0967	0.5598	3.1202	32.2812	2.7864	11.5854

4	1	0.7316	0.8043	0.1241	0.0888	2.3028	2.3047	25.9662	2.8655	9.0615
4	2	0.4217	0.9429	0.0839	0.0926	1.1624	2.4050	25.9720	2.5505	10.1831
4	3	0.3165	1.0150	0.0672	0.0943	0.7996	2.6074	27.6360	2.5689	10.7578
4	4	0.2612	1.0598	0.0575	0.0954	0.6256	2.7953	29.2982	2.6375	11.1082
4	5	0.2262	1.0911	0.0510	0.0961	0.5231	2.9465	30.6486	2.7004	11.3496
5	1	0.7131	0.7638	0.1137	0.0876	2.3026	2.3029	26.2893	3.0149	8.7199

Illustration

A company turns out 0.1% defective in a process comprising of lot of products. An agreement between the producer and the consumer is 95% the lot will be accepted if the process average is maintained. Determine the parameters of ILGAChSP if i=g=2.

Solution

It is given that AQL = 0.1%. Hence, p=0.001

@ AQL the Probability of acceptance of the lot is 0.95. Therefore from table (1), it is found that the constant np = 0.1106. Since p=0.001, the minimum sample size n = 110. Also one can find the number of units in each group such that rg = n. This implies that r= 55.

Hence the parameters of the ILGChSP are n = 110, r = 55, i=g=2.

Summary

In this article a novel Intra Lot Group Acceptance Chain Sampling plans are developed. The efficiency measures of ILGAChSP are derived and provided. It is found that the probability of acceptance of the batch or lot decreases rapidly if the quality deteriorates and has a good shoulder effect is found if the process average is maintained within the norms. The outgoing quality of the batch after the inspection is small when compared to the incoming quality of the lot. This is an added advantage for the consumers. It is found that the operating ratio decreases while increasing the chaining index i. This shows that the ratio LQL / AQL plays a vital role in the selection of the sampling plans. Tables are constructed to facilitate quality control practitioners to implement the ILGAChSP plans. Also one can select the sampling plans using the slope and relative index h_*.

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