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Selection Procedures for SKSP-2 Skip-Lot Plans through Relative Slopes

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Abstract

In skip-lot sampling plans, provision is made for skipping inspection of some of the lots when the quality of the submitted product is good. This paper presents selection of skip-lot plans of type SkSP-2 which use chain sampling plan (ChSP-1) as reference plan through relative slopes at various points on the OC curve, which describe the degree of steepness of the OC Curve.

Keywords:-Skip-lot Sampling Plan, Chain Sampling Plan, Acceptable Quality Level, Limiting Quality Level, Indifference Quality Level, Maximum Allowable Percent Defective Relative Slope.

Mathematical Subject Classification: 62P30/62D05

Introduction

Under skip-lot sampling inspection, samples may be drawn from only a fraction of the submitted lots. Here skipping of lots of good quality protection to the producer is ensured and economy of sample size is achieved. The main purpose of skip-lot sampling is to decrease the frequency of sampling inspection and thus reducing the total inspection costs.

A system of skip-lot sampling plans for lot-inspection was initially introduced by Dodge (1955b) and later was investigated extensively by Perry (1970). Dodge and Perry (1971) formalize the application of skip-lot sampling to the situation in which each lot to be inspected is sampled according to some lot inspection plan.

Perry (1970) has described a skip-lot plan of type SkSP-2 as one that uses a given lot-inspection plan by the method of attributes (single sampling, double sampling, sequential sampling, chain sampling, etc) called the “reference sampling plan”. Perry (1970, 1973) observed that, from an overall point of view, skip lotting appears to be a good and useful acceptance sampling procedure and might well qualify as a standard system of reduced inspection.

For situations involving costly or destructive testing and the lots are submitted in a continuous succession, it is advantageous to use SkSP-2 plan with ChSP-1 plan as reference plan, since both the plans (SkSP-2 and ChSP-1) ensure a relatively small sample size.

Operating Procedure for Skip-Lot Sampling Plan

The operating Procedure for SkSP-2 plan is listed below

- Start with normal inspection (inspecting every lot), using the reference plan.
- When i consecutive lots are accepted on normal inspection, switch to skipping inspection (inspect a fraction f of the lots)
- When a lot is rejected on skipping inspection, switch to normal inspection

Thus the values of f and i, called the skipping parameters, together with reference plan completely characterize a Type SkSP-2 plan. In general $0 < f < 1$, and i is a positive integer. When $f = 1$, the plan degenerates into the original reference plan.

Operating Procedure of Chain Sampling Plan

Chain Sampling Plan (ChSP-1), which was introduced by Dodge (1955a), is used as reference plan in this article. Chain Sampling Plans allow significant reductions in sample size under conditions of a continuing succession of lots from a stable and trusted supplier as stated by Dodge (1955a).

The reference plan ChSP-1 is operated as follows

- For each lot, select a sample of n units and test each unit for conformance to the specified requirements.
- Accept the lot, if d (the observed number of defectives) is 0, if $d > 1$, reject the lot
- Accept the lot, if d – 1 and if no defective units are found in the immediately preceding i_c samples of size n.

Thus a ChSP-1 plan has two parameters, namely, n, the sample size for each submitted lot and i_c the number of previous samples on which the decision of acceptance or rejection is based, Hence a SkSP-2 plan using ChSP-1 as reference plan has four parameters, namely, n,i_c, f and i.

Incoming Qualities and Relative Slopes

In this paper, four incoming quality levels, namely, Acceptable Quality Level (AQL), Limiting Quality Level (LQL), Indifference Quality Level (IQL) and Maximum Allowable Proportion Defective (MAPD) are considered along with their corresponding relative slopes on the OC curve for selection of SkSP-2 plans. AQL denoted by p_1, is the maximum percentage or proportion of variant units in a lot or batch that, for the purposes of acceptance sampling, can be considered as a satisfactory process average. In this paper, AQL is considered as the fraction defective with a 0.95 probability of acceptance of lots. LQL, denoted by p_2, is the percentage of proportion of variant units in a batch or lot that, for the purposes of acceptance to be restricted to a specified low value, usually 0.10. IQL, denoted by p_0, is the percentage of variant units in a lot or batch that, for the purposes of acceptance sampling, the probability of acceptance to be restricted to a specific value, namely 0.50. The point (p_0, 0.5) on the OC curve is referred to as point of control. The proportion nonconforming corresponding to the point of inflection (p^*, $P_a(p^*)$) of the OC curve is interpreted as MAPD (p^*). Fixing the AQL gives adequate protection to the producer and the interests of the consumer are protected by fixing LQL. Fixing IQL gives required protection not only to the consumer but also to the producer. MAPD is considered as standard incoming quality level for both producer and consumer.

The chief features of an OC curve are its location and the relative slope (denoted by h) at that location, which describes the degree of steepness of the OC curve. Hamaker (1950) has made elaborate studies on the slope h_0, which, along with p_0, may be used to design any sampling plan. In a similar manner, various other sets of parameters, such as (p_1,h_1), (p_2,h_2) and (p_*,h_*) can also be considered for selection of plans. Vedaldi (1986) has studied two principal effects of sampling inspection, which are filter and incentive effects, and has proposed a new criterion based on the AQL and LQL points on the OC curve. Suresh (1993) has presented and constructed tables for the selection of SkSP-2 with Single Sampling Plan as reference plan indexed through (p_1,h_1) and (p_2,h_2) involving incentive and filter effects. Vijayaraghavan (1990) has constructed tables and has provided selection procedures for SkSP-2 plans with single sampling plan as reference plan.

Selection procedures of SkSP-2 with ChSP-1 as reference plan will now be indicated under the conditions for application of Poisson model for OC curve. A table (Table 1) has been constructed for various parametric values indexed i_c, f, i, which can be used for selection of such plans.

Designing Plans for Given (p_1,h_1)

Column 4 and 8 of Table 1 is used to design plans for a given p_1 and h_1. For example, for given $p_1 = 0.01$ and $h_1 = 0.12$, from Table 1 under column headed h_1, locate the value equal to or just greater than specified h_1, which is 0.12054. Corresponding to this h_1, the i_c, f, i, and np_1 values associated are 3,1/3, 10 and 0.19706 respectively. From this one can obtain the sample size $n=np_1 / p_1 = 0.19706 / 0.01 = 19.106 = 20$. Thus the selected parameters for SkSP-2 plan are n=20, i_c=3, f=1/3 and i=10.

Designing Plans for Given (p_2,h_2)

Column 5 and 9 of Table 1 is used to design plans for a given p_2 and h_2. For example, for given $p_2 = 0.2$ and $h_2= 2.3$, from Table 1 under column headed h_2, locate the value equal to or just greater than specified h_2, which is 2.32196. Corresponding to this h_2, the i_c, f, i, and np_2 values associated are 3,2/3, 4 and 2.30522 respectively. From this one can obtain the sample size $n=np_2 / p_2 = 2.30522 / 0.2 = 11.5261 = 12$. Thus the selected parameters for SkSP-2 plan are n=12, i_c=3, f=2/3 and i=4.

Designing Plans for Given (p_0,h_0)

Column 6 and 10 of Table 1 is used to design plans for a given p_0 and h_0. For example, for given p_0 = 0.07 and h_0 = 0.8, from Table 1 under column headed h_0, locate the value equal to or just greater than specified h_0, which is 0.80396. Corresponding to this h_0, the i_c, f, i, and np_0 values associated are 5,1/3, 8 and 0.72003 respectively. From this one can obtain the sample size $n=np_0 / p_0$ = 0.72003 / 0.07 = 10.286 = 10. Thus the selected parameters for SkSP-2 plan are n=10, i_c=5, f=1/3 and i=8.

Designing Plans for Given (p_*,h_*)

Column 7 and 11 of Table 1 is used to design plans for a given p_* and h_*. For example, for given p_* = 0.025 and h_* = 0.25, from Table 1 under column headed h_*, locate the value equal to or just greater than specified h_*, which is 0.25008. Corresponding to this h_*, the i_c, f, i, and np_1 values associated are 5,2/3, 12 and 0.22832 respectively. From this one can obtain the sample size $n=np_* / p_*$ = 0.22832 / 0.025 = 9.13 = 9. Thus the selected parameters for SkSP-2 plan are n=9, i_c=5, f=2/3 and i=12.

Designing Plans through the Ratio of Relative Slopes

Columns 4 (or 5) and 12 of Table 1 is used to design plans for specified AQL (or LQL) with the ratio of relative slopes h_2/h_1. For example, for given p_1 = 0.01, h_1 = 0.15, and h_2 = 3.0, one can obtain the ration of h_2/h_1 = 20. By using Table 1, under column headed h_2/h_1, one can locate the value equal to or just greater than the desired ratio, which is 20.16793. Corresponding to this located value, one can find i_c, f, i, and np_1 values as 4, 1/3, 8 and 0.18434 respectively. From this one can obtain the sample size $n=np_1/p_1$=0.18434 / 0.01 = 18. Thus the selected parameters for plan are n=18, i_c=4, f=1/3 and i=8.

Conversion of Parameters

One may be interested in converting the given set of parameters into other familiar sets which provide information in the related parameters. For example when p_1 = 0.01, h_1=0.11 are specified, the other equivalent set of parameters are found using Table 1.

Corresponding to h_1 = 0.11, one finds tabulated h_1=0.11003. The np1 value associated to this h_1 is 0.17078. Now n= np_1/p_1 = 0.17078 / 0.01 = 17. The other associated values are np_2 = 2.30478, np_0 = 0.76737, np_*=0.27591, h_2 = 2.31850, h_0=0.86229, h_*=0.27852. Therefore $p_2=np_2/n$ = 2.30478 /17 = 0.13557, p_0=0.76737 / 17 = 0.04514, p_*=0.27591 / 17 = 0.01623. Thus, when p_1=0.01 and h_1=17, the other sets of parameters are

a) (p_1,p_2) = (0.01, 0.13557)
b) (p_1,p_0) = (0.01, 0.04514)
c) (p_1,p_*) = (0.01, 0.01623)
d) (p_2,h_2) = (0.13557, 2.31850)
e) (p_0,h_0) = (0.04514, 0.86226)
f) (p_*,h_*) = (0.01623, 0.27852)

Table 1: Certain Parametric Values for SkSP-2 plans with ChSP-1 Plan as Reference Plan

i_c	f	i	np_1	np_2	np_0	np_*	h_1	h_2	h_0	h_*	h_1/h_2
	1	*	0.16217	2.32449	0.83874	0.41292	0.09126	2.40415	0.93052	0.38625	26.34326
		4	0.19547	2.32493	0.86422	0.47893	0.09573	2.40766	1.01330	0.46711	25.14936
		6	0.19164	2.32450	0.84550	0.43128	0.09834	2.40420	0.96649	0.42281	24.44774
	2/3	8	0.18839	2.32449	0.84048	0.39799	0.10031	2.40415	0.94335	0.38468	23.96720
		10	0.18561	2.32449	0.83918	0.37423	0.10180	2.40415	0.93466	0.35500	23.61605
		12	0.18320	2.32449	0.83885	0.35708	0.10291	2.40415	0.93178	0.33243	23.36218
		4	0.22204	2.32536	0.88558	0.49253	0.09974	2.41118	1.08184	0.47247	24.17423
		6	0.21439	2.32450	0.85174	0.42724	0.10429	2.40426	0.99963	0.41665	23.05466
	1/2	8	0.20820	2.32449	0.84217	0.38349	0.10764	2.40415	0.95581	0.36953	22.33423
		10	0.20307	2.32449	0.83962	0.35201	0.11014	2.40415	0.93877	0.33234	21.82734
		12	0.19872	2.32449	0.83896	0.32814	0.11197	2.40415	0.93305	0.30283	21.47137
		4	0.26356	2.32623	0.92039	0.49808	0.10662	2.41815	1.19183	0.44027	22.67990
2		6	0.24883	2.32451	0.86300	0.41910	0.11394	2.40437	1.05906	0.38432	21.10187
	1/3	8	0.23762	2.32449	0.84540	0.36829	0.11920	2.40415	0.97971	0.33670	20.16929
		10	0.22869	2.32449	0.84047	0.33232	0.12303	2.40415	0.94687	0.29887	19.54159
		12	0.22135	2.32449	0.83918	0.35019	0.12581	2.40415	0.93556	0.26872	19.10977
		4	0.29580	2.32708	0.94839	0.49864	0.11239	2.42510	1.27879	0.39933	21.57838
		6	0.27481	2.32452	0.87296	0.41419	0.12167	2.40448	1.11133	0.34917	19.76250
	1/4	8	0.25944	2.32450	0.84848	0.36092	0.12820	2.40414	1.00236	0.30563	18.75257
		10	0.24752	2.32449	0.84131	0.32364	0.13293	2.40415	0.95482	0.27081	18.08584
		12	0.23789	2.32449	0.83940	0.29574	0.13634	2.40415	0.93806	0.24294	17.63399
		4	0.32232	2.32793	0.97194	0.49842	0.11736	2.43200	1.35093	0.36167	20.72323
		6	0.29575	2.32453	0.88191	0.41109	0.12812	2.40459	1.15806	0.31736	18.76830
	1/5	8	0.27685	2.32450	0.85141	0.35664	0.13562	2.40414	1.02390	0.27815	17.72743
		10	0.26244	2.32449	0.84214	0.31879	0.14099	2.40415	0.96263	0.24656	17.05223
		12	0.25096	2.32449	0.83961	0.29061	0.14487	2.40415	0.94055	0.22118	16.59538
	1	*	0.13892	2.30478	0.76716	0.33120	0.08999	2.31850	0.85997	0.33050	25.76739
		4	0.16794	2.30522	0.79242	0.39650	0.09411	2.32196	0.93490	0.40571	24.67370
		6	0.16459	2.30478	0.77385	0.35873	0.09670	2.31857	0.89281	0.37467	23.97691
3	2/3	8	0.16176	2.30478	0.76887	0.33110	0.09868	2.31851	0.87173	0.34431	23.49614
		10	0.15933	2.30478	0.76759	0.31077	0.10017	2.31850	0.86378	0.31921	23.14677
		12	0.15722	2.30478	0.76727	0.29556	0.10127	2.31850	0.86113	0.29917	23.89478
	1/2	4	0.19121	2.30567	0.81369	0.41282	0.09778	2.32538	0.99682	0.41247	23.78087

		6	0.18450	2.30479	0.78004	0.35945	0.10232	2.31861	0.92304	0.37264	22.66067
		8	0.17908	2.30478	0.77054	0.32285	0.10569	2.31851	0.88314	0.33505	21.93789
		10	0.17458	2.30478	0.76802	0.29623	0.10818	2.31850	0.86754	0.30392	21.43127
		12	0.17078	2.30478	0.76737	0.27591	0.11003	2.31850	0.86229	0.27852	21.07148
	1/3	4	0.22783	2.30656	0.84849	0.42157	0.10411	2.33221	1.09601	0.38473	22.40223
		6	0.21481	2.30480	0.79121	0.35567	0.11142	2.31872	0.97720	0.34522	20.81063
		8	0.20492	2.30478	0.77375	0.31271	0.11669	2.31851	0.90502	0.30737	19.86971
		10	0.19706	2.30478	0.76887	0.28215	0.12054	2.31850	0.87498	0.27579	19.23440
		12	0.19061	2.30478	0.76759	0.25907	0.12335	2.31850	0.86461	0.24990	18.79569
	1/4	4	0.25646	2.30744	0.87662	0.42377	0.10938	2.33900	1.17431	0.34844	21.38472
		6	0.23780	2.30480	0.80112	0.35271	0.11866	2.31885	1.02478	0.31364	19.54115
		8	0.22419	2.30478	0.77680	0.30743	0.12524	2.31851	0.92576	0.27928	18.51260
		10	0.21365	2.30478	0.76970	0.27563	0.13000	2.31850	0.88228	0.25031	17.83459
		12	0.20516	2.30478	0.76780	0.25180	0.13346	2.31850	0.86690	0.22640	17.37211
	1/5	4	0.28014	2.30831	0.90036	0.42454	0.11390	2.34576	1.23922	0.31506	20.59501
		6	0.25642	2.30481	0.81003	0.35071	0.12470	2.31896	1.06728	0.28484	18.59679
		8	0.23961	2.30478	0.77970	0.30428	0.13224	2.31851	0.94547	0.25411	17.53253
		10	0.22684	2.30478	0.77052	0.27192	0.13768	2.31850	0.88944	0.22794	16.83980
		12	0.21669	2.30478	0.76802	0.24779	0.14163	2.31850	0.86919	0.20621	16.36987
i_c	f	i	np_1	np_2	np_0	np_*	h_1	h_2	h_0	h_*	h_1/h_2
4	1	*	0.12413	2.30272	0.73162	0.27827	0.08876	2.30483	0.80428	0.28774	25.96604
	2/3	4	0.15050	2.30371	0.75742	0.34229	0.09254	2.30427	0.87410	0.35618	24.94434
		6	0.14745	2.30272	0.73844	0.31141	0.09512	2.30489	0.83491	0.33499	24.23054
		8	0.14487	2.30272	0.73337	0.28775	0.09709	2.30483	0.81526	0.31091	23.73841
		10	0.14266	2.30272	0.73206	0.26988	0.09859	2.30483	0.80784	0.28979	23.37898
		12	0.14074	2.30272	0.73173	0.25618	0.09969	2.30483	0.80537	0.27223	23.11949
	1/2	4	0.17176	2.30262	0.77918	0.36064	0.09591	2.31169	0.93188	0.36350	24.10299
		6	0.16562	2.30273	0.74476	0.31539	0.10043	2.30494	0.86311	0.33555	22.95025
		8	0.16066	2.30272	0.73507	0.28358	0.10379	2.30483	0.82591	0.30555	22.20666
		10	0.15656	2.30272	0.73250	0.26020	0.10631	2.30483	0.81136	0.27945	21.68085
		12	0.15309	2.30272	0.73184	0.24223	0.10816	2.30483	0.80645	0.25753	21.30898
	1/3	4	0.20543	2.30451	0.81488	0.37182	0.10170	2.31851	1.02470	0.33915	22.79853
		6	0.19343	2.30274	0.75618	0.31462	0.10900	2.30505	0.91365	0.31172	21.14720
		8	0.18434	2.30272	0.73834	0.27683	0.11428	2.30483	0.84633	0.28168	20.16793
		10	0.17712	2.30272	0.73336	0.24982	0.11815	2.30483	0.81861	0.25532	19.50765
		12	0.17712	2.30272	0.73206	0.22935	0.12099	2.30483	0.80861	0.23302	19.04905

		4	0.23194	2.30539	0.84380	0.37527	0.10650	2.32530	1.09825	0.30667	21.83331
		6	0.21464	2.30275	0.76630	0.31304	0.11578	2.30516	0.95807	0.28308	19.90910
	1/4	8	0.20207	2.30272	0.74145	0.27298	0.12239	2.30483	0.86569	0.25604	18.83231
		10	0.19236	2.30272	0.73421	0.24475	0.12719	2.30483	0.82511	0.23197	18.12122
		12	0.18455	2.30272	0.73228	0.22355	0.13069	2.30483	0.81076	0.21146	17.63569
		4	0.25399	2.30627	0.86826	0.37678	0.11061	2.33203	1.15944	0.27683	21.08362
		6	0.23190	2.30276	0.77543	0.31181	0.12142	2.30527	0.99776	0.25682	18.98652
	1/5	8	0.21632	2.30272	0.74442	0.27061	0.12901	2.30484	0.88409	0.23286	17.86532
		10	0.20452	2.30272	0.73505	0.24180	0.13451	2.30483	0.83180	0.21120	17.13461
		12	0.19516	2.30272	0.73250	0.22029	0.13853	2.30483	0.81289	0.19262	16.63826
	1	*	0.11371	2.30251	0.71313	0.24077	0.08761	2.30298	0.76383	0.25450	26.28806
		4	0.13825	2.30296	0.73962	0.30303	0.09104	2.30642	0.83094	0.31623	25.33307
		6	0.13540	2.30252	0.72013	0.27738	0.09362	2.30303	0.79311	0.30233	24.60036
	2/3	8	0.13300	2.30251	0.71493	0.25674	0.09559	2.30298	0.77430	0.28321	24.09172
		10	0.13094	2.30251	0.71358	0.24078	0.09709	2.30298	0.76722	0.26541	23.72081
		12	0.12916	2.30251	0.71324	0.22832	0.09821	2.30298	0.76487	0.25008	23.44943
		4	0.15815	2.30341	0.76198	0.32293	0.09413	2.30984	0.88671	0.32372	24.53864
		6	0.15239	2.30252	0.72662	0.28373	0.09864	2.30309	0.82009	0.30450	23.34930
	1/2	8	0.14775	2.30251	0.71667	0.25546	0.10200	2.30298	0.78447	0.28045	22.57859
		10	0.14391	2.30251	0.71403	0.23446	0.10451	2.30298	0.77057	0.25846	22.03493
		12	0.14067	2.30251	0.71335	0.21822	0.10639	2.30298	0.76590	0.23947	21.64741
		4	0.18986	2.30430	0.79868	0.33607	0.09942	2.31666	0.97676	0.30210	23.30246
		6	0.17853	2.30253	0.73834	0.28522	0.10671	2.30320	0.86850	0.28838	21.58426
5	1/3	8	0.16997	2.30251	0.72003	0.25118	0.11200	2.30298	0.80396	0.25945	20.56249
		10	0.16319	2.30251	0.71492	0.22672	0.11590	2.30298	0.77719	0.23732	19.87049
		12	0.15764	2.30251	0.71358	0.20815	0.11877	2.30298	0.76796	0.21809	19.39052
		4	0.21500	2.30519	0.82842	0.34054	0.10379	2.32344	1.04855	0.27280	22.38500
		6	0.19858	2.30254	0.74875	0.28468	0.11307	2.30331	0.91111	0.25716	20.37023
	1/4	8	0.18668	2.30251	0.72323	0.24839	0.11969	2.30298	0.82244	0.23585	19.24201
		10	0.17752	2.30251	0.71579	0.22272	0.12453	2.30298	0.78369	0.21576	18.48380
		12	0.17017	2.30251	0.71381	0.20341	0.12808	2.30298	0.77000	0.19811	17.98055
		4	0.23603	2.30607	0.85357	0.34264	0.10752	2.33017	1.10858	0.24587	21.67103
		6	0.21496	2.30255	0.75813	0.28404	0.11833	2.30341	0.94924	0.23305	19.46653
	1/5	8	0.20017	2.30251	0.72627	0.24659	0.12596	2.30298	0.84001	0.21434	18.28309
		10	0.18900	2.30251	0.71665	0.22033	0.13151	2.30298	0.79007	0.19637	17.51135
		12	0.18016	2.30251	0.71403	0.20070	0.13558	2.30298	0.77204	0.18045	16.98599

Construction of Tables

The expression for Pa(p) of SkSP-2 plan with parameters f and i has been derived by Perry (1973) as

$$P_a(p) = (f P + (1-f) P^i) / (f + (1 - f) P^i) \quad (1)$$

Here $P = e^{-np} + (np)\, e^{-np(ic+1)}$, which is the OC function for ChSP-1 reference plan having parameters n and i_c, as derived by Dodge (1955a), under the conditions for application of Poisson model for OC curve.

For given values of i_c, f, i and $P_a(p)$, equation (1) can be solved for np by the method of iterations. The entries of the columns np_1, np_2 and np_0 are such np values with $P_a(p) = 0.95$, 0.10 and 0.50 respectively.

The values of np_* are such values of np, which are obtained by equating the second derivative of $P_a(p)$ to 0 for given values of i_c, f ,i and $P_a(p)$. The entries of the columns h_1,h_2,h_0, and h_* are calculated through the expression.

$h = - (p / P_a(p)) (d P_a(p) /dp)$, for $p = p_1,p_2,p_0$ and p_*

The entries of column 12 are the values of the ratio of h_2 and h_1.

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