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Construction and selection of conditional double sampling plan indexed through AOQ_{cc}

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Abstract
In this paper a procedure for constructing a Conditional Double Sampling Plan indexed through a parameter which is a convex combination of AOQL (Average Outgoing Quality Limit) and MAAOQ (Maximum Allowable Average Outgoing Quality) with gain parameter λ is given. This plan may safeguard the interests of both producer as well as consumer by properly choosing a right combination using the gain parameter λ. Tables are also constructed for the easy selection of the plan.

Keywords: Operating characteristic curve, average outgoing quality limit, maximum allowable percent defective, maximum allowable average outgoing quality, poisson distribution, convex combination

1. Introduction

Conditional sampling plans are called special purpose plans. Baker and Brobst (1978) [1] proposed conditional sampling procedures which are similar to double sampling and these conditional double sampling procedures have Operating Characteristics curves identical to those of comparable double sampling procedures. Conditional double sampling is operationally different form double sampling in that the results of the second sample, if required, are obtained from related lot and not from the current lot. According to Baker and Brobst using sample information from related lots results in more attractive OC curves with smaller sample sizes. This reduction in sample size is the principal advantage of these procedures

In this paper a procedure is given to construct Conditional Double Sampling Plan (CDSP) indexed through AOQ_{cc} which safeguards the interest of both producer and consumer by properly choosing the right combination of gain parameter λ ($0<\lambda<1$). Necessary tables for the selection of the sampling plans are provided.

2. Definitions

2.1 Definition of AOQL

The AOQL is defined as the worst average that the consumer will receive in the end, when defective items are replaced by non-defective items. It is obtained by maximizing Average Outgoing Quality (AOQ), AOQ= $p.P_a(p)$.

2.2 Definition of MAPD

The MAPD is the value of fraction defective ($p=p^*$) at which

$$d^2P_a(p)/dp^2= 0 \text{ and } d^3P_a(p)/dp^3 \neq 0$$

It is also the inflection point of the operating characteristic (OC) curve and Pa(p) is the probability of acceptance at the quality level p fraction defective

2.3 Definition of MAAOQ

The MAAOQ is defined as average outgoing quality at MAPD, we have MAAOQ = AOQ at $p= p^*$

3. Review of Literature

The desirability of developing a set of sampling plans indexed through p*(MAPD) has been explained by Mandelson (1962) [2] and Soundararajan (1975) [7]. Vijayaraghavan (1990) [9] has provided procedures and tables for the selection of conditional double sampling plans for various entry parameters. Suresh and Ramkumar (1996) [8] suggested a procedure for constructing the sampling plans indexed through Maximum Allowable Average Outgoing Quality (MAAOQ).Taking into the criticisms leveled on AOQL by several authors and the importance of MAPD as a quality measure, Radhakrishnan (2002) [3] constructed continuous sampling plan, chain sampling, double and link sampling plan indexed through MAAOQ and established that the size of the sample is less in the sampling inspection when MAAOQ is used as an index parameter than AOQL Sampathkumar (2007) [6] constructed mixed sampling plan with conditional double sampling plan as a reference plan using various entry parameters. Radhakrishnan and Mallika (2008, 2009) [4] constructed Single Sampling Plan indexed through AOQ_{cc} which is the convex combination of AOQL and MAAOQ.

4. Operating procedure of CDSP

The Operating procedure of CDSP is as follows:

Step 1: Select a random sample of size n $(=n_1=n_2)$ from a lot of size N.

Step 2: Inspect all the articles included in the sample. Let d_1 be the number of non-conformities in the sample.

Step 3: If $d_1 \le c_1$, accept the lot, if $d_1 > c_3$, reject the lot.

Step 4: If $c_1+1 < d_1 \le c_3$ take a second sample of size n_2 from the remaining lot and find the number of non-conformities d_2.

Step 5: If $d_2 \le c_2$ or $d_1+d_2 \le c_3$ accept the lot, otherwise reject the lot.

5. Operating Characteristic function

Under the Poisson model, the OC function of the CDSP is given by

$$P_a(p) = \sum_{r=0}^{c_1} \frac{e^{-n_1 p}(n_1 p)^r}{r!} + \left[\sum_{k=c_1+1}^{c_2} \frac{e^{-n_1 p}(n_1 p)^k}{k!} \left\{\sum_{r=0}^{c_3-k} \frac{e^{-n_2 p}(n_2 p)^r}{r!}\right\}\right]$$

6. Construction and selection of CDSP indexed through AOQ_{cc}

The procedure presented in the section 4 is used for designing Conditional Double Sampling Plan indexed through AOQ_{cc} and are presented in Table 2. The values of np_*, nMAAOQ, nAOQL and $nAOQ_{cc}$ for the different values of λ (from 0.1 to 0.9) are calculated using Visual Basic program.

Table 2 is used to construct the plan when the np_* and $nAOQ_{cc}$ are specified. One can find the ratio $R_3 = nAOQ_{cc}/np_*$ and locate the value obtained under the column R_3 (for various values of λ) the corresponding value of np_* is noted and hence the parameters n_1, n_2, c_1, c_2, c_3 for CDSP are determined.

Example: 1

- For a specified AOQL=0.0025 and MAPD=0.0037 compute the ratio R_1= AOQL/MAPD=0.6757, which is nearer to 0.6709, the associated c_1 =7, c_2 =10, c_3 =18 are obtained from Table 2. The value of n can be obtained as n= np_*/MAPD= 8.8949/0.0037 =2404. Thus the sampling plan for specified AOQL = 0.0025 is n_1=2404 n_2=2404, c_1 =7, c_2 =10 and c_3 =18.
- For a specified MAAOQ =0.0023 and MAPD =0.0037 compute the ratio R_2 = MAAOQ/MAPD = 0.6216, which is nearer to 0.6222, the associated c_1 =2, c_2 =4, c_3 =6 are obtained from Table 2. The value of n can be obtained as n = np_*/MAPD = 3.0592/0.0037=827. Thus the sampling plan for the specified MAAOQ =0.0023 is n_1 =827, n_2=827, c_1 =2, c_2 =4 and c_3 =6.
- For a specified value of AOQL =0.0025, MAAOQ =0.0023 and MAPD =0.0037 a particular value of λ=0.7 the AOQ_{cc}=0.00244, compute the ratio R_3 = AOQ_{cc}/MAPD= 0.6595 which is nearer to 0.6575, corresponding to λ = 0.7, the associated c_1 =5, c_2 = 9, c_3 =12 are obtained from Table 2. The value of n can be obtained as n = np_*/MAPD =6.2379/0.0037=1686. Thus the sampling plan for the specified AOQ_{cc} =0.00244 and λ=0.7 is n_1 =1686, n_2=1686, c_1 =5, c_2 =9 and c_3 =12.

Practical Application: In a cell phone battery manufacturing company, if the producer fix the quality level MAAOQ= 0.0023 (23 non-conformities out of 10000) and the consumer fix the quality level AOQL = 0.0025 (25 non-conformities out of 10000) then suggest a compromising level of λ = 0.7, AOQ_{cc} = 0.00244 (244 non-conformities out of 100000) Select a sample of 1686 items from the lot and count the number of non-conformities (d_1). If $d_1 \le 5$ accept the lot and if $d_1 > 12$ reject the lot and inform the management for improving the quality of the product. If $5 < d_1 \le 12$ take another sample of size 1686 from the remaining lot and count the number of non-conformities (d_2). If $d_2 \le 9$ or if $d_1 + d_2 \le 12$ accept the lot, otherwise reject the lot and inform the management for improving the quality of the product. The OC and AOQ curves for the Example 1 are presented in Figure 1 and 2. Respectively

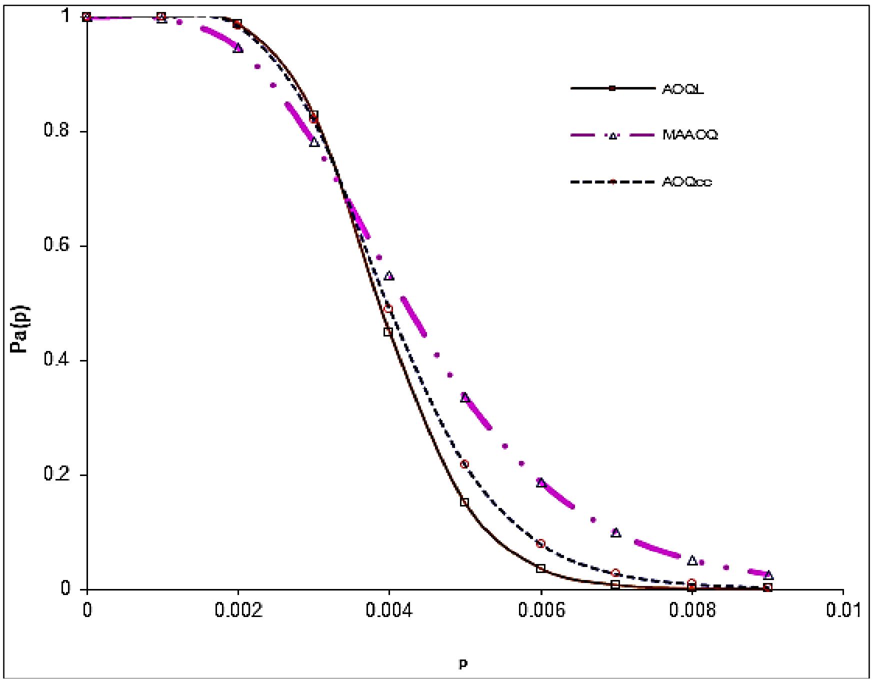

Fig 1: OC curves for n_1=2404, n_2=2404, c_1 =7, c_2 =10, c_3 =18(AOQL); n_1 = 827, n_2=827, c_1 = 2, c_2 = 4, c_3 = 6(MAAOQ); n_1 = 1686, n_2=1686, c_1 = 5, c_2 = 9, c_3 = 12 (AOQ_{cc})

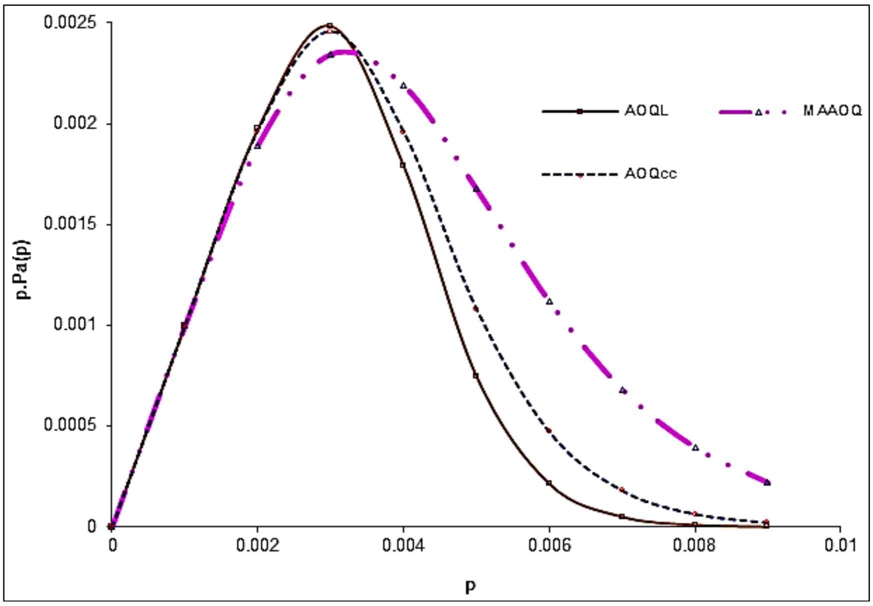

Fig 2: AOQ curves for n_1=2404, n_2=2404, c_1 =7, c_2 =10, c_3 =18 (AOQL); n_1 = 827, n_2=827, c_1 = 2, c_2 = 4, c_3 = 6(MAAOQ); n_1 = 1686, n_2=1686, c_1 = 5, c_2 = 9, c_3 = 12 (AOQ_{cc})

Example 2

- For a specified AOQL =0.0078 and MAPD =0.012 compute the ratio R_1 = AOQL/MAPD=0.6500, which is nearer to 0.6493, the associated c_1 =3, c_2 =7, c_3 =8 are obtained from Table 2. The value of n can be obtained as n= np_*/MAPD =4.1749/0.012=348. Thus the sampling plan for specified AOQL=0.0078 is n_1=348, n_2=348, c_1 =3, c_2 =7 and c_3 =8.
- For a specified MAAOQ =0.0074 and MAPD =0.012 compute the ratio R_2 = MAAOQ/MAPD = 0.6167, which is nearer to 0.6152, the associated c_1 =0, c_2 =3, c_3 =5 are obtained from Table 2. The value of n can be obtained as n = np_*/MAPD =2.3853/0.012=199. Thus the sampling plan for the specified MAAOQ =0.0074 is n_1 =199, n_2=199, c_1 =0, c_2 =3 and c_3 =5.
- For a specified value of AOQL =0.0078, MAAOQ =0.0074, MAPD =0.012 and a particular value of λ=0.6, AOQ_{cc} =0.00764, compute the ratio R_3 =AOQ_{cc}/MAPD = 0.6367 corresponding to λ = 0.6 which is exactly equal to 0.6367, the associated c_1 =2, c_2 =4, c_3 =6 are obtained from Table 2. The value of n can be obtained as n = np_*/MAPD =3.0592/0.012= 255. Thus the sampling plan for the specified AOQ_{cc} =0.00764 and λ=0.6 is n_1 =255, n_2=255, c_1 =2, c_2 =4, c_3 =6.

Practical Application: In a cell phone battery manufacturing company, if the producer fix the quality level MAAOQ= 0.0074 (74 non-conformities out of 10000) and the consumer fixes the quality level AOQL = 0.0078 (78 non-conformities out of 10000) then a compromising level, λ=0.6, AOQ_{cc} =0.00764(764 non-conformities out of 100000) Select a sample of 255 items from the lot and count the number of non-conformities (d_1). If $d_1 \leq 2$ accept the lot and if d_1>6 reject the lot and inform the management for improving the quality of the product. If $2< d_1 \leq 6$ take another sample of size 255 from the remaining lot and count the number of non-conformities (d_2). If $d_2 \leq 4$ or if $d_1 + d_2 \leq 6$ accept the lot, otherwise reject the lot and inform the management for improving the quality of the product. The OC and AOQ curves for the Example 2are presented in Figure 3 and 4 respectively.

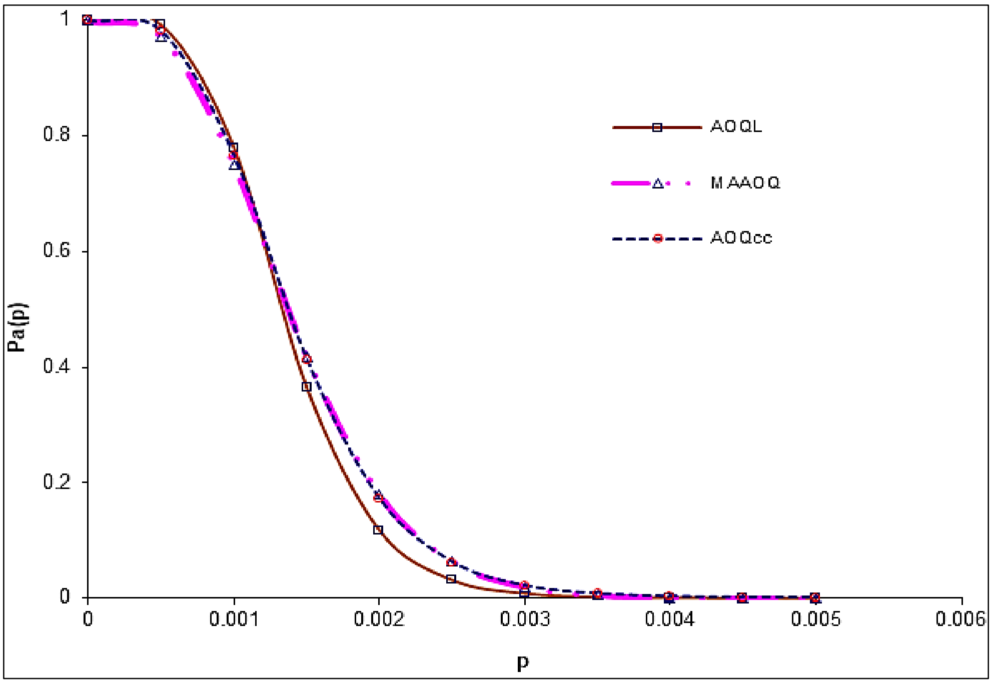

Fig 3: OC curves for n_1=348, n_2=348, c_1 =3, c_2 =7, c_3 =8(AOQL); n_1 = 199, n_2=199, c_1 = 0, c_2 = 3, c_3= 5(MAAOQ); n_1 = 255, n_2=255, c_1 = 2, c_2 = 4 c_3 = 6 (AOQ_{cc})

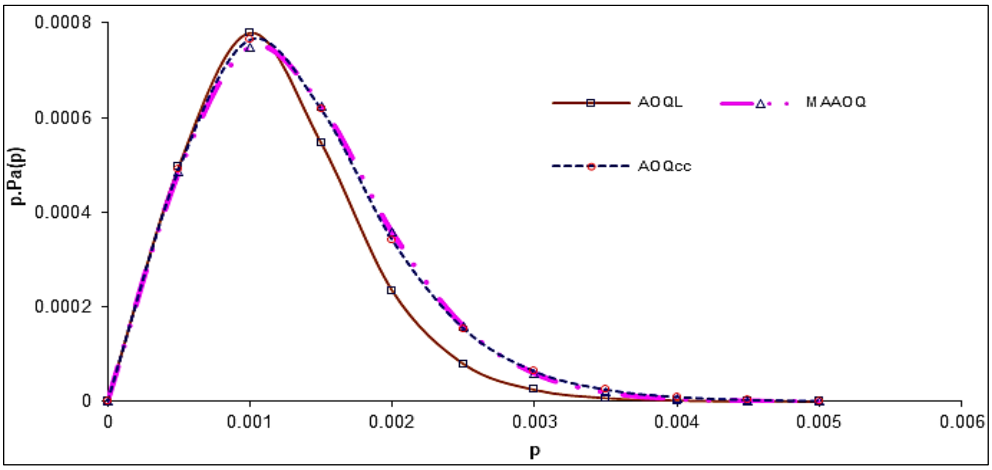

Fig 4: OC curves for n_1=348, n_2=348, c_1 =3, c_2 =7, c_3 =8(AOQL); n_1 = 199, n_2=199, c_1 = 0, c_2 = 3, c_3= 5(MAAOQ); n_1 = 255, n_2=255, c_1 = 2, c_2 = 4 c_3 = 6 (AOQ_{cc})

7. Comparison of CDSP

In order to compare sample sizes of the CDSP constructed through different parameters AOQL, MAAOQ and AOQ_{cc} (for different values of λ). The sample sizes of CDSP are calculated for various parameters such as AOQL, MAAOQ and AOQ_{cc} with the procedure provided in section 2 using Visual Basic Program and presented in Table 2.

Table 1: Comparison-CDSP with Various Parameters

λ	AOQcc	c_1,c_2,c_3	n
0	0.0023(MAAOQ)	2,4,6	827
0.1	0.00232	2,6,6	847
0.2	0.00234	0,3,4	535
0.3	0.00236	0,3,4	535
0.6	0.00242	0,2,3	393
0.7	0.00244	5,9,12	1686
0.8	0.00246	7,10,18	2404
0.9	0.00248	7,10,18	2404
1	0.0025(AOQL)	7,10,18	2404

8. Summary

In this paper the procedure for the construction of CDSP indexed through AOQ_{cc}, a convex combination of AOQL and MAAOQ with gain parameter λ is presented with examples. Further it is concluded the size of the sample required for CDSP indexed through (MAPD, AOQ_{cc}) is lesser than the size of the sample required indexed through (MAPD, AOQL). The engineers after knowing the interests of both producer and consumer can search for the quality level AOQ_{cc} and select the appropriate plan. These plans safeguard the interests of both producer and consumer, which can be understood from the OC and AOQ curves. Readymade tables are also provided in this paper for the engineers to take quick decisions on the nature of the sampling plan when the quality level of the producer and consumer are known.

Table 2: Characteristics of CDSP indexed through AOQ_{cc} for ($0<\lambda<1$)

c_1	c_2	c_3	np_*	n AOQL	R_1	nMAAOQ	R_2	$\lambda=0.1$		$\lambda=0.2$		$\lambda=0.3$		$\lambda=0.4$	
								$nAOQ_{cc}$	R_3	$nAOQ_{cc}$	R_3	$nAOQ_{cc}$	R_3	$nAOQ_{cc}$	R_3
0	1	1	0.5616	0.5032	0.8960	0.4228	0.7529	0.4389	0.7816	0.4527	0.8061	0.4651	0.8282	0.4754	0.8465
0	2	3	1.4556	0.9510	0.6533	0.9508	0.6532	0.9509	0.6533	0.9514	0.6536	0.9513	0.6535	0.9511	0.6534
0	3	4	1.9810	1.2611	0.6366	1.2502	0.6311	1.2522	0.6321	1.2547	0.6334	1.2557	0.6339	1.2571	0.6346
0	3	5	2.3853	1.4971	0.6276	1.4674	0.6152	1.4733	0.6177	1.4783	0.6197	1.4827	0.6216	1.4867	0.6233
1	3	4	2.0533	1.3265	0.6460	1.3211	0.6434	1.3224	0.6440	1.3231	0.6444	1.3244	0.6450	1.3250	0.6453
1	4	4	2.0897	1.3502	0.6461	1.3428	0.6426	1.3449	0.6436	1.3459	0.6441	1.3468	0.6445	1.3476	0.6449
2	4	6	3.0592	1.9566	0.6396	1.9034	0.6222	1.9133	0.6254	1.9218	0.6282	1.9301	0.6309	1.9368	0.6331
2	6	6	3.1354	2.0167	0.6432	1.9518	0.6225	1.9638	0.6263	1.9744	0.6297	1.9839	0.6327	1.9925	0.6355
2	6	8	4.0331	2.5974	0.6440	2.4118	0.5980	2.4440	0.6060	2.4738	0.6134	2.5004	0.6200	2.5245	0.6260
3	6	8	4.1538	2.6928	0.6483	2.5351	0.6103	2.5629	0.6170	2.5885	0.6232	2.6111	0.6286	2.6316	0.6335
3	6	11	5.2878	3.3833	0.6398	3.0474	0.5763	3.1046	0.5871	3.1575	0.5971	3.2057	0.6062	3.2490	0.6144
3	7	8	4.1749	2.7109	0.6493	2.5484	0.6104	2.5768	0.6172	2.6028	0.6235	2.6267	0.6292	2.6476	0.6342
3	7	11	5.4620	3.5658	0.6528	3.1756	0.5814	3.2412	0.5934	3.3023	0.6046	3.3575	0.6147	3.4075	0.6238
5	8	12	6.1920	4.1026	0.6626	3.6836	0.5949	3.7540	0.6063	3.8194	0.6168	3.8788	0.6264	3.9325	0.6351
5	9	12	6.2379	4.1515	0.6655	3.7153	0.5956	3.7882	0.6073	3.8561	0.6182	3.9178	0.6281	3.9743	0.6371
5	9	15	7.4453	4.9696	0.6675	4.2483	0.5706	4.3655	0.5863	4.4749	0.6010	4.5758	0.6146	4.6678	0.6270
6	9	15	7.5591	5.0501	0.6681	4.3805	0.5795	4.4903	0.5940	4.5920	0.6075	4.6860	0.6199	4.7716	0.6312
7	10	18	8.8949	5.9675	0.6709	5.0363	0.5662	5.1859	0.5830	5.3260	0.5988	5.4557	0.6134	5.5743	0.6267
7	11	18	9.0529	6.1701	0.6816	5.1647	0.5705	5.3247	0.5882	5.4742	0.6047	5.6131	0.6200	5.7411	0.6342
7	11	21	9.9086	6.8080	0.6871	5.7945	0.5848	5.9562	0.6011	6.1077	0.6164	6.2483	0.6306	6.3771	0.6436
9	13	23	11.4185	7.8883	0.6908	6.3704	0.5579	6.6052	0.5785	6.8272	0.5979	7.0341	0.6160	7.2262	0.6329
11	15	26	13.0585	9.1734	0.7025	7.3206	0.5606	7.6030	0.5822	7.8710	0.6027	8.1214	0.6219	8.3545	0.6398
11	16	26	13.1640	9.3304	0.7088	7.4153	0.5633	7.7055	0.5853	7.9802	0.6062	8.2386	0.6258	8.4790	0.6441
11	16	29	14.2794	10.0875	0.7064	7.9179	0.5545	8.2307	0.5764	8.5435	0.5983	8.8368	0.6189	9.1114	0.6381
15	19	34	17.0609	12.2548	0.7183	9.4534	0.5541	9.8688	0.5784	10.2641	0.6016	10.6372	0.6235	10.9862	0.6439
17	21	36	18.4191	13.4005	0.7275	10.3939	0.5643	10.8375	0.5884	11.2603	0.6113	11.6601	0.6330	12.0342	0.6534
23	28	52	25.8928	19.2946	0.7452	13.9562	0.5390	14.7118	0.5682	15.4355	0.5961	16.1267	0.6228	16.7806	0.6481
25	30	56	27.8840	20.9064	0.7498	14.9932	0.5377	15.8251	0.5675	16.6223	0.5961	17.3833	0.6234	18.1043	0.6493

c_1	c_2	c_3	np*	$\lambda=0.5$		$\lambda=0.6$		$\lambda=0.7$		$\lambda=0.8$		$\lambda=0.9$	
				$nAOQ_{cc}$	R_3	$nAOQ_{cc}$	R_3	$nAOQ_{cc}$	R_3	$nAOQ_{cc}$	R_3	$nAOQ_{cc}$	R_3
0	1	1	0.5616	0.4836	0.8611	0.4909	0.8741	0.4966	0.8843	0.5006	0.8914	0.5028	0.8953
0	2	3	1.4556	0.9516	0.6538	0.9514	0.6536	0.9513	0.6535	0.9511	0.6534	0.9516	0.6537
0	3	4	1.9810	1.2590	0.6355	1.2594	0.6357	1.2602	0.6361	1.2608	0.6365	1.2613	0.6367
0	3	5	2.3853	1.4894	0.6244	1.4924	0.6257	1.4948	0.6267	1.4960	0.6272	1.4974	0.6278
1	3	4	2.0533	1.3254	0.6455	1.3338	0.6496	1.3266	0.6461	1.3268	0.6462	1.3268	0.6462
1	4	4	2.0897	1.3489	0.6455	1.3495	0.6458	1.3498	0.6459	1.3501	0.6461	1.3502	0.6461
2	4	6	3.0592	1.9427	0.6350	1.9477	0.6367	1.3587	0.4441	1.9545	0.6389	1.9562	0.6394
2	6	6	3.1354	2.0000	0.6379	2.0057	0.6397	2.0105	0.6412	2.0142	0.6424	2.0161	0.6430
2	6	8	4.0331	2.5461	0.6313	2.5637	0.6357	2.5779	0.6392	2.5888	0.6419	2.5955	0.6435
3	6	8	4.1538	2.6491	0.6378	2.6644	0.6414	2.6767	0.6444	2.6859	0.6466	2.6913	0.6479
3	6	11	5.2878	3.2873	0.6217	3.3200	0.6279	3.3461	0.6328	3.3669	0.6367	3.3793	0.6391
3	7	8	4.1749	2.6662	0.6386	2.6818	0.6424	2.6943	0.6454	2.7037	0.6476	2.7092	0.6489
3	7	11	5.4620	3.4527	0.6321	3.4903	0.6390	3.5217	0.6448	3.5457	0.6492	3.5607	0.6519
5	8	12	6.1920	3.9805	0.6428	2.8656	0.4628	4.0547	0.6548	4.0805	0.6590	4.0969	0.6616
5	9	12	6.2379	4.0237	0.6450	4.0664	0.6519	4.1016	0.6575	4.1282	0.6618	4.1453	0.6645
5	9	15	7.4453	4.7503	0.6380	4.8221	0.6477	4.8823	0.6558	4.9280	0.6619	4.9595	0.6661
6	9	15	7.5591	4.8487	0.6414	4.9148	0.6502	4.9703	0.6575	5.0126	0.6631	5.0404	0.6668
7	10	18	8.8949	3.8754	0.4357	5.7740	0.6491	5.8522	0.6579	5.9132	0.6648	5.9528	0.6692
7	11	18	9.0529	5.8568	0.6470	5.9576	0.6581	6.0428	0.6675	6.1094	0.6749	6.1534	0.6797
7	11	21	9.9086	6.4939	0.6554	6.5960	0.6657	6.6814	0.6743	6.7478	0.6810	6.7926	0.6855
9	13	23	11.4185	7.4004	0.6481	7.5553	0.6617	7.6862	0.6731	7.7912	0.6823	7.8614	0.6885
11	15	26	13.0585	8.5671	0.6561	8.7568	0.6706	8.9196	0.6831	9.0501	0.6930	9.1397	0.6999
11	16	26	13.1640	8.6994	0.6608	8.8961	0.6758	9.0650	0.6886	9.2004	0.6989	9.2946	0.7061
11	16	29	14.2794	9.3624	0.6557	9.7904	0.6856	9.7814	0.6850	9.9377	0.6959	10.0465	0.7036
15	19	34	17.0609	11.3083	0.6628	11.5978	0.6798	11.8500	0.6946	12.0546	0.7066	12.1983	0.7150
17	21	36	18.4191	8.7103	0.4729	12.6915	0.6890	12.9633	0.7038	13.1854	0.7159	13.3400	0.7242
23	28	52	25.8928	17.3914	0.6717	17.9511	0.6933	18.4486	0.7125	18.8649	0.7286	19.1676	0.7403
25	30	56	27.8840	18.7802	0.6735	19.4084	0.6960	19.9532	0.7156	20.4193	0.7323	20.7616	0.7446

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