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ZERO-ONE DOUBLE ACCEPTANCE SAMPLING PLAN FOR TRUNCATED LIFE TESTS BASED ON MARSHALL - OLKIN EXTENDED EXPONENTIAL DISTRIBUTION

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ABSTRACT

The purpose of this paper is to propose a zero-one double acceptance sampling plan for the truncated life tests assuming the lifetime of a product follows the Marshall- Olkin extended exponential distribution. The minimum sample sizes of the first and second samples are determined for the specified consumers confidence level with minimum average sample number. The operating characteristics are analyzed and the minimum ratios of life time are obtained so as to meet the specified producer's risk. Numerical illustration is provided to explain the utility of the plan.Efficiency of the proposed plan is studied by comparing the single sampling plan.

Keywords: *Double acceptance sampling, Truncated life test, Producer's risk, Consumer's confidence level, Operating Characteristic Function.*

INTRODUCTION

Products or items have variations even though they are produced by the same producer, same machine and under the same manufacturing conditions. The producer and the consumer are subject to risks due to the decision on the acceptance or rejection of lot of products based on an sample results. Consumer's risk of accepting bad lots and Producer's risk of rejecting good lots may be minimized to a certain level by increasing the sample size. But this will increase the cost of inspection. Therefore an efficient acceptance sampling with truncation of test time is the only option.

Several studies have been done for designing single sampling plans based on the truncated life tests with a product quality following various statistical distributions .Several authors like Epstein [12], Goode and Kao [13], Gupta and Groll [14], Gupta [15] worked on single acceptance sampling plans for the truncated life tests based on various life time distributions.

Duncan [11] pointed out that double sampling plans reduces the sample size. Aslam and Jun [2] introduced double sampling plan for the truncated life test based on generalized log-logistic distribution. Muthulakshmi and Geetha Gnana Selvi[1] introduced zero-one double sampling plan for truncated life test based on Kumaraswamy log-logistic distribution.

The purpose of this paper is to propose the zero-one double sampling plan for the truncated life test assuming that the life time follows Marshall-Olkin extended exponential distribution using percentiles. The beauty and importance of this distribution lies in accommodating several characteristics in modeling lifetime data and minimum waiting time in the execution of the software. Also, it has been used extensively to study the time to failure for electrical component such as memory disc, mechanical component such as barings and systems such as aircraft, automobiles. The minimum sample sizes of the first and second samples for the proposed life test plan are determined at the specified consumers' confidence level by incorporating minimum ASN. The operating characteristics are analysed and the minimum percentile ratios of life time are obtained. A numerical example is provided to explain the utility of the plan. Comparision with single sampling plan is provided.

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MARSHALL- OLKIN EXTENDED EXPONENTIAL DISTRIBUTION

Assume that the lifetime of a product follows Marshall- Olkin extended exponential distribution. The probability density function (pdf) and cumulative distribution function (cdf) of Marshall- Olkin extended exponential distribution are given by

$$f(t)=\frac{\frac{a}{\sigma}\exp(-t/\sigma)}{\left[1-(1-a)\exp\left(-t/\sigma\right)\right]^2};\ t>0,a,\sigma>0 \tag{1}$$

and

$$F(t)=\frac{1-\exp\left(-t/\sigma\right)}{1-(1-a)\exp\left(-t/\sigma\right)};\ t>0,a,\sigma>0 \tag{2}$$

where σ is the scale parameter and a is the shape parameter. The $100q^{th}$ percentile is given by

$$t_q=\sigma\ln\left[\left(1-(1-a)q\right)/\left(1-q\right)\right] \tag{3}$$

Where $0<q<1$ .When $q=0.5$, t_q reduces to σln(1+a) which is the median of Marshall- Olkin extended exponential distribution. It is seen that, t_q depends only on **a** and **σ** . Also it is seen that t_q is increasing with respect to **a** for $q> 0.5$ and decreasing with respect to **a** for $q< 0.5$.

If $\eta=\ln\left[\left(1-(1-a)q\right)/\left(1-q\right)\right]$ then (4)

$$\sigma=t_q/\eta \tag{5}$$

cdf of Marshall- Olkin extended exponential distribution may be expressed in terms of a and η as

$$F(t)=\frac{1-\exp\left[-t/\left(t_q/\eta\right)\right]}{1-(1-a)\exp\left[-t/\left(t_q/\eta\right)\right]},\ t>0 \tag{6}$$

Let $\delta=t/t_q$, then $F(t)$ becomes

$$F(t)=\frac{1-\exp\left(-\delta\eta\right)}{1-(1-a)\exp\left(-\delta\eta\right)},\ t>0 \tag{7}$$

The designing of double acceptance sampling plan using percentiles under a truncated life test is to set up the minimum sample sizes for the given shape parameter **a** such that the consumer's risk, the probability of accepting a bad lot, does not exceed 1- P* with the minimum ASN . A bad lot means that the true $100q^{th}$ percentile t_q , is below the specified percentile t_q^0 . Thus, the probability P* is a confidence level in the sense that the chance of rejecting a bad lot with $t_q<t_q^0$ is at least equal to P*.

DESIGN OF THE PROPOSED SAMPLING PLAN

Assume that the acceptable quality of a product can be represented by its percentile lifetime t_q^0 . The lot will be accepted if the data supports the null hypothesis, H_0: $t_q\geq t_q^0$ against the alternative hypothesis, H_1: $t_q<t_q^0$. The significance level for the test is 1−P*, where *P**is the consumer's confidence level.

The operating procedure of zero-one double sampling plan for the truncated life test has the following steps:

(1) Select a first random sample of size n_1 from the submitted lot and put on test for time t_0.if there are c_1=0 failures within the experimental time, accept the lot.If there are 2 or more than 2 failures within the experimental time ,reject the lot.
(2) If the number of failures by t_0 is c_1=1 then select a second random sample of size n_2, if the number of failures in the second sample c_2=0,accept the lot .Otherwise reject the lot.

It is convenient to make a termination time in terms of acceptable percentile lifetime t_q^0 and depend only on $\delta = t/t_q^0$. Since the partial derivative of (7) with respect to δ is an increasing function, F(t) is a non-decreasing function of δ. Therefore, for a given P*, the proposed acceptance sampling plan can be characterized by (n_1, n_2, a, η, δ).

The minimum sample sizes n_1 and n_2 at the consumer's confidence level P* can be found as the solution of

$$(1-p)^{n_1}\left[1+n_1 p(1-p)^{n_2-1}\right] \le 1-P* \tag{8}$$

where, p is the probability that an item fails before t_0, which is given by

$$p=\frac{1-\exp(-\delta\eta)}{1-(1-a)\exp(-\delta\eta)} \tag{9}$$

Equation (8) provides multiple solutions for sample sizes n_1 and n_2 satisfying the specified consumer's confidence level.In order to find the optimal sample sizes the minimum of ASN is incorporated along with the probability of the acceptance of the lot less than or equal to 1-P* and $n_2 \le n_1$

The ASN for double sampling plan is

$$ASN = n_1P_1 + (n_1+n_2)(1-P_1) \tag{10}$$

where P_1, the probability of acceptance or rejection based on the first sample is given by

$$P_1 = 1 - n_1 p(1-p)^{n_1-1}$$

For c_1=0 and c_2=1 we have

$$ASN = n_1 + n_1n_2p(1-p)^{n_1-1} \tag{11}$$

Therefore, determination of the minimum sample sizes for zero-one double sampling plan scheme reduces to

Minimize $ASN = n_1 + n_1 n_2 p_0 (1-p_0)^{n_1-1}$ (12)

Subject to $(1-p_0)^{n_1}[1+n_1 p_0(1-p_0)^{n_2-1}] \le 1-P^*$

where n_1 and n_2 are integers. The minimum sample sizes satisfying the condition (12) can be obtained by search procedure. Table 1 is constructed for the minimum sample sizes of zero-one double sampling plan for fixed q with various values of P*(=0.75,0.90,0.95,0.99), shape parameter a (=2,3,4,5) and δ (=0.5,1.0,1.5,2.0,2.5,3.0,3.5).

Numerical values in Table 1 reveals that, increase in consumers confidence level

(i) increases the first and the second sample sizes quite rapidly, when the test time is short
(ii) increase in percentile, increases sample sizes with increase in shape parameter **a**.
(iii) increase in consumer's confidence level, decreases the sample sizes .

OPERATING CHARACTERISTICS VALUES OF THE SAMPLING PLAN

OC values depict the performance of the sampling plan according to the quality of the submitted product. The probability of acceptance will increase more rapidly if the true percentile increases beyond the specified life. Therefore, we need to know the operating characteristic values for the proposed plan according to the ratio t_q/t_q^0 of the true percentile to the specified life. Obviously, a plan will be more desirable if its operating characteristic values increase more sharply to one.

PRODUCERS RISK

Producer wants to know the minimum product quality level in order to maintain the producers risk at the specified level. At the specified producers risk α, the minimum ratio t_q/t_q^0 can be obtained by solving $P_a \ge 1-\alpha$ where P_a is given in (8).

Table 4 shows the minimum such ratios for the acceptability of a lot at the producers risk of α = 0.05 using the sample sizes presented in Table 1 for specified consumer's confidence level .

APPLICATION

Suppose that the manufacture wants to adopt zero-one double sampling plan for assuring the specified percentile with shape parameter a=2 and q =0.05 when the lifetime of a product follows a Marshall-Olkin extended exponential distribution. The specified life time is 1000hrs with consumers confidence level of 0.75.The experimenter wants to stop an experiment at 500 hours, which leads to the experiment termination time of δ =0.5. Then, from Table 1, the minimum sample sizes required are n_{1} = 67 and n_2 = 64. This sampling plan is interpreted as follows. First, 67 items are put on test for 500 hours and the lot will be accepted if no failure occurs during the experiment and is rejected if more than one failure occurs. When exactly one failure is observed, a second sample of size 64 will be drawn and put on test for 500 hours. The lot will be accepted if there are no failures from the second sample and is rejected otherwise.

The following table shows the increase of OC values gradually by increasing the percentiles for zero-one double sampling plan with confidence level P*=0.90,t/t_q^0=3.5 and t_q/t_q^0=15 with a=3 .

q	0.05	0.01	0.1	0.15	0.2	0.25
OC values	0.9738 (13,12)	0.9845 (47,46)	0.9901 (6,1)	0.9895 (4,1)	0.9888 (3,10)	0.9912 (2,1)

Also, the ASN values of single sampling and zero-one double sampling plan for a=2, q=0.1 P*=0.75 with δ=2,2.5,3,3.5 are obtained as follows:

SSP	C=0	7	5	5	4
	C=1	13	11	9	8
DSP	DSP(0,1)	10.366	8.2671	6.8	6.5171

On comparing the values of life test plans, the zero-one double sampling plan using percentiles provide minimum sample size and hence economical.

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Table-1: Minimum sample sizes for zero-one double sampling plan with q=0.05

a	P*	δ						
		0.5	1	1.5	2	2.5	3	3.5
2	0.75	67,64	34,28	23,17	17,14	14,12	11,9	9,9
	0.9	100,97	51,47	33,28	25,20	19,18	17,14	15,12
	0.95	126,120	63,60	41,36	31,28	26,24	23,20	25,22
	0.99	185,180	108,105	60,57	45,40	37,33	32,28	25,24
3	0.75	212,206	185,179	94,90	17,14	13,11	10,10	9,7
	0.9	317,304	287,281	111,107	24,21	20,17	15,14	13,12
	0.95	395,388	367,360	122,118	3,028	24,21	19,17	16,15
	0.99	586,575	403,397	135,131	44,40	34,33	28,27	24,23
4	0.75	1043, 1038	691,186	561,545	71,62	38,35	18,15	12,11
	0.9	1561, 1560	772,767	384,380	101,111	55,52	25,23	15,13
	0.95	1958, 1953	827,821	308,307	127,125	66,63	30,28	22,17
	0.99	2911, 2907	912,907	202,202	187,186	92,90	42,32	45,38
5	0.75	1870, 1865	555,550	131,130	108,99	24,20	17,12	13,9
	0.9	2801, 2779	663,658	188,186	156,154	27,24	20,18	15,11
	0.95	3517, 3512	788,784	252,247	197,195	36,34	28,23	22,18
	0.99	5232, 5228	863,860	333,328	292,291	45,41	38,37	32,28

Table-2: Minimum sample sizes for zero-one double sampling plan with q=0.1.

a	P*	δ						
		0.5	1	1.5	2	2.5	3	3.5
2	0.75	33,32	17,13	11,9	8,7	7,4	5,5	4,2
	0.9	50,47	24,23	16,14	12,9	10,6	8,7	7,4
	0.95	63,61	30,28	20,16	15,11	12,8	12,8	8,6
	0.99	104,91	45,34	29,25	22,14	17,12	17,12	12,7
3	0.75	34,31	17,13	11,8	8,6	6,5	5,4	4,4
	0.9	51,44	24,23	16,15	11,11	9,7	7,6	6,5
	0.95	63,57	30,28	19,19	14,12	11,8	9,6	7,7
	0.99	93,84	45,34	29,20	21,14	16,11	13,8	11,6
4	0.75	35,31	17,13	11,8	8,6	6,4	5,3	4,4
	0.9	53,41	24,23	16,15	11,9	9,5	7,4	6,5
	0.95	65,55	30,28	19,19	14,9	10,9	8,7	7,6
	0.99	96,74	45,34	28,22	20,14	15,11	12,8	10,6
5	0.75	39,22	16,16	11,8	7,7	6,4	4,4	4,2
	0.9	55,39	24,23	16,15	11,10	8,6	7,4	6,5
	0.95	67,53	30,28	19,19	13,11	10,9	8,5	6,5
	0.99	99,68	45,34	28,22	19,15	14,11	11,8	9,5

Table-3: Operating Characteristic values of zero-one double sampling plan a=3 and q=0.05.

P*	t/t_q^0	n_1	n_2	t_q/t_q^0					
				15	20	25	30	35	40
0.75	0.5	212	206	0.8826	0.9272	0.9505	0.9643	0.9729	0.9788
	1	185	179	0.7306	0.8216	0.8738	0.9063	0.9277	0.9426
	1.5	94	90	0.8177	0.8837	0.9196	0.9412	0.9552	0.9647
	2	17	14	0.9858	0.9918	0.9947	0.9962	0.9972	0.9979
	2.5	13	11	0.9868	0.9924	0.9951	0.9965	0.9974	0.9981
	3	10	10	0.9874	0.9928	0.9953	0.9967	0.9976	0.9981
	3.5	9	7	0.9882	0.9932	0.9956	0.9969	0.9977	0.9982
0.9	0.5	317	304	0.7841	0.8601	0.9024	0.9281	0.9449	0.9565
	1	287	281	0.5382	0.6702	0.7549	0.8116	0.8509	0.8793
	1.5	111	107	0.7671	0.8482	0.8937	0.9215	0.9398	0.9523
	2	24	21	0.9719	0.9835	0.9892	0.9924	0.9943	0.9956
	2.5	20	17	0.9702	0.9826	0.9885	0.9919	0.9939	0.9954
	3	15	14	0.9741	0.9849	0.9901	0.9931	0.9948	0.9961
	3.5	13	12	0.9738	0.9847	0.9899	0.9929	0.9948	0.9959
0.95	0.5	395	388	0.7047	0.8024	0.8592	0.8949	0.9186	0.9352
	1	367	360	0.4129	0.5587	0.6606	0.7325	0.7844	0.8229
	1.5	122	118	0.7341	0.8244	0.8759	0.9079	0.9289	0.9436
	2	30	28	0.9563	0.9741	0.9829	0.9879	0.9909	0.9931
	2.5	24	21	0.9579	0.9751	0.9835	0.9883	0.9913	0.9933
	3	19	17	0.9611	0.9771	0.9849	0.9894	0.9921	0.9938
	3.5	16	15	0.9613	0.9772	0.9851	0.9919	0.9941	0.9939
0.99	0.5	586	575	0.5283	0.6617	0.7479	0.8057	0.8461	0.8752
	1	403	397	0.3644	0.5119	0.6191	0.6965	0.7535	0.7962
	1.5	135	131	0.6953	0.7956	0.8542	0.8911	0.9156	0.9327
	2	44	40	0.9162	0.9491	0.9658	0.9755	0.9816	0.9857
	2.5	34	33	0.9181	0.9503	0.9667	0.9761	0.9821	0.9861
	3	28	27	0.9199	0.9515	0.9675	0.9767	0.9825	0.9864
	3.5	24	23	0.9201	0.9516	0.9676	0.9768	0.9826	0.9865

Table-4: Operating Characteristic values of zero-one double sampling plan with a=3 and q=0.1.

P*	t/t_q^0	n_1	n_2	t_q/t_q^0					
				15	20	25	30	35	40
0.75	0.5	34	31	0.9853	0.9915	0.9945	0.9961	0.9971	0.9978
	1	17	13	0.9869	0.9924	0.9951	0.9965	0.9974	0.9981
	1.5	11	8	0.988	0.9931	0.9955	0.9969	0.9977	0.9982
	2	8	6	0.9886	0.9934	0.9957	0.9971	0.9978	0.9983
	2.5	6	5	0.9893	0.9939	0.9961	0.9972	0.9981	0.9984
	3	5	4	0.9897	0.9941	0.9962	0.9973	0.9981	0.9985
	3.5	4	4	0.9923	0.9956	0.9972	0.998	0.9985	0.9989

0.9	0.5	51	44	0.9699	0.9823	0.9884	0.9918	0.9939	0.9953
	1	24	23	0.9714	0.9832	0.9891	0.9922	0.9942	0.9955
	1.5	16	15	0.9718	0.9835	0.9892	0.9924	0.9943	0.9956
	2	11	11	0.9751	0.9855	0.9905	0.9933	0.9951	0.9962
	2.5	9	7	0.9777	0.9871	0.9915	0.9941	0.9956	0.9961
	3	7	6	0.9793	0.9881	0.9922	0.9945	0.9959	0.9969
	3.5	6	5	0.9797	0.9883	0.9924	0.9947	0.9961	0.9971
0.95	0.5	63	57	0.9548	0.9731	0.9822	0.9874	0.9906	0.9927
	1	30	28	0.9578	0.9751	0.9835	0.9883	0.9913	0.9932
	1.5	19	19	0.9599	0.9763	0.9844	0.9889	0.9918	0.9936
	2	14	12	0.9645	0.9791	0.9863	0.9903	0.9928	0.9944
	2.5	11	8	0.9687	0.9817	0.9881	0.9915	0.9937	0.9952
	3	9	6	0.9712	0.9832	0.9891	0.9923	0.9943	0.9956
	3.5	7	7	0.9696	0.9823	0.9884	0.9918	0.9939	0.9953
0.99	0.5	93	84	0.9731	0.9841	0.9896	0.9926	0.9945	0.9958
	1	45	34	0.9771	0.9866	0.9912	0.9938	0.9954	0.9964
	1.5	29	20	0.9741	0.9848	0.9901	0.9931	0.9948	0.9961
	2	21	14	0.9812	0.9891	0.9929	0.9951	0.9963	0.9971
	2.5	16	11	0.9826	0.9899	0.9934	0.9954	0.9966	0.9974
	3	13	8	0.9844	0.9911	0.9941	0.9959	0.9971	0.9977
	3.5	11	6	0.9857	0.9918	0.9947	0.9962	0.9972	0.9979

Table -5: Minimum percentile ratio of zero-one double sampling plan with q=0.05 and producer's risk of 0.05.

a	P*	t/t_q^0						
		0.5	1	1.5	2	2.5	3	3.5
2	0.75	0.1299	0.1294	0.1321	0.1319	0.1285	0.1375	0.1389
	0.9	0.0876	0.0877	0.0875	0.0874	0.0878	0.0872	0.0871
	0.95	0.0687	0.0685	0.0701	0.0711	0.0682	0.0657	0.0495
	0.99	0.0453	0.0403	0.0473	0.0493	0.0483	0.0463	0.0481
3	0.75	0.0421	0.0231	0.0311	0.1323	0.1371	0.1413	0.1493
	0.9	0.0278	0.0148	0.0258	0.0918	0.0917	0.0978	0.0988
	0.95	0.0212	0.0119	0.0234	0.0662	0.0768	0.0804	0.0808
	0.99	0.0132	0.0102	0.0214	0.0512	0.0482	0.0512	0.0524
4	0.75	0.0085	0.0065	0.0052	0.0332	0.0482	0.0812	0.0999
	0.9	0.0058	0.0059	0.0078	0.0199	0.0332	0.0603	0.0891
	0.95	0.0043	0.005	0.0091	0.0179	0.0268	0.0497	0.0612
	0.99	0.0031	0.0049	0.0136	0.0121	0.0192	0.0391	0.0273
5	0.75	0.0049	0.0081	0.0232	0.0212	0.0412	0.0812	0.1041
	0.9	0.0031	0.0069	0.0159	0.0149	0.0692	0.0763	0.0913
	0.95	0.0024	0.0053	0.0119	0.0109	0.0472	0.0563	0.0613
	0.99	0.0017	0.0054	0.0093	0.0078	0.0424	0.0373	0.0413

Table -6: Minimum percentile ratio of zero-one double sampling plan with q=0.1 and producer's risk of 0.05.

a	P*	t/t_q^0						
		0.5	1	1.5	2	2.5	3	3.5
2	0.75	0.2609	0.2634	0.2621	0.2619	0.2685	0.2775	0.2789
	0.9	0.1676	0.1777	0.1875	0.1874	0.1878	0.1872	0.1979
	0.95	0.1287	0.1385	0.1401	0.1591	0.1632	0.1657	0.1595
	0.99	0.0853	0.0972	0.0973	0.1093	0.1083	0.1163	0.1181
3	0.75	0.2421	0.2831	0.2911	0.2923	0.2971	0.2913	0.2993
	0.9	0.1779	0.1432	0.1718	0.1918	0.1917	0.1998	0.209
	0.95	0.1312	0.1419	0.1534	0.1662	0.1768	0.1804	0.1808
	0.99	0.0932	0.1002	0.1099	0.1099	0.1189	0.1212	0.1294
4	0.75	0.2485	0.2865	0.2852	0.2932	0.3092	0.3212	0.2999
	0.9	0.1858	0.1859	0.1878	0.2099	0.2332	0.2503	0.2191
	0.95	0.1343	0.145	0.1491	0.1679	0.1668	0.1898	0.1912
	0.99	0.0931	0.1049	0.1096	0.1199	0.1192	0.1391	0.1373
5	0.75	0.2599	0.2781	0.2832	0.3112	0.3112	0.3412	0.3541
	0.9	0.1839	0.1929	0.1759	0.2412	0.2412	0.2363	0.2191
	0.95	0.1394	0.1453	0.1519	0.1712	0.1712	0.1963	0.2099
	0.99	0.1017	0.1054	0.1093	0.1324	0.1324	0.1373	0.1593

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