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An economic reliability test plan for exponentiated half logistic distributed lifetimes

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Abstract
The exponentiated half logistic distribution introduced by Cordeiro *et al*. (2014) is a probability model for the life time of an item. A submitted lot will be accepted or rejected based on the sampling plans where items are to be tested and for collecting the life of items, these plans are called reliability test plans. The present reliability test plan is more desirable than similar plans exists in literature is entrenched with respect to termination time of the experiment. For a range of stated acceptance number we determine the minimum life test termination time, sample size, and producer's risk.

Keywords: Exponentiated half log logistic distribution, economic reliability test plan, producer's risk, experimental time

Introduction
In quality control the study of reliability play a key role. The researcher can minimize the time and cost in the process of accepting or rejecting the submitted lot on the basis of reliability study. If the unpretentious items will be rejected based on the sample information, which is called type-I error (producer's risk α). On the contrary, if the unpretentious items will be accepted, which is called type-II error (consumer's risk β). The procedure of acceptance or rejection of the lot conditional upon the risks related with two types of errors is known as 'reliability test plan' or 'acceptance sampling based on life test'; for further details, see Duncan (1986) [7] and Stephens (2001) [24].

Asymmetrical probability distributions are the basis for reliability test plans. The reliability sampling plans which are more cost-effective for the researcher used to found by skewed distributions. The truncated life tests in exponential distribution was first contemplated by Epstein and Sobel (1954) [8]. The median is a preferable quality parameter than the mean which was suggested by Gupta (1962) [9]. On the contrary, the mean is better parameter for symmetrical distributions. The acceptance sampling plans will be used for the quantiles suggested by Balakrishnan *et al.* (2007) [4] and also derived the formulae. The generalized exponential distribution was contemplated to justify economic reliability test plan by Aslam and Shahbaz (2007) [3]. The economic reliability test plan for a generalized Rayleigh Distribution was also presented by Aslam (2008) [1]. The need of engineering on the definite percentile of strength or breaking stress may not be satisfied by the acceptance sampling plans based on mean suggested by Lio *et al.* (2009, 2010) [14, 15] and they also suggested that the acceptance sampling plans based on the truncated life tests to Birnbaum-Saunders distribution and Burr type XII for percentiles. The economic reliability group acceptance sampling plans for lifetimes of Marshall-Olkin extended distribution introduced by Mugahal *et al.* (2010) [16]. The economic reliability group acceptance sampling plan for Pareto second kind distribution conferred by Aslam *et al.* (2010) [2]. The economic reliability test plan on the basis of Marshall-Olkin extended exponential distribution described by Rao *et al.* (2011) [18]. The reliability test plans for type-II exponentiated log-logistic distribution was conferred by Rao *et al.* (2012) [19]. The economic reliability test plan for a generalized log-logistic distribution presented by Rao *et al.* (2013) [20]. The acceptance sampling plans based on median life for Fréchet distribution was developed by Balamurali *et al.* (2013). The economic reliability test plan based on truncated life tests for Marshall-Olkin extended Weibull Distribution was considered by Rao (2015) [17]. The economic reliability test plan for Type-I and Type-II generalized half logistic distribution was considered by Rosaiah *et al.* (2014a, 2014b) [22, 23].

Under the reliability test plans the test termination time can be determined. The probability distributions/models have been in use to evolve the reliability test plans. The best reliability sampling plans which are more inexpensive for the researcher can be determined using these probability distributions. The log-logistic distribution to develop the acceptance sampling plans could be used by Kantam *et al*. (2001). Also studied the reliability test plans using the log- logistic distribution by Kantam *et al*. (2006) [11].

The experiment will be terminated in reliability test plan if the r^{th} failure occurs if we put the nr sample units on test or if the termination time t ends, whichever occurs first.

In this paper we establish the economic reliability test plans based on exponentiated half logistic distribution (EHLD) with reference to the above cited economic reliability test plans for various distributions. In Unit 2, we define briefly about the EHLD. The plan of the suggested economic reliability test plans is conferred in in Unit 3. In Unit 4, we describe the proposed design and attain the required results and illustrative example with real data is also provided. Finally, in Unit 5 conclusions are made.

2. The Exponentiated Half Logistic Distribution

Let us consider the life time of an item follows the exponentiated half logistic distribution (EHLD). The EHLD was established and studied quite extensively by Cordeiro *et. al*. (2014). The probability density function (pdf), cumulative distribution function (cdf) and hazard function (hf) of EHLD are respectively given as follows:

$$f(t;\nu,\sigma)=\frac{2\nu\left(1-e^{-t/\sigma}\right)^{\nu-1}e^{-t/\sigma}}{\sigma\left(1-e^{-t/\sigma}\right)^{\nu+1}}\ ;\ t\geq 0 \tag{1}$$

$$F(t;\ \nu,\ \sigma)=\left[F(t;\sigma)\right]^{\nu}=\left(\frac{1-e^{-t/\sigma}}{1+e^{-t/\sigma}}\right)^{\nu};\ t\geq 0 \tag{2}$$

$$h(x;\ \sigma,\nu)=\frac{2\nu\left(1-e^{-x/\sigma}\right)^{\nu-1}e^{-x/\sigma}}{\sigma\left(1+e^{-x/\sigma}\right)\left[\left(1+e^{-x/\sigma}\right)^{\nu}-\left(1-e^{-x/\sigma}\right)^{\nu}\right]};\ x\geq 0 \tag{3}$$

Where, σ is the scale parameter and ν is shape parameter.

3. An Economic Reliability Test Plan for EHLD

The minimum sample size needed to establish a percentile life when the observed number of failures does not exceed a given acceptance number c and when the test is terminated at a pre-assigned time t_q^0 was obtained and also to make decision about the submitted lot, the minimum sample sizes required are determined by Rao and Ramesh Naidu (2014) [21] for the given acceptance number c, the waiting time in terms of t_q^0 (i.e., t/t_q^0), and some risk probability, say α, based on the median/percentile for EHLD. The conservation to the consumer is provided by the procedure of accepting the lot only if the specified percentile of lifetime can be established with a pre-assigned high probability α. The brief contents of Rao and Ramesh Naidu (2014) [21] are given for the reference. The minimum sample size 'n' can be determined for spedific values of α (0 < α < 1), t/t_q^0, for a specified t_q^0 of t_q and the acceptance number c such that

$$\sum_{i=0}^{c}\binom{n}{i}p^{i}(1-p)^{n-i}\geq 1-\alpha \tag{4}$$

holds, where $p=F(t;\nu,\sigma)$ given by eqn. (2) which designates the failure probability before time t, and depends on the ratio t_q/t_q^0. It is appropriate to stipulate this ratio for designing the experiment.

Rao and Ramesh Naidu (2014) [21] obtained the minimum values of n satisfying the inequality (4) for ν =2, α =0.75, 0.90, 0.95, 0.99 and t_q/t_q^0 =0.7, 0.9, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 which are provided in Table-4 for ready reference.

The inequality (4) is presented in different way in the current study. Let the sample size n is fixed and r ($<n$) be a natural number, the process will be stopped and the lot is rejected as soon as the $r^{th}(r=c+1)$ failure occurs. The probability that the rejection of that lot must be as small as possible for the given $t_q > t_q^0$ and it is given by:

$$\sum_{i=r}^{n}\binom{n}{i}p^{i}(1-p)^{n-i}\leq 1-\alpha \qquad (5)$$

The inequality (5) can be viewed as an inequality in an unknown quantity t_q/t_q^0 with known parameter ν by taking n as a multiple of r say kr (k =1, 2 …). The inequality (5) will be solved for the smallest p say p_0 from which the value of t_q/t_q^0 can be attained by inverting the $F(t;\nu,\sigma)$ given by eqn. (2) by choosing certain values of r,k,α. Here the value of termination time t can be obtained for the definite population average in terms of t_q^0. These values are provided in Table 1 for different values of n, r =1(1)10, ν =2 at α =0.75, 0.90, 0.95, 0.99 and Table 2 and Table 3 provide different values of r =1(1)10 for ν =3 and the estimated values $\hat{\nu}$ =1.1358 respectively at α =0.75, 0.90, 0.95, 0.99 and also Table-5 and Table-6 provided the comparison between Rao and Ramesh Naidu (2014) [21] and the current smpling plan for α =0.95 and 0.99.

The operating characteristic function of sampling plan (*n, c,* t_q/t_q^0) gives the probability of accepting the lot as

$$L(p)=\sum_{i=0}^{c}\binom{n}{i}p^{i}(1-p)^{n-i} \qquad (6)$$

Where $p=F(t;\nu,\sigma)$. It will be taken in terms of the quality parameter σ. It is observed that for specific α and t_q/t_q^0 the operating characteristic is an increasing function of t_q.

4. Real Data example

In this section, the proposed economic reliability test plan for EHLD is illustrated with following real lifetime data on clean up gradient ground-water monitoring wells in (µg/L) from vinyl chloride data. This data was used by Bhaumik and Gibbons (2006) [5] and Krishanamoorty, Mathew and Mukhejee (2008). For ready reference the data is given below:

0.1, 0.1, 0.2, 0.2, 0.4, 0.4, 0.4 , 0.5, 0.5, 0.5, 0.6, 0.6, 0.8, 0.9, 0.9, 1.0, 1.1, 1.2, 1.2, 1.3, 1.8, 2.0, 2.0, 2.3, 2.4, 2.5, 2.7, 2.9, 3.2, 4.0, 5.1, 5.3, 6.8, 8.0.

Assume that the data set follows the EHLD, the MLE of the shape parameter ν is given by $\hat{\nu}=1.1358$. To test the goodness of fit we apply the Kolmogorov-Smirnov test, it is observed that for the data set Kolmogorov-Smirnov statistic is 0.1192 with p-value is 0.719. Thus, the data set is reasonably fitted for EHLD. Figure 1 display Superimposed Empirical, Theoretical Density plots and Q-Q plot, which shows that EHLD well fitted for this data set.

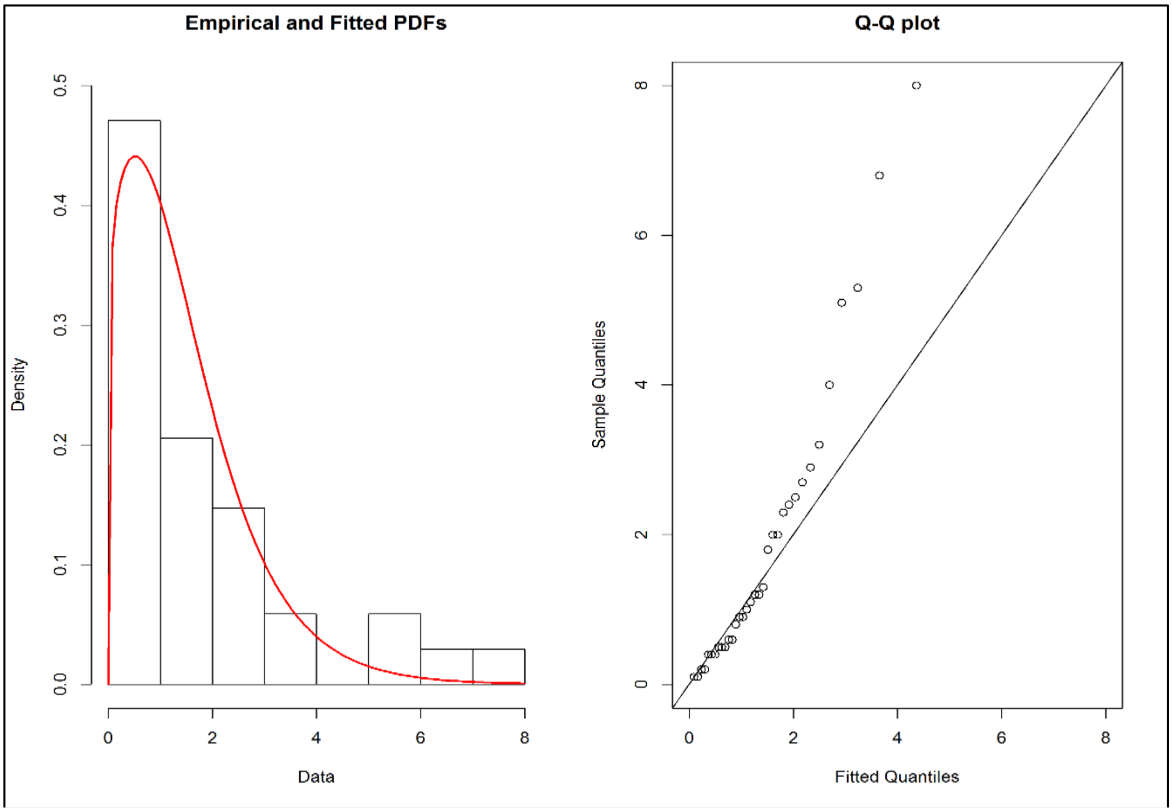

Fig 1: Superimposed empirical, Theoretical density plots and Q-Q Plot of the fitted EHLD for vinyl chloride data.

4.1. Acceptance Sampling Plan
It is assumed that the clean up gradient ground-water monitoring wells in (µg/L) from vinyl chloride data follows the EHLD. Let the specified median gradient ground-water be 0.4 µg/L and the target median gradient ground-water be 0.36 µg/L, this leads to ratio 0.90 with corresponding *n* =5, *c* =0 from Table 1 of Rao and Rameshnaidu (2014) [21] with confidence level of 0.95. Then for this sampling plan (5, 0, 0.90), we accept the product if no more than zero failure occurs during 0.36 µg/L. From data we can see that there are four readings before 0.36 µg/L. Then according to existing acceptance sampling plan we reject the product.

4.2. The Reliability Sampling Plan
Form Table 1, the entry against r =1 (r = c+1) under the column 5*r* is 0.0356. Since the specified median gradient ground-water be 0.4 µg/L, for the EHLD. If the termination median gradient ground-water is given by 't_q' the table value says that t_q / t_q^0 =0. 0356, which gives that is t_q = 0.0356 × 0.4 = 0.01424 µg/L.

This test will be implemented as follows: Select 5 items from the submitted lot of a product and reject this lot if more than zero failure is recorded in this sample before the experiment median gradient ground-water 0.01424 µg/L otherwise accept the lot in either case terminating the experiment as soon as the 1st failure is reached before 0.01424 µg/L or 0.01424 µg/L of the test gradient ground-water is reached whichever is earlier. In the proposed approach, we see that in the sample of 5 gradient ground-water measurements there is no gradient ground-water measurement before 0.01424 µg/L; therefore we accept the product with probability of acceptance 0.95. Then for this gradient ground-water measurement sampling plan (5, 0, 0. 0356) is more economic than the sampling plan (5, 0, 0.90).

4.3. Comparison of Probability of Acceptance
The probability of acceptance of sampling plan (5, 0, 0.90) given by Rao and Rao (2012) [19] is 0.00001. The probability of acceptance of the sampling plan (5, 0, 0. 0356) is 0.8342. This plan also gives less producer's risk than the acceptance sampling plans given by Rao and Rameshnaidu (2014) [21]. Figure 2 display the operating characteristic curves for the sampling plans (8, 1, 0. 4377), (12, 2, 0. 5497) and (15, 2, 0. 4864) respectively.

In both of these approaches the sample size, acceptance number (termination number), the risk probability and the final decision about the lot are the same. But the decision on the first approach can be reached at the 0.90 gradient ground-water measurements and that in the second approach reached at the 0.0356 gradient ground-water measurements, thus second approach (the present sampling plan) requiring a less waiting time and also minimum experimental cost. Hence, the present sampling plan is preferred.

5 Conclusions
In this article, an economic reliability test plans under the assumption that the life of a product follows EHLD is proposed. The proposed plan yields the minimum ratio of the termination time that is required to test the items to decide upon whether a submitted lot is accept or reject. The operating characteristic curve for values of the plan against a specified producer's risk is also presented. The proposed plan is useful in minimizing the producer's risk. Further, the decision based on the ratio of the termination times of the experiment using proposed plans are found to be less than that of existing sampling plans constructed by of Rao and Ramesh Naidu (2014) [21].

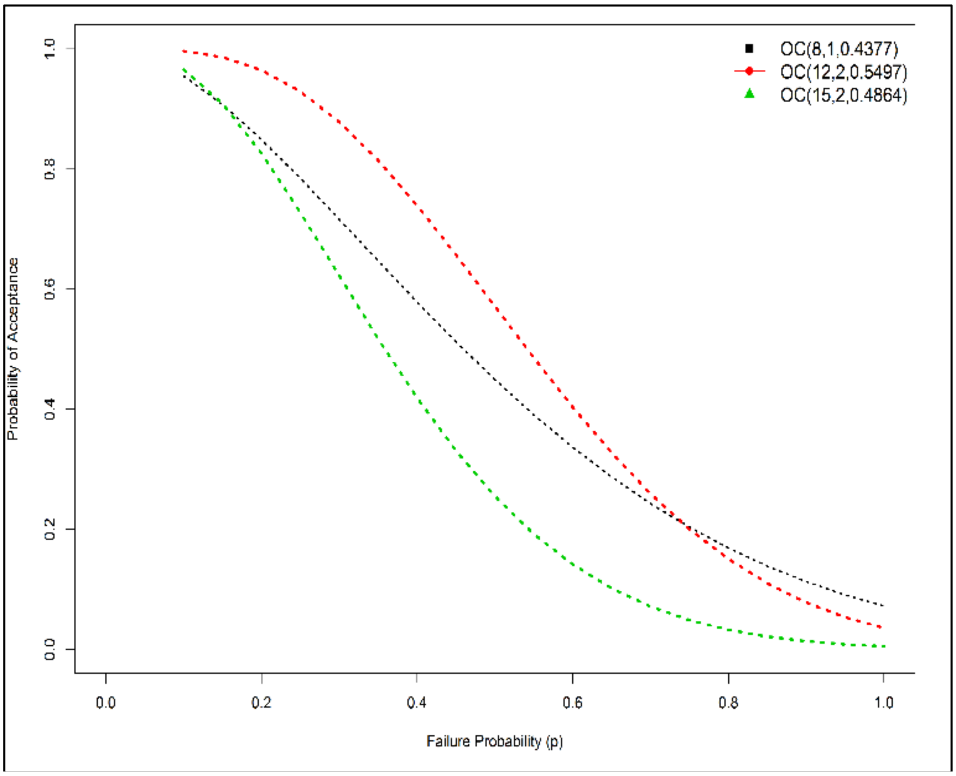

Fig 2: Operating Characteristic Curve for different sampling plans

Table 1: The minimum sample size required to emphasize the average life to exceed specified average life t_q^0 with probability $1-\alpha$ and the corresponding acceptance number c, using binomial probability for ν =2 in EHLD.

r	n=2r	3r	4r	5r	6r	7r	8r	9r	10r
					α=0.75				
1	0.7677	0.6245	0.5396	0.4824	0.4401	0.4070	0.3808	0.3588	0.3403
2	1.0802	0.8509	0.7250	0.6425	0.5827	0.5372	0.5009	0.4711	0.4464
3	1.2224	0.9501	0.8047	0.7108	0.6436	0.5926	0.5521	0.5189	0.4909
4	1.3060	1.0073	0.8506	0.7499	0.6785	0.6242	0.5812	0.5461	0.5164
5	1.3621	1.0454	0.8812	0.7762	0.7015	0.6450	0.6005	0.5640	0.5335
6	1.4030	1.0729	0.9032	0.7949	0.7181	0.6602	0.6143	0.5769	0.5453
7	1.4340	1.0938	0.9198	0.8090	0.7309	0.6716	0.6249	0.5865	0.5549
8	1.4587	1.1106	0.9332	0.8206	0.7409	0.6809	0.6332	0.5945	0.5621
9	1.4789	1.1241	0.9439	0.8296	0.7490	0.6880	0.6400	0.6009	0.5680
10	1.4960	1.1355	0.9529	0.8374	0.7560	0.6945	0.6457	0.6061	0.5730
					α=0.90				
1	0.4615	0.3764	0.3253	0.2912	0.2661	0.2462	0.2299	0.2172	0.2057
2	0.7946	0.6285	0.5367	0.4761	0.4323	0.3986	0.3719	0.3499	0.3316
3	0.9652	0.7535	0.6397	0.5656	0.5125	0.4720	0.4401	0.4137	0.3917
4	1.0711	0.8299	0.7025	0.6201	0.5613	0.5164	0.4811	0.4521	0.4278
5	1.1448	0.8826	0.7454	0.6574	0.5945	0.5469	0.5091	0.4784	0.4525
6	1.1994	0.9215	0.7772	0.6846	0.6190	0.5691	0.5297	0.4979	0.4707
7	1.2422	0.9518	0.8020	0.7062	0.6382	0.5865	0.5461	0.5130	0.4851
8	1.2769	0.9764	0.8218	0.7234	0.6535	0.6005	0.5589	0.5248	0.4961
9	1.3054	0.9966	0.8380	0.7374	0.6661	0.6121	0.5695	0.5347	0.5057
10	1.3296	1.0136	0.8521	0.7493	0.6768	0.6220	0.5785	0.5433	0.5138
					α=0.95				
1	0.3215	0.2623	0.2273	0.2037	0.1860	0.1725	0.1603	0.1513	0.1445
2	0.6468	0.5125	0.4377	0.3885	0.3529	0.3253	0.3036	0.2862	0.2707
3	0.8269	0.6471	0.5497	0.4864	0.4411	0.4060	0.3786	0.3558	0.3372
4	0.9428	0.7322	0.6201	0.5477	0.4961	0.4568	0.4254	0.3997	0.3781
5	1.0245	0.7918	0.6692	0.5903	0.5343	0.4918	0.4577	0.4303	0.4070
6	1.0861	0.8366	0.7062	0.6223	0.5629	0.5176	0.4820	0.4530	0.4283
7	1.1347	0.8715	0.7348	0.6475	0.5854	0.5384	0.5009	0.4707	0.4449
8	1.1745	0.9000	0.7582	0.6678	0.6035	0.5549	0.5164	0.4851	0.4587
9	1.2075	0.9238	0.7775	0.6846	0.6183	0.5684	0.5289	0.4970	0.4698
10	1.2355	0.9439	0.7940	0.6988	0.6314	0.5804	0.5400	0.5070	0.4793
					α=0.99				
1	0.1431	0.1168	0.1021	0.0917	0.0825	0.0775	0.0721	0.0693	0.0664
2	0.4158	0.3304	0.2826	0.2511	0.2281	0.2105	0.1966	0.1849	0.1748
3	0.5998	0.4707	0.4002	0.3547	0.3215	0.2961	0.2760	0.2599	0.2462
4	0.7260	0.5656	0.4797	0.4244	0.3841	0.3541	0.3298	0.3097	0.2933
5	0.8188	0.6350	0.5376	0.4748	0.4298	0.3955	0.3685	0.3464	0.3279
6	0.8905	0.6880	0.5815	0.5134	0.4642	0.4273	0.3981	0.3736	0.3535
7	0.9478	0.7306	0.6168	0.5441	0.4918	0.4525	0.4213	0.3960	0.3747
8	0.9952	0.7655	0.6457	0.5691	0.5147	0.4734	0.4406	0.4137	0.3912
9	1.0349	0.7946	0.6699	0.5903	0.5335	0.4904	0.4568	0.4288	0.4055
10	1.0692	0.8197	0.6907	0.6084	0.5497	0.5053	0.4702	0.4416	0.4178

Table 2: The minimum sample size required to emphasize the average life to exceed specified average life t_q^0 with probability $1-\alpha$ and the corresponding acceptance number c, using binomial probability for ν =3 in EHLD

r	n=2r	3r	4r	5r	6r	7r	8r	9r	10r
					α=0.75				
1	1.1301	0.9710	0.8735	0.8062	0.7552	0.7146	0.6820	0.6540	0.6303
2	1.4634	1.2203	1.0832	0.9913	0.9233	0.8707	0.8281	0.7927	0.7628
3	1.6113	1.3264	1.1704	1.0676	0.9925	0.9346	0.8881	0.8493	0.8162
4	1.6975	1.3869	1.2200	1.1106	1.0316	0.9705	0.9215	0.8811	0.8463
5	1.7551	1.4270	1.2529	1.1394	1.0572	0.9941	0.9437	0.9018	0.8663
6	1.7970	1.4558	1.2764	1.1597	1.0756	1.0111	0.9593	0.9167	0.8801
7	1.8288	1.4777	1.2942	1.1751	1.0897	1.0239	0.9714	0.9277	0.8913
8	1.8539	1.4952	1.3084	1.1876	1.1007	1.0343	0.9808	0.9368	0.8996
9	1.8746	1.5093	1.3198	1.1974	1.1096	1.0422	0.9885	0.9441	0.9064
10	1.8920	1.5212	1.3294	1.2058	1.1173	1.0494	0.9949	0.9501	0.9122
					α=0.90				
1	0.7810	0.6764	0.6108	0.5655	0.5314	0.5036	0.4805	0.4621	0.4452
2	1.1594	0.9755	0.8702	0.7987	0.7457	0.7042	0.6707	0.6427	0.6190
3	1.3424	1.1145	0.9881	0.9037	0.8418	0.7938	0.7552	0.7229	0.6956
4	1.4539	1.1977	1.0583	0.9660	0.8986	0.8463	0.8046	0.7697	0.7403

5	1.5308	1.2544	1.1057	1.0080	0.9368	0.8820	0.8378	0.8014	0.7703
6	1.5875	1.2960	1.1404	1.0385	0.9647	0.9077	0.8620	0.8245	0.7921
7	1.6318	1.3282	1.1674	1.0624	0.9864	0.9277	0.8811	0.8423	0.8094
8	1.6675	1.3542	1.1889	1.0814	1.0036	0.9437	0.8959	0.8562	0.8225
9	1.6970	1.3756	1.2065	1.0968	1.0177	0.9568	0.9082	0.8678	0.8338
10	1.7218	1.3935	1.2216	1.1099	1.0297	0.9681	0.9184	0.8778	0.8433
α=0.95									
1	0.6058	0.5261	0.4767	0.4422	0.4156	0.3948	0.3757	0.3611	0.3500
2	0.9961	0.8418	0.7523	0.6915	0.6465	0.6108	0.5822	0.5588	0.5377
3	1.1945	0.9965	0.8853	0.8110	0.7564	0.7134	0.6792	0.6503	0.6263
4	1.3186	1.0911	0.9660	0.8829	0.8225	0.7754	0.7372	0.7055	0.6785
5	1.4050	1.1564	1.0212	0.9320	0.8673	0.8173	0.7766	0.7433	0.7146
6	1.4696	1.2049	1.0624	0.9685	0.9005	0.8478	0.8056	0.7709	0.7409
7	1.5204	1.2425	1.0940	0.9969	0.9264	0.8721	0.8281	0.7921	0.7611
8	1.5617	1.2730	1.1197	1.0197	0.9471	0.8913	0.8463	0.8094	0.7777
9	1.5959	1.2984	1.1408	1.0385	0.9639	0.9068	0.8610	0.8235	0.7910
10	1.6248	1.3198	1.1587	1.0542	0.9787	0.9207	0.8740	0.8353	0.8024
α=0.99									
1	0.3477	0.3030	0.2768	0.2575	0.2398	0.2300	0.2192	0.2133	0.2072
2	0.7254	0.6174	0.5539	0.5105	0.4780	0.4524	0.4316	0.4140	0.3984
3	0.9428	0.7921	0.7062	0.6488	0.6058	0.5721	0.5449	0.5228	0.5036
4	1.0843	0.9037	0.8030	0.7360	0.6861	0.6480	0.6166	0.5902	0.5684
5	1.1856	0.9828	0.8711	0.7970	0.7427	0.7003	0.6664	0.6381	0.6141
6	1.2628	1.0422	0.9220	0.8428	0.7844	0.7396	0.7036	0.6728	0.6473
7	1.3240	1.0893	0.9623	0.8787	0.8173	0.7703	0.7323	0.7009	0.6743
8	1.3741	1.1277	0.9949	0.9077	0.8443	0.7954	0.7558	0.7229	0.6949
9	1.4159	1.1594	1.0220	0.9320	0.8663	0.8157	0.7754	0.7415	0.7127
10	1.4519	1.1866	1.0453	0.9526	0.8853	0.8332	0.7916	0.7570	0.7279

Table 3: The minimum sample size required to emphasize the average life to exceed specified average life t_q^0 with probability $1-\alpha$ and the corresponding acceptance number c, using binomial probability for $\hat{\nu}$ =1.1358 in EHLD.

r	n=2r	3r	4r	5r	6r	7r	8r	9r	10r
α=0.75									
1	0.3442	0.2448	0.1915	0.1584	0.1354	0.1185	0.1057	0.0953	0.0870
2	0.5925	0.4065	0.3134	0.2567	0.2180	0.1901	0.1689	0.1522	0.1388
3	0.7159	0.4848	0.3715	0.3034	0.2574	0.2242	0.1991	0.1793	0.1632
4	0.7905	0.5315	0.4063	0.3312	0.2809	0.2446	0.2170	0.1954	0.1778
5	0.8414	0.5632	0.4300	0.3504	0.2968	0.2583	0.2293	0.2064	0.1879
6	0.8788	0.5864	0.4473	0.3642	0.3085	0.2685	0.2381	0.2144	0.1950
7	0.9074	0.6041	0.4605	0.3747	0.3176	0.2762	0.2450	0.2204	0.2008
8	0.9301	0.6185	0.4711	0.3834	0.3247	0.2826	0.2505	0.2254	0.2052
9	0.9489	0.6301	0.4798	0.3903	0.3305	0.2875	0.2550	0.2295	0.2088
10	0.9648	0.6399	0.4870	0.3963	0.3356	0.2919	0.2588	0.2329	0.2120
α=0.90									
1	0.1469	0.1036	0.0805	0.0664	0.0568	0.0496	0.0440	0.0398	0.0362
2	0.3640	0.2474	0.1898	0.1549	0.1314	0.1143	0.1014	0.0913	0.0832
3	0.4970	0.3338	0.2548	0.2074	0.1756	0.1527	0.1354	0.1218	0.1109
4	0.5848	0.3905	0.2975	0.2419	0.2047	0.1778	0.1577	0.1418	0.1290
5	0.6479	0.4311	0.3280	0.2666	0.2254	0.1959	0.1736	0.1562	0.1421
6	0.6956	0.4618	0.3511	0.2852	0.2412	0.2095	0.1857	0.1671	0.1519
7	0.7334	0.4861	0.3695	0.3001	0.2538	0.2204	0.1954	0.1758	0.1599
8	0.7643	0.5061	0.3844	0.3122	0.2640	0.2293	0.2032	0.1827	0.1662
9	0.7900	0.5226	0.3967	0.3222	0.2725	0.2367	0.2098	0.1886	0.1716
10	0.8119	0.5367	0.4074	0.3308	0.2798	0.2431	0.2153	0.1937	0.1763
α=0.95									
1	0.0789	0.0554	0.0431	0.0356	0.0304	0.0266	0.0234	0.0212	0.0195
2	0.2595	0.1756	0.1342	0.1093	0.0927	0.0805	0.0714	0.0644	0.0585
3	0.3883	0.2597	0.1976	0.1607	0.1360	0.1180	0.1046	0.0940	0.0857
4	0.4789	0.3185	0.2419	0.1964	0.1662	0.1443	0.1278	0.1148	0.1044
5	0.5458	0.3619	0.2746	0.2228	0.1884	0.1637	0.1448	0.1303	0.1185
6	0.5975	0.3956	0.3001	0.2434	0.2057	0.1785	0.1582	0.1423	0.1293
7	0.6392	0.4225	0.3203	0.2600	0.2197	0.1908	0.1689	0.1519	0.1380
8	0.6738	0.4448	0.3372	0.2736	0.2312	0.2008	0.1778	0.1599	0.1453
9	0.7027	0.4636	0.3513	0.2852	0.2407	0.2091	0.1852	0.1666	0.1514
10	0.7274	0.4798	0.3635	0.2950	0.2493	0.2165	0.1918	0.1724	0.1567
α=0.99									
1	0.0192	0.0134	0.0106	0.0088	0.0073	0.0065	0.0058	0.0054	0.0050
2	0.1229	0.0827	0.0630	0.0513	0.0434	0.0377	0.0335	0.0301	0.0272

3	0.2288	0.1519	0.1151	0.0935	0.0789	0.0684	0.0605	0.0545	0.0496
4	0.3141	0.2074	0.1569	0.1273	0.1072	0.0932	0.0824	0.0739	0.0672
5	0.3821	0.2517	0.1903	0.1542	0.1301	0.1127	0.0999	0.0897	0.0816
6	0.4373	0.2875	0.2173	0.1761	0.1484	0.1288	0.1141	0.1022	0.0929
7	0.4829	0.3173	0.2398	0.1942	0.1637	0.1421	0.1257	0.1130	0.1028
8	0.5215	0.3425	0.2588	0.2095	0.1768	0.1534	0.1357	0.1218	0.1107
9	0.5544	0.3640	0.2751	0.2228	0.1879	0.1629	0.1443	0.1296	0.1177
10	0.5832	0.3828	0.2894	0.2343	0.1976	0.1714	0.1516	0.1362	0.1239

Table 4: Minimum sample sizes necessary to assert the 50th percentile to exceed a given values, $t_{0.5}^{0}$, with probability p^* and the corresponding acceptance number, *c*, for the EHLD using the binomial approximation with ν =1.1358.

p^*	*c*	$t_{0.5} / t_{0.5}^{0}$							
		0.7	**0.9**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**
0.75	0	4	3	2	2	1	1	1	1
0.75	1	7	6	5	3	3	2	2	2
0.75	2	11	8	7	5	4	4	3	3
0.75	3	14	11	10	7	5	5	4	4
0.75	4	17	13	12	8	7	6	6	5
0.75	5	20	16	14	10	8	7	7	6
0.75	6	23	18	16	11	9	8	8	7
0.75	7	26	20	18	13	11	9	9	8
0.75	8	29	23	21	14	12	11	10	10
0.75	9	32	25	23	16	13	12	11	11
0.75	10	36	28	25	17	14	13	12	12
0.90	0	6	4	4	2	2	2	1	1
0.90	1	10	7	7	4	3	3	3	2
0.90	2	14	10	9	6	5	4	4	3
0.90	3	17	13	12	8	6	5	5	5
0.90	4	21	16	14	10	8	7	6	6
0.90	5	24	19	17	11	9	8	7	7
0.90	6	28	21	19	13	10	9	8	8
0.90	7	31	24	21	15	12	10	9	9
0.90	8	34	26	24	16	13	11	11	10
0.90	9	38	29	26	18	14	13	12	11
0.90	10	41	31	28	19	16	14	13	12
0.95	0	7	5	5	3	2	2	2	1
0.95	1	12	9	8	5	4	3	3	3
0.95	2	16	12	11	7	5	5	4	4
0.95	3	20	15	13	9	7	6	5	5
0.95	4	23	18	16	11	8	7	6	6
0.95	5	27	21	18	12	10	8	8	7
0.95	6	31	23	21	14	11	10	9	8
0.95	7	34	26	23	16	12	11	10	9
0.95	8	38	29	26	17	14	12	11	10
0.95	9	41	31	28	19	15	13	12	11
0.95	10	44	34	30	21	17	14	13	13
0.99	0	11	8	7	4	3	3	2	2
0.99	1	16	12	11	7	5	4	3	3
0.99	2	21	15	14	9	7	5	5	4
0.99	3	25	19	17	11	8	7	6	5
0.99	4	29	22	19	13	10	8	7	7
0.99	5	33	25	22	15	11	9	8	8
0.99	6	37	28	25	16	13	11	10	9
0.99	7	41	31	27	18	14	12	11	10
0.99	8	44	34	30	20	16	13	12	11
0.99	9	48	36	33	22	17	15	13	12
0.99	10	52	39	35	23	18	16	14	13

Table 5: Comparison of life test termination times in units of scale parameter t_q/t_q^0 for the present sampling plans and the sampling plans of Rao & Rameshnaidu (2014) [21] with producer's risk α =0.95 and for $\hat{v}$ =1.1358 (t_q/t_q^0 Values of Rao et al. (2016) are given in the parenthesis).

n / r	**2r**	**3r**	**4r**	**5r**	**6r**	**7r**	**8r**	**9r**	**10r**
1	0.0789 2.0	0.0554 1.5		0.0356 0.9		0.0266 0.7			
2	0.2595 2.0		0.1342 1.0		0.0927 0.7				
3		0.2597 0.9							
4				0.1964 0.7					
5									
6	0.5975 1.5	0.3956 1.0							
7	0.6392 1.5	0.4225 1.0							
8	0.6738 1.5								
9									
10									

Table 6: Comparison of life test termination times in units of scale parameter t_q/t_q^0 for the present sampling plans and the sampling plans of Rao & Rameshnaidu (2014) [21] with producer's risk α =0.99 and for $\hat{v}$ =1.1358 *(t_q/t_q^0 Values of Rao et al. (2016) are given in the parenthesis).*

n / r	**2r**	**3r**	**4r**	**5r**	**6r**	**7r**	**8r**	**9r**	**10r**
1	0.0192 3.0	0.0134 2.0	0.0106 1.5			0.0065 1.0	0.0058 0.9		
2	0.1229 2.5				0.0434 0.9		0.0335 0.7		
3		0.1519 1.5		0.0935 0.9		0.0684 0.7			
4	0.3141 2.0								
5	0.3821 2.0								
6									
7			0.2398 0.9						
8									
9									
10									

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