STUDY ON ACCEPTANCE SAMPLING PLAN BASED ON PERCENTILES FOR EXPONENTIATED GENERALIZED INVERSE RAYLEIGH DISTRIBUTION

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Abstract

An acceptance sampling plan is a sampling procedure with a set of rules for making decisions about a lot of products. The decision is based on the number of defectives in a sample. The sampling inspection plans which are developed for taking decision about a lot based on lifetime of the product are called reliability sampling plans. In this paper, we have developed Acceptance sampling plan (ASP) based on truncated life tests when the lifetime of a product follows the exponentiated generalized inverse Rayleigh distribution (EGIR). The minimum sample sizes needed to ensure the specified life percentile are obtained for a fixed value of the consumer™s confidence level. The operating characteristic values according to the different quality levels are obtained and the minimum ratios of the mean life to the specified life are calculated. The important tables based on the suggested acceptance sampling plan are calculated and illustrated.

Keywords: Acceptance Sampling Plan, Truncated Life Tests, Percentiles, Exponentiated Generalized Inverse Rayleigh Distribution, Operating Characteristic function, producer's Risk

1. Introduction

Two important tools for ensuring quality are statistical quality control and acceptance sampling (AS). Acceptance sampling is concerned with inspection and decision-making regarding lots of products and constitutes one of the oldest techniques in quality control. If the quality characteristic is about the lifetime of the product, the acceptance sampling problem becomes a life test. To determine the sample size from a lot under consideration is the main issue in most acceptance sampling plans for a truncated life test.

If the life test indicates that the true mean lifetime of products exceeds the specified one, then the lot is accepted, otherwise it is rejected. For the purpose of reducing the test time and cost, a truncated life test may be conducted to determine the smallest sample size to ensure certain mean lifetime or percentile lifetime of products when the life test is terminated at a pre-determined time, and the number of failures observed does not exceed a given acceptance number c. The decision is to accept the lot if a pre-determined mean life time or percentile life can be reached with a pre-determined high probability which provides protection to the consumer. Therefore, the life test is ended at the time the failure is observed or at the pre-assigned time, whichever is earlier. For such a truncated life test and the associated decision rule, we are interested in determining the smallest sample size to arrive at a decision.

Epstein [3] was the first who considered truncated life tests in the exponential distribution. Truncated life tests are considered by many authors for various distributions. Sobel and Tischendrof [15], Gupta and Groll [5] using Gamma distribution, Kantam and Rosaiah [6] based on Half logistic distribution, Ayman et al. [1] using Rayleigh model, Tsai and Wu [17] based on Generalized Rayleigh distribution, Balakrishnan et al. [2] discussed generalized Birnbaum"Saunders distribution. Kantam et al. [7] considered truncated life tests for log-logistic distribution, Rao [13] considered acceptance sampling plans for Marshall"Olkin extended Lomax distribution.

Percentiles provide more information about a life distribution than the mean life does. When the life distribution is symmetric, the 50^{th} percentile or the median is equivalent to the mean life. Hence, developing acceptance sampling plans based on percentiles of a life distribution can be treated as a generalization of developing acceptance sampling plans based on the mean life of it. Lio et al. [8] developed acceptance sampling plans for percentiles using Birnbaum-Saunders distribution. Rao and Kantam [12] considered acceptance sampling plans for truncated life tests based on the log-logistic distribution for percentiles. Rao et al. [11] developed acceptance sampling plans for percentiles based on the inverse Rayleigh distribution. Srinivasa Rao and Kantam [16] studied acceptance sampling plans for percentiles of half logistic distribution. Rao and Naidu [14] considered acceptance sampling plans for Percentiles based on the Exponentiated Half Logistic distribution. Pradeepa Veerakumari and Ponneeswari [10] designed acceptance double sampling plan for life test based on percentiles of Exponentiated Rayleigh distribution. Neena Krishna and Jayalakshmi [9] studied special type double sampling plan for life tests based on percentiles using Exponentiated Frechet Distribution. Percentiles are taken into account because lesser percentile provides more information than mean life regarding the life distribution.

2. Exponentiated Generalized Inverse Rayleigh Distribution

The Exponentiated Generalized Inverse Rayleigh distribution was developed by Fatima et al. in 2018. The CDF of the Exponentiated Generalized Inverse Rayleigh distribution is given by

$$F(t;\alpha,\sigma,\gamma) = [1-[1-e^{(}\frac{-\sigma^2}{t^2})]^{\alpha}]^{\gamma} \tag{1}$$

The PDF of the distribution is given as

$$f(t;\alpha,\sigma,\gamma) = \frac{2\alpha\gamma\sigma^2}{t^2}e^{\frac{-\sigma^2}{t^2}}[1-e^{(}\frac{-\sigma^2}{t^2})]^{\alpha-1}][1-[1-e^{(}\frac{-\sigma^2}{t^2}/)]^{\alpha}]^{\gamma-1}]; t>0 \tag{2}$$

For given 0 < q < 1 the $100q^{t^{`}}$ actual percentile of the Exponentiated Generalized Inverse Rayleigh distribution can be given by

$$t_q = \frac{1}{\sigma}[-ln(1-(1-q^{\frac{1}{\gamma}})^{1/\alpha})]^{-1/2} \tag{3}$$

The t_q increase as q increases Let

$$\eta = [-ln(1-(1-q^{\frac{1}{\gamma}})^{1/\alpha})]^{-1/2} \tag{4}$$

Then from (3), $\sigma = \eta/t_q$
By letting $\delta = t/t_q$, F(t) becomes

$$F(t) = [1-[1-e^{-}(\delta\eta)^{-}2]^{\alpha}]^{\gamma} \tag{5}$$

Equation (5) gives the modified cdf and by partially differentiating the equation (5) w.r.t a we will get the modified pdf for percentiles of Exponentiated Generalized Inverse Rayleigh distribution where t_q is the 10^{th} percentile of the given distribution.

3. Proposed Acceptance Sampling Plan

Main goal of this study is to obtain minimum sample size required to ensure a percentile life when the life test is terminated at a pre-determined time t_q^0 and when the observed number of failures does not exceed a given acceptance number. The operating procedure of the sampling plan is to accept a lot only if the specified percentile of lifetime is fixed with pre-specified probability λ, which is an indicator of consumer confidence. The life test experiment gets terminated at the time $(c+1)^{th}$ failure is observed or at quantile time t_q whichever is earlier.

A sampling plan in which a decision about the acceptance or rejection of a lot is based on a single sample that has been inspected is known as a single sampling plan. A single sampling plan requires the specification of two quantities which are known as parameters of the single sampling plan. These parameters are n " size of the sample and c " acceptance number for the sample. The Reliability Single Sampling Plan can be represented as $(n, c, t/(t_q^0))$. Here n and c are the sample size and acceptance number for the sampling plan. Assume that a life test is conducted and will be terminated at time t_q^0.

3.1. Operating Procedure

The acceptance sampling plan based on truncated life tests consists of the following:

1. Draw a random sample of size n from the lot received from the supplier. The maximum test duration time is t.
2. We inspect each and every unit of the sample and classify it as defective or non-defective. At the end of the inspection, we count the number of defective units found in the sample. Suppose the number of defective units found in the sample is d.
3. We compare the number of defective units (d) found in the sample with the stated acceptance number (c).
4. We take the decision of acceptance or rejection of the lot on the basis of the sample as follows: If the number of defective units (d) in the sample is less than or equal to the stated acceptance number (c), i.e., if $d \leq c$ defectives out of n occur at the end of the test period t_q^0, we accept the lot and if $d > c$, we reject the lot.

3.2. Minimum sample size

Given P^* and assuming that the lot size is large enough to be considered infinite, then the probability of accepting a lot can be evaluated by the binomial cdf up to c and the smallest sample size n required to assert that $t_q > t_q^0$ must satisfy

$$\sum_{i=0}^{c} p^i (1-p)^{(n-i)} \leq (1 - P^*) \tag{6}$$

where p=F(t,δ_q), is the probability of a failure observed during the time t given a specified 100qth percentile of lifetime t_q^0 and depends only on δ=$t/(t_q^0)$ since t_q^0 increases as q increases. Accordingly, we have

$$F(t, \delta) < F(t, \delta_0) \iff \delta \leq \delta_0$$

Or, equivalently

$$F(t; t_q) < F(t; t_q^0) \iff t_q \geq t_q^0$$

The smallest sample size n satisfying eq. (6) can be obtained for any given sampling plan $(n, c, t/t_q^0)$ is given in Table 1.

3.3. Operating Characteristic (OC) Function

The OC function L(p) of the acceptance sampling plan (n,c,t/t_q^0) is the probability of accepting a lot. It is given as

$$L(p) = \sum_{i=0}^{c} p^i (1-p)^{(n-i)} \tag{7}$$

where $p = F(t, \delta_q)$. It should be noticed that $F(t, \delta_q)$ can be represented as a function of $\delta_q = t/t_q$. Therefore, we have

$$p = F(t, \delta) = F(\frac{t}{t_q}\frac{1}{d_q})$$

where d_q=t_q/t_q^0

Using eq. (7) the OC values can be obtained for any sampling plan $(n, c, t/t_q^0)$. The OC values for the proposed sampling plan is presented in Table 2.

3.4. Producer's Risk

The producer's risk is defined as the probability of rejecting the lot when $t_q > t_q^0$. For a given value of the producer's risk, say λ , we are interested in knowing the value of d_q to ensure the producer's risk is less than or equal to λ if a sampling plan $(n, c, t/t_q^0)$ is developed at a specified confidence level P^*. Thus, one needs to find the smallest value d_q according to euation (7).

$$L(p) \geq 1 - \lambda$$

Based on the sampling plans (n,c,$t/{t_q}^0$) given in Table 1 the minimum ratios of $d_{0.10}$ at the producer's risk of $\lambda = 0.05$ are presented in Table 3.

4. Illustration

Assume that the life distribution is Exponentiated Generalized Inverse Rayleigh distribution, and the experimenter is interested in showing that the true unknown 10^{th} percentile life $t_{0.10}$ is at least 1000 hrs. Let $\alpha = 2$,$\gamma = 1$ and $\lambda = 0.05$. It is desire to stop the experiment at time t=1500 hrs. For the acceptance number c=1 from the Table 1 one can obtain the Single Sampling plan $(n, c, t/t_q^0)$= (9,1,1.5). The optimum sample sizes needed for the given requirement is found to be as n=9. The respective OC values for the proposed acceptance sampling plan $(n, c, t/t_q^0)$ with $P^* = 0.95$ for Exponentiated Generalized Inverse Rayleigh distribution from the Table 2 are given in below table. This shows that if the actual 10^{th} percentile is equal to the required 10^{th} percentile

$t_q/(t_q^0)$	0.75	1	1.25	1.5	1.75	2	2.25	2.5
L(p)	0.0002	0.0525	0.3297	0.7748	0.9629	0.9965	0.9998	1

$(t_{0.10}/t_{0.10^0} = 1)$, the producer's risk is approximately 0.9475 $(1 - 0.0525)$. The producer's risk almost equal to zero when the actual 10^{th} percentile is greater than or equal to 2.5 times the specified 10^{th} percentile. Table 3 gives the $d_{0.10}$ values for c=1 and $t/t_{0.10}^0 = 1.5$ to assure that the producer's risk is less than or equal to 0.05.

In this example, the value of $d_{0.10}$ is 1.7136 for c=1,$t/t_{0.10}^0 = 1.5$ and λ =0.05. This means the product can have a 10th percentile life of 1.7136 times the required 10^{th} percentile lifetime. That is under the above Single Sampling Plan the product is accepted with probability of at least 0.95.

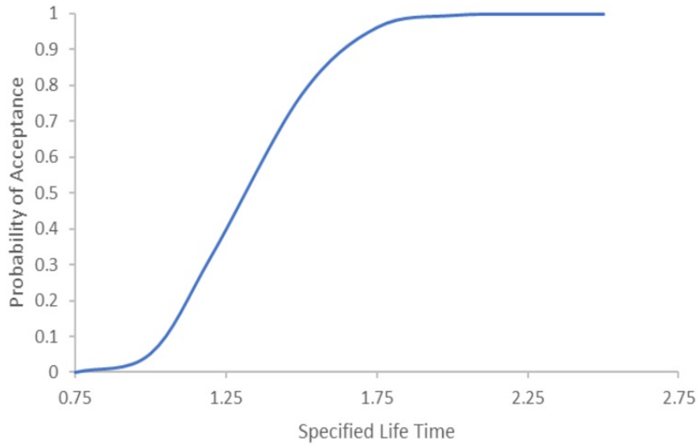

Figure 1: *OC curve for the sampling plan* $(n = 9, c = 1, t/t^0_{0.10} = 1.5)$

5. Construction of the Table

Step 1: Find the value of η for the fixed values of $\alpha = 2, \gamma = 1$ and q=0.10

Step 2: Set the value of $t/t_q{}^0$ =0.7, 0.9, 0.9, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5

Step 3: Find the sample size n by satisfying $L(p) \leq 1 - P^*$ when $P^* = 0.99, 0.95, 0.90$ and 0.75. Here P^* is the probability of rejecting a bad lot and

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

Step 4: for the n value obtained find the $d_{0.10}$ value such that $L(p) \geq 1 - \lambda$ where $\lambda = 0.05$ and $p = F(t/t^0_q, 1/d_q)$; $d_q = t_q/t^0_q$

Table 1: *Minimum Sample Size values necessary to assure* 10^{th} *percentile for Exponentiated Generalized Inverse Rayleigh distribution*

p^*	c	$t/(t^0_q)$							
		0.7	0.9	1.0	1.5	2.0	2.5	3	3.5
0.75	1	576	53	27	5	5	3	3	2
	2	841	77	39	8	4	4	3	3
	3	1096	101	51	10	7	5	5	3
	4	1346	124	62	13	8	6	6	5
	5	1592	146	73	15	9	7	7	5
0.90	1	834	76	38	8	5	4	3	2
	2	1143	105	52	10	6	5	5	3
	3	1433	131	66	12	7	6	5	5
	4	1714	156	78	16	8	7	6	6
	5	1988	182	91	18	11	8	8	7
0.95	1	1017	93	46	9	5	4	3	3
	2	1349	123	61	12	7	5	4	4
	3	1662	152	76	15	8	7	5	5
	4	1960	180	90	18	10	8	7	7
	5	2253	206	103	20	12	9	8	7
0.99	1	1417	128	63	12	7	4	4	3
	2	1794	162	81	16	8	7	5	5
	3	2143	194	97	18	10	8	7	6
	4	2480	225	113	21	12	10	8	8
	5	2803	255	127	24	13	10	9	8

Table 2: *Operating characteristic values of the sampling plan $(n, c = 1, t/(t_q^0))$ for a given P^* under Exponentiated Genereralized Inverse Rayleigh Distribution distribution*

p^*	$t/(t_q{}^0)$	n	$t_q/(t_q{}^0)$							
			0.75	1	1.25	1.5	1.75	2	2.25	2.5
0.75	0.7	576	0	0.2508	0.9963	1	1	1	1	1
	0.9	53	0	0.2451	0.9533	0.9996	1	1	1	1
	1	27	0.0002	0.2326	0.9055	0.9979	1	1	1	1
	1.5	5	0.0222	0.2372	0.6578	0.9185	0.9887	0.9990	0.9999	1
	2	5	0.0008	0.0222	0.1537	0.446	0.7469	0.9185	0.9806	0.9964
	2.5	3	0.0087	0.0555	0.1848	0.3975	0.6303	0.8128	0.9212	0.972
	3	3	0.0024	0.0177	0.0705	0.1848	0.3584	0.5555	0.7306	0.8569
	3.5	2	0.0322	0.0905	0.189	0.3223	0.4738	0.6223	0.7497	0.8469
0.90	0.7	834	0	0.0997	0.9924	1	1	1	1	1
	0.9	76	0	0.0983	0.9123	0.9992	1	1	1	1
	1	38	0	0.0953	0.8345	0.9958	1	1	1	1
	1.5	8	0.0007	0.0546	0.3973	0.8131	0.9705	0.9972	0.9998	1
	2	5	0.0008	0.0222	0.1537	0.446	0.7469	0.9185	0.9806	0.9964
	2.5	4	0.0006	0.0105	0.0658	0.217	0.4541	0.6927	0.8601	0.9477
	3	3	0.0024	0.0177	0.0705	0.1848	0.3584	0.5555	0.7306	0.8569
	3.5	2	0.0322	0.0905	0.189	0.3223	0.4738	0.6223	0.7497	0.8469
0.95	0.7	1017	0	0.0498	0.9889	1	1	1	1	1
	0.9	93	0	0.0481	0.8773	0.9989	1	1	1	1
	1	46	0	0.048	0.7787	0.994	0.9999	1	1	1
	1.5	9	0.0002	0.0525	0.3297	0.7748	0.9629	0.9965	0.9998	1
	2	5	0.0008	0.0222	0.1537	0.446	0.7469	0.9185	0.9806	0.9964
	2.5	4	0.00006	0.0105	0.0658	0.217	0.4541	0.6927	0.8601	0.9477
	3	3	0.0024	0.0177	0.0705	0.1848	0.3584	0.5555	0.7306	0.8569
	3.5	3	0.0008	0.0062	0.0277	0.0827	0.1848	0.3311	0.4996	0.6606
0.99	0.7	1417	0	0.0102	0.0102	1	1	1	1	1
	0.9	128	0	0.0103	0.0107	0.9979	1	1	1	1
	1	63	0	0.0105	0.0109	0.9889	0.9999	1	1	1
	1.5	12	0	0.0065	0.0084	0.659	0.9366	0.9936	0.9996	1
	2	7	0	0.0023	0.0023	0.2496	0.5898	0.8503	0.9618	0.9927
	2.5	4	0.0006	0.0105	0.0105	0.217	0.4541	0.6927	0.8601	0.9477
	3	4	0.0001	0.0019	0.0019	0.0658	0.1844	0.3701	0.5791	0.7581
	3.5	3	0.0008	0.0062	0.0062	0.0827	0.1848	0.3311	0.4996	0.6606

Table 3: *Minimum ratio of true $d_{0.10}$ for the acceptability of a lot for the Exponentiated Generalized Inverse Rayleigh distribution and producer's risk of $\lambda = 0.05$*

p^*	$t/(t_q^0)$	n	$t_q/(t_q^0)$							
0.75	0.7	576	1.1554	1.1546	1.1551	1.1551	1.1552	1.1549	1.155	1.1553
	0.9	53	1.246	1.2456	1.246	1.2459	1.2459	1.2458	1.2461	1.2464
	1	27	1.2985	1.2983	1.2985	1.2981	1.2987	1.2987	1.299	1.2988
	1.5	5	1.5676	1.5677	1.5672	1.5665	1.5681	1.5683	1.5696	1.5688
	2	5	2.0896	2.0902	2.0899	2.09	2.0878	2.0886	2.0902	2.0909
	2.5	3	2.3645	2.3641	2.3639	2.3618	2.3618	2.3637	2.3626	2.3652
	3	3	2.8339	2.8365	2.8371	2.8367	2.8322	2.8374	2.8371	2.8336
	3.5	2	2.9629	2.962	2.9633	2.9627	2.9585	2.9636	2.9629	2.9631
0.90	0.7	834	1.1811	1.1809	1.1812	1.181	1.1813	1.1811	1.1814	1.1815
	0.9	76	1.2846	1.2847	1.2842	1.2841	1.2853	1.2854	1.285	1.2854
	1	38	1.3426	1.3426	1.3426	1.3432	1.342	1.3421	1.3422	1.3436
	1.5	8	1.6855	1.6857	1.6856	1.6856	1.6881	1.6864	1.688	1.6857
	2	5	2.0896	2.0902	2.0899	2.09	2.0878	2.0886	2.0902	2.0909
	2.5	4	2.5101	2.5081	2.507	2.5098	2.5098	2.5095	2.5074	2.5107
	3	3	2.8339	2.8365	2.8371	2.8367	2.8322	2.8374	2.8371	2.8336
	3.5	2	2.9629	2.962	2.9633	2.9627	2.9585	2.9636	2.9629	2.9631
0.95	0.7	1017	1.1956	1.1947	1.1951	1.195	1.1947	1.1951	1.1952	1.1945
	0.9	93	1.306	1.3057	1.3059	1.3057	1.3065	1.3064	1.3064	1.3065
	1	46	1.3663	1.3666	1.3663	1.3657	1.367	1.3667	1.3674	1.3657
	1.5	9	1.7136	1.7136	1.7132	1.7129	1.7139	1.7131	1.7135	1.7151
	2	5	2.0896	2.0902	2.0899	2.09	2.0878	2.0886	2.0902	2.0909
	2.5	4	2.5101	2.5081	2.507	2.5098	2.5098	2.5095	2.5074	2.5107
	3	3	2.8339	2.8365	2.8371	2.8367	2.8322	2.8374	2.8371	2.8336
	3.5	3	3.3055	3.3101	3.3104	3.3101	3.3094	3.3103	3.31	3.3079
0.99	0.7	1417	1.2173	1.2171	1.2178	1.2174	1.2176	1.218	1.2178	1.2169
	0.9	128	1.3392	1.3388	1.3391	1.3396	1.3394	1.3389	1.3395	1.3395
	1	63	1.4046	1.4044	1.4051	1.4056	1.4052	1.4054	1.4051	1.4063
	1.5	12	1.7802	1.7775	1.7782	1.7787	1.7778	1.78	1.7796	1.7804
	2	7	2.202	2.2049	2.2048	2.2034	2.2033	2.2021	2.2023	2.206
	2.5	4	2.5101	2.5081	2.507	2.5098	2.5098	2.5095	2.5074	2.5107
	3	4	3.0117	3.0072	3.0121	3.0084	3.0116	3.0102	3.0077	3.0082
	3.5	3	3.3055	3.3101	3.3104	3.3101	3.3094	3.3103	3.31	3.3079

6. CONCLUSION

In this paper, acceptance sampling plan based on percentiles is suggested assuming that the lifetime of the products follows the Exponentiated Generalized Inverse Rayleigh distribution. The suggested Acceptance Sampling Plan is studied for fixed consumer's confidence level, minimum sample sizes necessary to assert the specified percentile life. The required Acceptance Sampling Plan tables are calculated and illustrated.

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