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A Repetitive Group Sampling Plan For Truncated Life Tests Using Log – Logistic, Exponentiated Log – Logistic, Rayleigh And Inverse Rayleigh Distributions

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ABSTRACT

In this paper, a repetitive group acceptance sampling plan is developed for a truncated life test when the lifetime of an item follows different lifetime distributions. Sample sizes required for the acceptance numbers are determined when the consumer's risk and the test termination time are specified. The operating characteristic values according to various quality levels are obtained. The results are explained with examples.

Keywords

Log - Logistic, exponentiated log – logistic, inverse Rayleigh and generalized Rayleigh distributions, repetitive group sampling plan, consumer's risk, Operating characteristics, Producer's risk, Truncated life test.

1. INTRODUCTION

The companies compete with each other on the basis of quality and reliability. Thus quality control has become one of the most important tools to differentiate between the competitive enterprises in a global business market.

Sherman in 1965 was the one who introduced the repetitive group sampling plan. According to him the attribute repetitive group plan is more efficient than the single sampling plan even its operation is similar to sequential sampling. Later in 1984 and 1986 Soundarajan and Ramasamy tabulated values for the selection of repetitive group sampling plan indexed through (AQL, AOQL); (p0, h0) and (p*, h*). The study was followed by Govindaraju who established OC functions for the repetitive group sampling plans in 1987. In 2004, Moon, Jun, Balamurali and Lee worked on the variable repetitive group sampling plan for minimizing average sample. Again in 2005, Moon, Jun, Balamurali and Lee along with Kim studied the designing of variable repetitive group sampling plan involving minimum average sample number. It was Balamurali and Jun again joined hands to determine the repetitive group sampling procedure for variables inspection in the year 2006. This repetitive group sampling plans is used to determine the number of groups by Aslam, Niaki, Rasool and Fallahnezhad in the year 2012.

Kantam R.R. L., Rosaiah K. and Srinivasa Rao G. (2001) discussed acceptance sampling based on life tests with Log-logistic models. Rosaiah K. et. Al., in 2007 studied exponentiated Log – Logistic distribution. In 2005, Rosaiah, K. et. Al., presented acceptance sampling based on the inverse Rayleigh distribution.

Muhammad Aslam in 2007, presented double acceptance sampling based on truncated life tests in Rayleigh distribution.

We here used the same repetitive group sampling to determine the sample size instead of determining the group. One can find that this method is far better than the other single sampling procedures due to its reduced sample sizes.

2. CUMULATIVE DISTRIBUTIVE FUNCTION

2.1 Log – Logistic distribution

The cumulative distribution function (cdf) of the Log – Logistic distribution is given by

$$F(t,\sigma) = \frac{\left(\frac{t}{\sigma}\right)^{\lambda}}{1+\left(\frac{t}{\sigma}\right)^{\lambda}}, \quad t > 0 \qquad (1)$$

where σ is a scale parameter and λ is the shape parameter and it is fixed as 2.

2.2 Exponentiated Log – Logistic Distribution

The cumulative distribution function (cdf) of the exponentiated Log – Logistic distribution is given by

$$F(t,\sigma) = \left(\frac{t/\sigma}{1+t/\sigma}\right)^{\lambda}, \quad t > 0 \qquad (2)$$

where σ is a scale parameter and λ is the shape parameter and it is fixed as 2.

2.3 Rayleigh distribution

The cumulative distribution function (cdf) of the Rayleigh distribution is given by

$$F(t/\sigma) = 1 - e^{-\frac{1}{2}\left(\frac{t}{\sigma}\right)^{2}}, \quad t > 0 \qquad (3)$$

where σ is a scale parameter.

2.4 Inverse Rayleigh Distribution

The cumulative distribution function (cdf) of the Inverse Rayleigh distribution is given by

$$F(t) = e^{-\frac{\sigma^2}{t^2}}, \quad t > 0 \qquad (4)$$

where σ is a scale parameter.

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If some other parameters are involved, then they are assumed to be known, for an example, if shape parameter of a distribution is unknown it is very difficult to design the acceptance sampling plan. In quality control analysis, the scale parameter is often called the quality parameter or characteristics parameter. Therefore it is assumed that the distribution function depends on time only through the ratio of t/ σ.

3. DESIGN OF THE PROPOSED PLAN

3.1 Conditions for its application

Repetitive group sampling plan comes under special purpose plans. It is intermediate in sample size efficiency between the single sampling plan and sequential probability ratio test plan. It has certain conditions for its application.

1. The size of the lot is taken to be sufficiently large.
2. Under normal conditions, the lots are expected to be of eventually the same quality.
3. The product comes from a source in which the consumer has confidence.

3.2 Operating Procedure for Repetitive Group Sampling Plan for Truncated Life Test

The operating procedure for a repetitive group sampling plan for truncated life tests is as follows:

1. Select the number of groups *g* and allocate predefined r items to each groups so that the sample size for a lot will be $n = rg$.
2. Accept the lot if the number of failures, d is smaller than or equal to c_1 in every group, before time t_0. Truncate the test and reject the lot of the product as soon as the number of failures, d, from a group exceeds c_2, (where $c_2 \geq c_1$), before time t_0.
3. If the number of failures, d, with $c_1 < d \leq c_2$, for every group, then go to step 1 and repeat the experiment.

The following is the operation characteristic function for the repetitive group sampling plan given by Sherman.

$$L(p) = \frac{p_a}{p_a + p_r} \quad ; 0 < p < 1 \tag{5}$$

Here p_a and p_r is the binomial model and equation (5) becomes

$$L(p) = \frac{\sum_{i=0}^{c_1} \binom{n}{i} p^i (1-p)^{n-i}}{1 - \sum_{i=0}^{c_2} \binom{n}{i} p^i (1-p)^{n-i} + \sum_{i=0}^{c_1} \binom{n}{i} p^i (1-p)^{n-i}} \tag{6}$$

Where in equation 5,

$$p_a = \sum_{i=0}^{c_1} \binom{n}{i} p^i (1-p)^{n-i}$$

and

$$p_r = 1 - \sum_{i=0}^{c_2} \binom{n}{i} p^i (1-p)^{n-i}$$

where p is the failure probability. These failure probabilities are the cumulative distribution function of the life time distributions.

By fixing the time termination ratios t/σ_0 as 0.628, 0.912, 1.257, 1.571, 2.356, 3.141, 3.927 and 4.712, the consumer's risk β as 0.25, 0.10, 0.05, and 0.01 and the mean ratios σ/σ_0 = 2, 4, 6, 8, 10 and 12, one can find the size of the first sample size n by substituting the failure probability p in the equations (5) and (6) and using the following inequality.

$$L(p) \leq \beta$$

The sample size generated using repetitive group sampling plan for the log – logistic, exponentiated log – logistic, Rayleigh and inverse Rayleigh distributions are presented in the Tables 1 – 4 respectively and their corresponding operating characteristic values are presented in the Tables 5 – 8 respectively.

4. NOTATION

g	-	Number of groups
r	-	Number of items in a group
n	-	Sample size
c	-	Acceptance number
t_0	-	Termination time
a	-	Test termination time multiplier
γ	-	Shape parameter
σ	-	Scale parameter
α	-	Producer's risk
β	-	Consumer's risk
p	-	Failure probability
L(*p*)	-	Probability of acceptance
μ	-	Mean life
μ_0	-	Specified life

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Table 1: Minimum sample size *n* for RGS plan when the lifetime of the items follows the log - logistic distribution

β	c_1	c_2	t/σ_0							
			0.628	**0.942**	**1.257**	**1.571**	**2.356**	**3.141**	**3.927**	**4.712**
0.25	**0**	**1**	6	3	3	2	2	2	2	2
	0	**2**	7	4	3	3	3	3	3	3
	0	**3**	9	5	4	4	4	4	4	4
	0	**4**	10	6	5	5	5	5	5	5
0.10	**0**	**1**	8	5	3	3	2	2	2	2
	0	**2**	9	5	4	3	3	3	3	3
	0	**3**	11	6	5	4	4	4	4	4
	0	**4**	12	7	5	5	5	5	5	5
0.05	**0**	**1**	10	6	4	3	2	2	2	2
	0	**2**	11	6	4	4	3	3	3	3
	0	**3**	12	7	5	4	4	4	4	4
	0	**4**	13	8	6	5	5	5	5	5
0.01	**0**	**1**	15	8	5	4	3	3	2	2
	0	**2**	15	8	6	5	3	3	3	3
	0	**3**	16	9	6	5	4	4	4	4
	0	**4**	16	9	7	6	5	5	5	5

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Table 2: Minimum sample size *n* for RGS plan when the lifetime of the items follows the exponentiated log - logistic distribution

β	c_1	c_2	t/σ_0							
			0.628	**0.942**	**1.257**	**1.571**	**2.356**	**3.141**	**3.927**	**4.712**
0.25	**0**	**1**	22	8	4	3	2	2	2	2
	0	**2**	26	9	6	4	3	3	3	3
	0	**3**	31	11	7	5	4	4	4	4
	0	**4**	36	13	8	6	5	5	5	5
0.10	**0**	**1**	31	11	6	4	3	2	2	2
	0	**2**	35	12	7	5	3	3	3	3
	0	**3**	39	14	8	6	4	4	4	4
	0	**4**	43	15	9	7	5	5	5	5
0.05	**0**	**1**	38	13	7	5	3	2	2	2
	0	**2**	41	14	8	6	4	3	3	3
	0	**3**	45	16	9	6	4	4	4	4
	0	**4**	49	17	10	7	5	5	5	5
0.01	**0**	**1**	56	19	10	7	4	3	3	2
	0	**2**	58	20	11	7	4	3	3	3
	0	**3**	60	20	11	8	5	4	4	4
	0	**4**	63	22	12	8	5	5	5	5

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Table 3: Minimum sample size *n* for RGS plan when the lifetime of the items follows the Rayleigh distribution

β	c_1	c_2	t/σ_0							
			0.628	**0.942**	**1.257**	**1.571**	**2.356**	**3.141**	**3.927**	**4.712**
0.25	**0**	**1**	10	5	3	2	2	2	2	2
	0	**2**	12	6	4	3	3	3	3	3
	0	**3**	14	7	5	4	4	4	4	4
	0	**4**	16	8	6	5	5	5	5	5
0.10	**0**	**1**	13	6	4	3	2	2	2	2
	0	**2**	15	7	4	3	3	3	3	3
	0	**3**	17	8	5	4	4	4	4	4
	0	**4**	19	9	6	5	5	5	5	5
0.05	**0**	**1**	17	8	5	3	2	2	2	2
	0	**2**	18	8	5	4	3	3	3	3
	0	**3**	19	9	6	4	4	4	4	4
	0	**4**	20	10	7	5	5	5	5	5
0.01	**0**	**1**	24	11	6	4	2	2	2	2
	0	**2**	25	11	7	5	3	3	3	3
	0	**3**	26	12	7	5	4	4	4	4
	0	**4**	27	13	8	6	5	5	5	5

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Table 4: Minimum sample size *n* for RGS plan when the lifetime of the items follows the inverse Rayleigh distribution

β	c_1	c_2	t/σ_0							
			0.628	**0.942**	**1.257**	**1.571**	**2.356**	**3.141**	**3.927**	**4.712**
0.25	**0**	**1**	22	5	3	2	2	2	2	2
	0	**2**	27	6	4	3	3	3	3	3
	0	**3**	32	8	5	4	4	4	4	4
	0	**4**	37	9	6	5	5	5	5	5
0.10	**0**	**1**	31	7	4	3	2	2	2	2
	0	**2**	35	8	5	4	3	3	3	3
	0	**3**	39	9	5	4	4	4	4	4
	0	**4**	44	10	6	5	5	5	5	5
0.05	**0**	**1**	39	9	5	3	2	2	2	2
	0	**2**	42	9	5	4	3	3	3	3
	0	**3**	45	10	6	5	4	4	4	4
	0	**4**	49	11	7	5	5	5	5	5
0.01	**0**	**1**	57	12	7	5	3	3	2	2
	0	**2**	58	13	7	5	3	3	3	3
	0	**3**	60	13	7	5	4	4	4	4
	0	**4**	63	14	8	6	5	5	5	5

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Table 5: Probability of acceptance for RGS plans with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the log – logistic distribution.

β	t/σ	n	σ/σ₀					
			2	4	6	8	10	12
0.25	0.628	7	0.964268	0.999463	0.999953	0.999992	0.999998	0.999999
	0.912	4	0.955939	0.999309	0.99994	0.999989	0.999997	0.999999
	1.257	3	0.941943	0.999038	0.999915	0.999985	0.999996	0.999999
	1.571	3	0.809784	0.996343	0.999678	0.999943	0.999985	0.999995
	2.356	3	0.272315	0.95992	0.996348	0.999348	0.999829	0.999943
	3.141	3	0.062482	0.810078	0.979833	0.99635	0.999041	0.999679
	3.927	3	0.017151	0.5276	0.927122	0.986203	0.996346	0.998773
	4.712	3	0.005813	0.272315	0.80998	0.95992	0.989173	0.996348
0.10	0.628	9	0.91435	0.998696	0.999888	0.99998	0.999995	0.999998
	0.912	5	0.891406	0.998249	0.999848	0.999973	0.999993	0.999998
	1.257	4	0.786851	0.996068	0.999658	0.999939	0.999984	0.999995
	1.571	3	0.809784	0.996343	0.999678	0.999943	0.999985	0.999995
	2.356	3	0.272315	0.95992	0.996348	0.999348	0.999829	0.999943
	3.141	3	0.062482	0.810078	0.979833	0.99635	0.999041	0.999679
	3.927	3	0.017151	0.5276	0.927122	0.986203	0.996346	0.998773
	4.712	3	0.005813	0.272315	0.80998	0.95992	0.989173	0.996348
0.05	0.628	11	0.837456	0.99741	0.999778	0.999961	0.99999	0.999997
	0.912	6	0.794898	0.996456	0.999695	0.999946	0.999986	0.999995
	1.257	4	0.786851	0.996068	0.999658	0.999939	0.999984	0.999995
	1.571	4	0.479727	0.984982	0.998691	0.999768	0.999939	0.99998
	2.356	3	0.272315	0.95992	0.996348	0.999348	0.999829	0.999943
	3.141	3	0.062482	0.810078	0.979833	0.99635	0.999041	0.999679
	3.927	3	0.017151	0.5276	0.927122	0.986203	0.996346	0.998773
	4.712	3	0.005813	0.272315	0.80998	0.95992	0.989173	0.996348
0.01	0.628	15	0.625657	0.992707	0.999382	0.999892	0.999972	0.999991
	0.912	8	0.551097	0.989859	0.999136	0.999848	0.99996	0.999987
	1.257	6	0.376022	0.979677	0.998255	0.999694	0.99992	0.999973
	1.571	5	0.240208	0.961889	0.996677	0.999416	0.999848	0.999949
	2.356	3	0.272315	0.95992	0.996348	0.999348	0.999829	0.999943
	3.141	3	0.062482	0.810078	0.979833	0.99635	0.999041	0.999679
	3.927	3	0.017151	0.5276	0.927122	0.986203	0.996346	0.998773
	4.712	3	0.005813	0.272315	0.80998	0.95992	0.989173	0.996348

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Table 6: Probability of acceptance for RGS plans with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the exponentiated log – logistic distribution

β	t/σ	n	σ/σ₀					
			2	4	6	8	10	12
0.25	0.628	26	0.998543	0.999999	1	1	1	1
	0.912	9	0.996509	0.999998	1	1	1	1
	1.257	6	0.986054	0.999989	1	1	1	1
	1.571	4	0.979779	0.999976	1	1	1	1
	2.356	3	0.882848	0.999641	0.999994	1	1	1
	3.141	3	0.481217	0.995089	0.999886	0.999994	0.999999	1
	3.927	3	0.167549	0.969041	0.999036	0.99994	0.999994	0.999999
	4.712	3	0.05713	0.882848	0.995085	0.999641	0.99996	0.999994
0.10	0.628	35	0.99627	0.999999	1	1	1	1
	0.912	12	0.990667	0.999995	1	1	1	1
	1.257	7	0.975313	0.999981	1	1	1	1
	1.571	5	0.948904	0.999939	0.999999	1	1	1
	2.356	3	0.882848	0.999641	0.999994	1	1	1
	3.141	3	0.481217	0.995089	0.999886	0.999994	0.999999	1
	3.927	3	0.167549	0.969041	0.999036	0.99994	0.999994	0.999999
	4.712	3	0.05713	0.882848	0.995085	0.999641	0.99996	0.999994
0.05	0.628	41	0.993863	0.999998	1	1	1	1
	0.912	14	0.98438	0.999992	1	1	1	1
	1.257	8	0.96022	0.999969	1	1	1	1
	1.571	6	0.898868	0.999878	0.999999	1	1	1
	2.356	4	0.625595	0.998542	0.999976	0.999999	1	1
	3.141	3	0.481217	0.995089	0.999886	0.999994	0.999999	1
	3.927	3	0.167549	0.969041	0.999036	0.99994	0.999994	0.999999
	4.712	3	0.05713	0.882848	0.995085	0.999641	0.99996	0.999994
0.01	0.628	58	0.981799	0.999994	1	1	1	1
	0.912	20	0.950137	0.999976	1	1	1	1
	1.257	11	0.884266	0.999909	0.999999	1	1	1
	1.571	7	0.829246	0.999786	0.999998	1	1	1
	2.356	4	0.625595	0.998542	0.999976	0.999999	1	1
	3.141	3	0.481217	0.995089	0.999886	0.999994	0.999999	1
	3.927	3	0.167549	0.969041	0.999036	0.99994	0.999994	0.999999
	4.712	3	0.05713	0.882848	0.995085	0.999641	0.99996	0.999994

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Table 7: Probability of acceptance for RGS plans with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the Rayleigh distribution

β	t/σ	n	σ/σ₀					
			2	4	6	8	10	12
0.25	0.628	12	0.969091	0.999569	0.999963	0.999993	0.999998	0.999999
	0.912	6	0.96594	0.999546	0.999962	0.999993	0.999998	0.999999
	1.257	4	0.957927	0.999475	0.999956	0.999992	0.999998	0.999999
	1.571	3	0.954929	0.999485	0.999958	0.999993	0.999998	0.999999
	2.356	3	0.498958	0.99325	0.999486	0.999913	0.999978	0.999993
	3.141	3	0.064977	0.955025	0.996843	0.999486	0.999871	0.999958
	3.927	3	0.004911	0.808161	0.986557	0.997905	0.999485	0.999834
	4.712	3	0.000294	0.498958	0.954993	0.99325	0.998384	0.999486
0.10	0.628	15	0.935721	0.9991	0.999923	0.999987	0.999996	0.999999
	0.912	7	0.940194	0.9992	0.999932	0.999988	0.999997	0.999999
	1.257	4	0.957927	0.999475	0.999956	0.999992	0.999998	0.999999
	1.571	3	0.954929	0.999485	0.999958	0.999993	0.999998	0.999999
	2.356	3	0.498958	0.99325	0.999486	0.999913	0.999978	0.999993
	3.141	3	0.064977	0.955025	0.996843	0.999486	0.999871	0.999958
	3.927	3	0.004911	0.808161	0.986557	0.997905	0.999485	0.999834
	4.712	3	0.000294	0.498958	0.954993	0.99325	0.998384	0.999486
0.05	0.628	18	0.886199	0.998372	0.999862	0.999976	0.999994	0.999998
	0.912	8	0.905002	0.998712	0.999892	0.999981	0.999995	0.999998
	1.257	5	0.896072	0.998672	0.99989	0.999981	0.999995	0.999998
	1.571	4	0.829292	0.997901	0.999829	0.99997	0.999992	0.999997
	2.356	3	0.498958	0.99325	0.999486	0.999913	0.999978	0.999993
	3.141	3	0.064977	0.955025	0.996843	0.999486	0.999871	0.999958
	3.927	3	0.004911	0.808161	0.986557	0.997905	0.999485	0.999834
	4.712	3	0.000294	0.498958	0.954993	0.99325	0.998384	0.999486
0.01	0.628	25	0.714183	0.995321	0.999607	0.999931	0.999982	0.999994
	0.912	11	0.746042	0.996132	0.999678	0.999944	0.999985	0.999995
	1.257	7	0.687195	0.995247	0.999609	0.999932	0.999982	0.999994
	1.571	5	0.63962	0.994664	0.999569	0.999925	0.999981	0.999994
	2.356	3	0.498958	0.99325	0.999486	0.999913	0.999978	0.999993
	3.141	3	0.064977	0.955025	0.996843	0.999486	0.999871	0.999958

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	3.927	**3**	0.004911	0.808161	0.986557	0.997905	0.999485	0.999834
	4.712	**3**	0.000294	0.498958	0.954993	0.99325	0.998384	0.999486

Table 8: Probability of acceptance for RGS plans with $c_1 = 0$ and $c_2 = 2$ when the lifetime of the items follows the inverse Rayleigh distribution

β	**t/σ**	**n**	**σ/σ_0**					
			2	**4**	**6**	**8**	**10**	**12**
0.25	**0.628**	**27**	1	1	1	1	1	1
	0.912	**6**	0.999972	1	1	1	1	1
	1.257	**4**	0.997371	1	1	1	1	1
	1.571	**3**	0.985242	1	1	1	1	1
	2.356	**3**	0.540576	0.999791	1	1	1	1
	3.141	**3**	0.111087	0.985298	0.999981	1	1	1
	3.927	**3**	0.025311	0.858169	0.998768	0.999996	1	1
	4.712	**3**	0.007634	0.540576	0.98528	0.999791	0.999999	1
0.10	**0.628**	**35**	1	1	1	1	1	1
	0.912	**8**	0.999921	1	1	1	1	1
	1.257	**5**	0.99331	1	1	1	1	1
	1.571	**4**	0.940197	1	1	1	1	1
	2.356	**3**	0.540576	0.999791	1	1	1	1
	3.141	**3**	0.111087	0.985298	0.999981	1	1	1
	3.927	**3**	0.025311	0.858169	0.998768	0.999996	1	1
	4.712	**3**	0.007634	0.540576	0.98528	0.999791	0.999999	1
0.05	**0.628**	**42**	1	1	1	1	1	1
	0.912	**9**	0.999882	1	1	1	1	1
	1.257	**5**	0.99331	1	1	1	1	1
	1.571	**4**	0.940197	1	1	1	1	1
	2.356	**3**	0.540576	0.999791	1	1	1	1
	3.141	**3**	0.111087	0.985298	0.999981	1	1	1
	3.927	**3**	0.025311	0.858169	0.998768	0.999996	1	1
	4.712	**3**	0.007634	0.540576	0.98528	0.999791	0.999999	1
0.01	**0.628**	**58**	1	1	1	1	1	1
	0.912	**13**	0.999593	1	1	1	1	1
	1.257	**7**	0.975958	1	1	1	1	1

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	1.571	**5**	0.855316	1	1	1	1	1
	2.356	**3**	0.540576	0.999791	1	1	1	1
	3.141	**3**	0.111087	0.985298	0.999981	1	1	1
	3.927	**3**	0.025311	0.858169	0.998768	0.999996	1	1
	4.712	**3**	0.007634	0.540576	0.98528	0.999791	0.999999	1

5. EXAMPLE

Assume that an experimenter wants to establish that the lifetime of the electric switches produced in the factory ensures that the true unknown mean life is at least 1000 hours. It is desired to stop the experiment at 628 hours. It is assumed that $c_1 = 0$, $c_2 = 2$ and $\beta = 0.25$. Based on consumer's risk values and the time termination ratio, the minimum sample size is determined using the repetitive group acceptance sampling plan for truncated life test. Following are the results obtained when the lifetime of the test items follows the log – logistic, exponentiated log – logistic, Rayleigh and inverse Rayleigh distributions, respectively.

Minimum sample size and the probability of acceptance for different lifetime distributions when $c_1 = 0$, $c_2 = 2$ and $\beta = 0.25$

Lifetime distribution	***n***	***L(p)***
Log – Logistic	7	0.964268
Exponentiated Log – Logistic	26	0.998543
Rayleigh	12	0.969091
Inverse Rayleigh	27	1.000000

From all the above distributions one can see that log - logistic distribution is comparatively better than the other life time distribution in case of sample sizes and the probability of acceptance ($n = 7$ and $L(p) = 0.964268$) when the repetitive group sampling plan is used (from Tables 1 to 4).

6. CONCLUSION

It is observed that the sample size decreases as the time termination ratio increases. Moreover the operating characteristic values increases when the quality improves. This sampling plan can be suggested for the industrial purposes to save time and cost of the life test experiments.

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