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Research paper

Limited Failure Censored Life Test Sampling Plan: Pareto-Rayleigh Model

G. Prasad[1], R. Subba Rao[2*], R.R.L. Kantam[3]

[1]*Department of Statistics, Aditya Degree College, Rajahmundry, Andhra Pradesh, India-533 103*
[2]*Department of Engineering Mathematics, S. R. K. R. Engineering College, Bhimavaram, Andhra Pradesh, India-534 204*
[3]*Retd. Professor of Statistics, Acharya Nagarjuna University, Nagarjuna Nagar, Andhra Pradesh, India -522 510.*
** Corresponding Author Email: rsubbarao9@gmail.com*

Abstract

A combination of Pareto and Rayleigh distributions considered for a new *T-X* probability model named as Pareto-Rayleigh distribution (PR distribution). We have chosen a life time random variable X from PR distribution whose lots are to be decided for acceptance or otherwise based on sample lifetimes drawn from the lot. A sampling scheme is developed in such way that the sample is divided into different groups and experiment is terminated whenever the first failure noticed in each group. The theory of ordered statistics is applied for the criterion of acceptance and is compared with the similar works proposed by other authors.

Keywords: *Group sampling plan; PR - distribution; Reliability test plan; truncated life tests; T-X family.*

1. Introduction

For assessing the time to failure of an item generally we carry out life test experiment on sample products. The most general practice in life testing experiments is to terminate the test at a prefixed time and the number of failures in the time period will be observed or when a prefixed number of failures are realized. The former termination is generally called truncated life tests/time censored life test and the latter is called a failure censored life test.

A sampling plan in which the experimenter can decide to group the test units into several groups and then conduct the life-tests on all the groups simultaneously until the first failure in each group is realized (Johnson 1964 [1]). Based on the recorded first failure time in each group if a decision process of submitted lot regarding the acceptance/rejection is developed, the procedure may be named as **Limited Failure Censored Life Test Sampling Plan (LFCLTSP)**. Balasooriya (1995) [2] proposed a sampling plan for the two-parameter exponential distribution. Wu and Tsai (2000) [3], Wu *et al*. (2001) [4], Jun *et al*. (2006) [5] have proposed LFCLTSP on Weibull distribution, with respective distinct approaches in working out the parameters of the sampling plan. Kantam and Ravi Kumar (2016) [6] developed LFCLTSP for Burr Type X distribution. Subba Rao *et al*. (2016) [7] worked on Economic Reliability Sampling Plan with PR distribution.

The present paper dealt with a new transformed probability model, Pareto-Rayleigh Distribution and attempt is made to develop LFCLTSPs for Pareto-Rayleigh distribution on lines of Jun *et al.* (2006) [5] in Section 2. We proposed a new criterion alternative to that of Jun *et al.* (2006) [5] and is applied to Pareto-Rayleigh distribution to construct a new LFCLTSP in Section 3. The two methods are compared through an illustration in Section 4.

2. Construction of Sampling Plan by Method I (Suggested by Jun *Et Al.*)

The cumulative distribution function of the Transformed Transformer family of models proposed by Alzaatreh, *et al*. (2012) [8] is given by

$$G(x)=\int_0^{-\log[1-F(x)]} r(t)dt \qquad (1)$$

If a random variable T follows the Pareto distribution type IV with parameter α and another random variable X follows the Rayleigh distribution with parameter σ then using equation (1), we get a new Transformed Transformer family of distribution called Pareto-Rayleigh distribution (P-R distribution) and its CDF and PDF are given as equations (2) and (3)

$$G(x)=1-\left[1+\frac{x^2}{2\sigma^2}\right]^{-\alpha} \;;\quad x>0,\alpha>1,\sigma>0 \qquad (2)$$

$$g(x)=\frac{\alpha}{\sigma^2}x\left[1+\frac{x^2}{2\sigma^2}\right]^{-\alpha-1} \;;\quad x>0,\alpha>1,\sigma>0 \qquad (3)$$

Where α, σ are respectively the shapes and scale parameter

Based on the number of available testers for experiment the total number of products, say N, divided into groups of equal size so that N = m × n where n is number items in each group and m is number of groups. The items on different testers in each group are tested identically and simultaneously. The first group of items is run until the first failure noticed. At this point the surviving items are suspended and removed from testing. An equal set of new items numbering n is next tested until the first failure. This process is repeated until one failure is generated from each of the m groups. In the end, m failures are observed while $(n-1)m$ items are suspended. When testing the original sample of N items, the characteristics like number of testers *m*, groups size *n* and the probability values *p* are considered parallel to that Jun *et al.* (2006) [5] and developed LFCLTSP for Pareto-Rayleigh distribution (PR distribution) for various values of α.

In this paper, we assumed that X is a random variable follows Pareto-Rayleigh distribution with a known shape parameter (α). *L* is a lower specification limit (L) regarding the life time, p_0 is a desirable lot quality level (proportion of non-conformities) at the pre-specified producer's risk α^*. p_1 (> p_0) is an undesirable lot quality level (proportion of non-conformities) at the pre-specified consumer's risk β and *c* is acceptance number.

Let the life time of a product be given by Pareto-Rayleigh distribution with shape parameter α so that cdf is given by the equation (2). Let L denote the p^{th} quantile of a Pareto-Rayleigh variate, we can define equations (4) and (5) such that

$$G(L) = p \qquad (4)$$

If *p* is given, the corresponding *L* is obtained from

$$w = L = \sqrt{2\left[(1-p)^{\frac{-1}{\alpha}} - 1\right]} \qquad (5)$$

Product with life time less than *L* is considered nonconforming. Suppose the producer and the consumer have an agreement that lots with non-conforming fraction less than or equal to p_0 are considered to be good and have to be accepted with probability of at least 1 - α^*. Here α^* is called producer's risk. Furthermore, suppose that lots with non-conforming fraction greater than p_1 (> p_0) are not acceptable to the consumer and should be rejected with a probability of at least 1- β. Here β is called consumer's risk.

If a random sample of *N* items grouped into *m* groups of size *n* each is put to test, an LFCLTSP on lines of Jun *et al*. (2006) [5] an LFCLTSP can be constructed with the following decision process.

- Observe Y_i the time to the first failure in the i^{th} group (*i* = 1, 2, ..., *m*).
- Calculate the quantity. $V = \sum_{i=1}^{m} Y_i$
- Accept the lot if $V \geq cL$ and reject the lot otherwise

In order to get the plan parameters *m* and *c*, we need the percentiles of the sampling distribution of *V* which is the sum of *m* i.i.d observations on the first order statistic in a random sample of size *n* modeled by Pareto-Rayleigh distribution with shape parameter *α*. In view of the mathematical structure of the Pareto-Rayleigh model the sampling distribution of *V* cannot be analytically tractable. We therefore resorted to the empirical sampling distribution of *V* for various known values of the shape parameter *α* are calculated (α = 2, 3 and 4) and tabulated the percentiles of *V* in Tables 1 through 3 for α = 2, 3, 4; *m* = 2(1)10; *n* = 5, 10.

If *G(.)* stands for the cdf of the random variable *V*, the percentiles in Tables 1 through 3 are the values of $G^{-1}(p)$. If $Gk^{-1}(q)$ stands for the qth percentile of *V* with the shape parameter α. Considering the inequalities of (6) and (7) are proposed Jun *et al.* (2006) [5].

$$G_k(ncw_0) \leq \alpha^* \qquad (6)$$

$$G_k(ncw_1) \geq 1-\beta \qquad (7)$$

$$ncw_0 \leq G_k^{-1}(1-\alpha^*) \qquad (8)$$

$$ncw_1 \leq G_k^{-1}(\beta), \qquad (9)$$

which jointly lead to

$$\frac{w_0}{w_1} \leq \frac{G_k^{-1}(1-\alpha^*)}{G_k^{-1}(\beta)} \qquad (10)$$

Therefore, we can find *m* by choosing the smallest integer satisfying (10). The acceptability constant *c* can be obtained from the equality case in either of the expressions (8), (9). We have tabulated the values of *m* and *c* determined for the same combinations of p_0, p_1 as chosen by Jun *et al*. (2006) [5] and are presented in Tables 4 through 6 for α = 2, 3, 4. It may be noted that *m* is solved as integer values only and *m*, *c* depend on the shape parameter α of the Pareto-Rayleigh distribution.

3. Construction of Sampling Plan by Method – II (Suggested by Kantam And Srinivasa Rao)

The statistic $V = \sum_{i=1}^{m} Y_i$ introduced for the decision process of the sampling plan described in Sections - 2 seems to have been considered as the total test time to get the limited failure censored sample - $Y_1, Y_2, ...Y_m$ which are *m* first order statistics in *m* independent random samples of size *n* each. If *Z* denotes the maximum of $Y_1, Y_2, ...Y_m$ it may also be viewed as the total test time / experimental time as obtained by Kantam and Srinivasa Rao (2004) [9]. Hence, larger realized value of *Z* can be considered as an indication that the products in the submitted lot have longer life prompting one to consider the lot as a good lot for acceptability. In other words, " $Z > cL$ " can be taken as a criterion of acceptance of the lot. Thus, we propose the following decision rule in method II.

(i) Draw a random sample of size $N = m \times n$ and allocate *n* items to each of the *m* groups.

(ii) Observe Y_i the time to the first failure in the i^{th} group (*i*=1,2, ……, *m*).

(iii) Identify the quantity . $Z = Max(Y_1, Y_2, ..., Y_m)$

(iv) Accept the lot if $Z > cL$ and reject the lot otherwise

Using the theory of order statistics, we can get the cdf of *Z* in a closed form as long as the cdf of the base line distribution is in a closed form. Hence the percentiles of *Z* can be used to get the design parameters *m*, *c* analytically. For our focal distribution namely Pareto-Rayleigh distribution with shape parameter *α*, the following is the analytical procedure of calculating design parameters of LFCLTSP by Method - II.

Let $X_1, X_2, ...X_m$ be a random sample of size *n* from Pareto-Rayleigh distribution. The cdf of least of $X_1, X_2, ...X_m$ is given by

$$F_{(1)}(x) = 1 - [1 - F(x)]^n \qquad (11)$$

$$\text{i.e. } F_{(1)}(x) = 1 - \left[1 + \frac{x^2}{2\sigma^2}\right]^{-n\alpha} \qquad (12)$$

$Y_1, Y_2, ...Y_m$ of the limited failure censored test are now a random sample of size *m* from $F_{(1)}(x)$. Hence, the cdf of *Z* – the largest of $Y_1, Y_2, ...Y_m$ is given by

$$G_{(m)}(z) = [F_{(1)}(z)]^m \qquad (13)$$

$$G_{(m)}(z) = \left\{ 1 - \left[1 + \frac{x^2}{2\sigma^2} \right]^{-n\alpha} \right\}^m \tag{14}$$

The design parameters m and c of LFCLTSP are obtained with the help of percentiles of $G_{(m)}(z)$ given in (14). If α^* and β are respectively the producer's and consumer's risks for desirable/acceptable lot quality level p_0, undesirable/lot tolerance quality level p_1 then m and c are the solutions of the following two inequalities.

$$G_m(cw_0) \le \alpha^* \tag{15}$$

$$G_m(cw_1) \ge 1 - \beta \tag{16}$$

Where w_0 and w_1 are as defined in Section – 2.
The inequalities (15), (16) respectively imply

$$cw_0 \le G_m^{-1}(1-\alpha^*) \tag{17}$$

$$cw_1 \ge G_m^{-1}(\beta) \tag{18}$$

Which jointly lead to

$$\frac{w_0}{w_1} \le \frac{G_m^{-1}(1-\alpha^*)}{G_m^{-1}(\beta)} \tag{19}$$

Therefore, we can find m by choosing the smallest integer satisfying (19). The acceptability constant c can be obtained from the equality case in either of the expressions (17) and (18). We have tabulated the values of m and c analytically determined for the same combinations of p_0, p_1 as chosen in Method I and are presented in Table 4 through 6 for α = 2, 3, 4 along with the values of the design parameters of LFCLTSP of Method - I.

4. Illustration

From Jun *et al*. (2006) [5] we consider the following example in which a sample of 6 groups of size 5 each are put to test and the first failure times in each group are recorded as follows

$Y_1 = 120$, $Y_2 = 200$, $Y_3 = 185$, $Y_4 = 55$, $Y_5 = 265$ and $Y_6 = 90$

From Table 4, we consider the combination of $p_0 = 0.01$, $p_1 = 0.05$, $\alpha^* = 0.05$, $\beta = 0.1$, shape parameter α = 2 and the number of test positions (size of each group, n) = 5 which give 5 subgroups (testers) according to Method I and 6 subgroups (testers) according to Method II.

Using equation (5), we get the value of L is 0.100377. The decision procedure as per method I is to accept or reject the lot according as $\sum_{i=1}^{5} Y_i$ is less than or greater than or equal to cL here c is given in Table 4 namely 12.76334. That is, $\sum_{i=1}^{5} Y_i = 825$, $cL = 1.28115$. Since $\sum_{i=1}^{5} Y_i > cL$ we conclude that the lot from which the sample is drawn is to be rejected.

The decision procedure as per Method – II is to accept or reject the lot according as $Max(Y_1, Y_2, ..., Y_6)$ is less than or greater than or equal to cL where c is acceptability constant.

For this situation $Max(Y_1, Y_2, ..., Y_6)$ = 265 and $cL = 0.44079$. Since $Max(Y_1, Y_2, ..., Y_6) > cL$, we conclude that the lot from which the sample is drawn is to be rejected

4. Conclusion

As per illustration we see that both the methods lead to the same conclusion under the same parametric combinations like p_0, p_1, α^*, β. However, the conclusion based on Method – I is from the simulated results, where as the conclusion based on Method – II is from exact results. This is already mentioned in the narration of the methods separately. We may recall that Method – I requires percentiles of sum of ordered statistics and Method – II requires percentiles of extreme ordered statistics. Generally, the latter is theoretical, and the former is empirical. As theory suggest theoretical results are more acceptable than empirical.

Table 1: Percentiles of $V = \sum_{i=1}^{m} Y_i$ for α = 2

m	n \ p	0.99865	0.995	0.99	0.975	0.95	0.9	0.1	0.05	0.025	0.01	0.005	0.00135
2	5	2.03333	1.82491	1.71835	1.55887	1.41213	1.25419	0.43419	0.35260	0.28969	0.22788	0.19696	0.15207
	10	1.34453	1.20736	1.13989	1.04748	0.95547	0.85946	0.30850	0.25079	0.20670	0.15947	0.13243	0.10507
3	5	2.75575	2.46711	2.31179	2.11863	1.95273	1.77109	0.76022	0.64903	0.56103	0.46834	0.40231	0.30410
	10	1.78602	1.64188	1.55379	1.42393	1.33141	1.22090	0.53577	0.45969	0.39957	0.33204	0.29552	0.24882
4	5	3.38224	3.05907	2.85132	2.63111	2.46805	2.26247	1.08694	0.95662	0.85442	0.74406	0.66500	0.55485
	10	2.19081	2.00741	1.92384	1.80185	1.68708	1.56230	0.75511	0.67082	0.59697	0.49761	0.44220	0.37698
5	5	3.82399	3.51273	3.38454	3.16668	2.95621	2.73857	1.43522	1.28115	1.16326	1.01677	0.92961	0.81202
	10	2.58925	2.39640	2.30087	2.15583	2.03051	1.88246	0.99370	0.89647	0.81817	0.72397	0.65465	0.56002
6	5	4.37718	4.10341	3.92822	3.70230	3.47607	3.22951	1.77476	1.60382	1.46749	1.31866	1.22576	1.05733
	10	2.94605	2.79591	2.68660	2.50760	2.36411	2.21205	1.24191	1.12914	1.03985	0.92758	0.86509	0.76406
7	5	4.92481	4.62364	4.45506	4.16632	3.95469	3.68619	2.13974	1.95522	1.78166	1.60222	1.48449	1.26059
	10	3.38276	3.16852	3.03157	2.83536	2.68887	2.52000	1.48199	1.36445	1.26039	1.13870	1.07307	0.93499
8	5	5.58577	5.18377	4.98039	4.66492	4.43003	4.15578	2.48183	2.29467	2.11338	1.92279	1.82745	1.55982
	10	3.73653	3.48726	3.36573	3.19743	3.03523	2.85809	1.73077	1.59250	1.48363	1.36801	1.29281	1.12974
9	5	6.13309	5.69974	5.45561	5.17171	4.91126	4.60272	2.83594	2.62720	2.46088	2.28216	2.14904	1.88072
	10	4.06569	3.84402	3.73602	3.52080	3.35571	3.18111	1.98283	1.85074	1.72275	1.58521	1.50112	1.40181
10	5	6.49847	6.23334	5.98004	5.63621	5.37517	5.06455	3.20775	2.97656	2.78409	2.55852	2.41791	2.22809
	10	4.52136	4.26440	4.07971	3.86711	3.69331	3.50200	2.24798	2.08718	1.96315	1.80061	1.69792	1.57047

Table 2: Percentiles of $V = \sum_{i=1}^{m} Y_i$ for α = 3

m	n \ p	0.99865	0.995	0.99	0.975	0.95	0.9	0.1	0.05	0.025	0.01	0.005	0.00135
2	5	1.58900	1.43406	1.35599	1.23939	1.12357	1.00362	0.35332	0.28741	0.23620	0.1859	0.16074	0.12409
	10	1.07740	0.97072	0.91397	0.84472	0.77073	0.69505	0.25140	0.20446	0.16865	0.13014	0.10811	0.08577
3	5	2.16063	1.94655	1.83163	1.68645	1.55888	1.41764	0.61770	0.52812	0.45707	0.38186	0.32816	0.24812
	10	1.42570	1.31726	1.25173	1.14762	1.07464	0.98717	0.43621	0.37450	0.32590	0.27097	0.24119	0.20307
4	5	2.60983	2.41401	2.26557	2.09386	1.97006	1.81110	0.88192	0.77815	0.69549	0.60658	0.54146	0.45242
	10	1.75582	1.60943	1.54748	1.45272	1.36281	1.26305	0.61496	0.54632	0.48678	0.40591	0.36085	0.30764
5	5	3.02664	2.78957	2.69085	2.52751	2.36222	2.19357	1.16464	1.03971	0.94676	0.82773	0.75645	0.66165
	10	2.08258	1.93300	1.85329	1.74465	1.64273	1.52297	0.80821	0.72994	0.66678	0.58992	0.53387	0.45683
6	5	3.45369	3.26345	3.13118	2.95452	2.78121	2.58855	1.43850	1.30128	1.19320	1.07168	0.99818	0.86106
	10	2.37002	2.25751	2.16937	2.02825	1.91129	1.79010	1.01055	0.91877	0.84698	0.75422	0.70491	0.62315
7	5	3.90871	3.68067	3.54319	3.32966	3.16384	2.95664	1.73450	1.58548	1.44601	1.30259	1.20818	1.02632
	10	2.70909	2.55568	2.44687	2.29197	2.17464	2.03985	1.20525	1.11052	1.02668	0.92762	0.87359	0.76207
8	5	4.44440	4.13297	3.96269	3.72648	3.54871	3.33328	2.01078	1.86085	1.71632	1.56176	1.48100	1.26955
	10	3.00590	2.81560	2.71757	2.58500	2.45585	2.31379	1.40830	1.29606	1.20766	1.11500	1.05326	0.92140
9	5	4.87699	4.55140	4.35816	4.14038	3.93471	3.69484	2.29749	2.13045	1.99404	1.85526	1.74257	1.52936
	10	3.27708	3.10539	3.0119	2.84870	2.71469	2.57442	1.61209	1.50537	1.40204	1.28999	1.22275	1.14204
10	5	5.19107	4.95988	4.77695	4.51155	4.30630	4.06246	2.59741	2.41270	2.25941	2.0754	1.96686	1.80922
	10	3.64620	3.43929	3.29327	3.12455	2.98640	2.83581	1.82873	1.69794	1.59664	1.46578	1.38364	1.27992

Table 3: Percentiles of $V = \sum_{i=1}^{m} Y_i$ for $\alpha = 4$

m	n \ p	0.99865	0.995	0.99	0.975	0.95	0.9	0.1	0.05	0.025	0.01	0.005	0.00135
2	5	1.35011	1.22137	1.15588	1.05558	0.96163	0.86046	0.30569	0.24865	0.20440	0.16099	0.13917	0.10743
	10	0.92340	0.83415	0.78481	0.72686	0.66365	0.59911	0.21755	0.17693	0.14600	0.11268	0.09361	0.07427
3	5	1.83708	1.65899	1.56538	1.44028	1.33591	1.21589	0.53392	0.45625	0.39554	0.33047	0.28405	0.21480
	10	1.21938	1.12890	1.07506	0.98851	0.92594	0.85065	0.37739	0.32393	0.28201	0.23461	0.20883	0.17583
4	5	2.20217	2.06569	1.93678	1.79181	1.68776	1.55423	0.76152	0.67247	0.60148	0.52491	0.46827	0.39154
	10	1.50672	1.38093	1.33156	1.25187	1.17482	1.08847	0.53192	0.47282	0.42115	0.35136	0.31241	0.26635
5	5	2.58543	2.38686	2.30074	2.16703	2.02358	1.88451	1.00572	0.89796	0.81772	0.71530	0.65295	0.57242
	10	1.79026	1.66398	1.59422	1.50208	1.41480	1.31220	0.69889	0.63130	0.57698	0.51062	0.46206	0.39544
6	5	2.95414	2.78950	2.68126	2.52367	2.38586	2.22151	1.24106	1.12384	1.03147	0.92569	0.86331	0.74473
	10	2.03855	1.94274	1.86809	1.74855	1.64816	1.54421	0.87386	0.79475	0.73286	0.65218	0.60986	0.53936
7	5	3.34032	3.14709	3.02704	2.85485	2.71170	2.53817	1.49675	1.36894	1.24799	1.12549	1.04418	0.88755
	10	2.32801	2.19671	2.10562	1.97544	1.87478	1.75891	1.04163	0.96035	0.88808	0.80211	0.75545	0.65939
8	5	3.79977	3.53968	3.39045	3.19510	3.04343	2.86083	1.73512	1.60666	1.48199	1.34901	1.27893	1.09790
	10	2.58518	2.42448	2.33948	2.22726	2.11694	1.99543	1.21725	1.12070	1.04413	0.96465	0.91133	0.79751
9	5	4.17543	3.89536	3.73685	3.55209	3.37763	3.17461	1.98266	1.83781	1.72096	1.60246	1.50394	1.32178
	10	2.82005	2.67552	2.59455	2.45571	2.34120	2.22062	1.39324	1.30093	1.21286	1.11612	1.05767	0.98795
10	5	4.45284	4.23577	4.09484	3.87010	3.69450	3.48750	2.24039	2.08046	1.95081	1.79161	1.70012	1.56254
	10	3.13848	2.95967	2.83795	2.69149	2.57501	2.44663	1.58072	1.46806	1.38016	1.26728	1.19710	1.10742

Table 4: Design Parameters of LFCLTSP of Methods –I and II for $\alpha = 2$, $\alpha^* = 0.05$ and $\beta = 0.1$

p_0	p_1	m				c			
		n = 5		n = 10		n = 5		n = 10	
		M - I	M - II	M - I	M - II	M - I	M - II	M - I	M - II
0.001	0.002	---	---	---	---	---	---	---	---
	0.004	7	10	6	9	61.80644	17.00552	35.69303	11.40848
	0.005	5	7	5	6	40.49835	14.91253	28.33826	9.77383
	0.01	3	3	3	3	20.51637	9.69404	14.53123	6.81524
	0.05	2	2	2	2	11.14604	7.15729	7.92768	5.04493
	0.1	2	2	2	2	11.14604	7.15729	7.92768	5.04493
0.005	0.01	---	---	---	---	---	---	---	---
	0.015	10	24	9	18	42.01583	9.75811	26.12431	6.25875
	0.02	7	10	6	8	27.59914	7.59367	15.93842	4.88605
	0.025	5	7	5	6	18.08419	6.65906	12.65421	4.36442
	0.05	3	3	3	3	9.16141	4.32879	6.48880	3.04329
	0.25	2	2	2	2	4.97717	3.19603	3.54004	2.25277
0.01	0.02	---	---	---	---	---	---	---	---
	0.04	6	10	6	8	15.97791	5.35941	11.24891	3.44844
	0.05	5	6	5	6	12.76334	4.40794	8.93100	3.08029
	0.1	3	3	3	3	6.46587	3.05514	4.57962	2.14787
	0.15	2	2	2	2	3.51275	2.25567	2.49846	1.58995
	0.3	2	2	2	2	3.51275	2.25567	2.49846	1.58995
0.05	0.1	2	26	2	26	1.54690	3.06290	1.10024	2.10598
	0.2	2	8	2	7	1.54690	2.17953	1.10024	1.44403
	0.25	2	5	2	5	1.54690	1.78693	1.10024	1.25090
	0.3	2	4	2	4	1.54690	1.59543	1.10024	1.11908
	0.5	2	2	2	2	1.54690	0.99332	1.10024	0.70016
0.1	0.2	---	---	---	---	---	---	---	---
	0.4	5	6	5	5	3.89508	1.34520	2.72554	0.86688
	0.5	3	4	3	4	1.97324	1.10564	1.39760	0.77553

Table 5: Design Parameters of LFCLTSP of Methods –I and II for $\alpha = 3$, $\alpha^* = 0.05$ and $\beta = 0.1$

p_0	p_1	m				c			
		n = 5		n = 10		n = 5		n = 10	
		M - I	M - II	M - I	M - II	M - I	M - II	M - I	M - II
0.001	0.002	---	---	---	---	---	---	---	---
	0.004	5	9	5	8	50.38146	16.22080	35.57206	10.88909
	0.005	4	6	4	6	40.25421	13.87724	28.26118	9.73603
	0.01	2	3	2	3	20.44736	9.65716	14.49942	6.80244
	0.05	1	2	1	2	11.12779	7.14246	7.91600	5.03982
	0.1	1	2	1	2	11.12779	7.14246	7.91600	5.03982
0.005	0.01	---	---	---	---	---	---	---	---
	0.015	8	20	8	16	36.83888	9.16742	26.03027	6.02427
	0.02	5	9	5	8	22.50117	7.24447	15.88706	4.86324
	0.025	4	6	4	6	17.97818	6.19780	12.62190	4.34827
	0.05	2	3	2	3	9.13212	4.31304	6.47568	3.03808
	0.25	1	2	1	2	4.96985	3.18994	3.53541	2.25086
0.01	0.02	---	---	---	---	---	---	---	---
	0.04	5	9	5	8	15.88406	5.11403	11.21501	3.43307
	0.05	4	6	4	5	12.69118	4.37516	8.91007	2.83231
	0.1	2	3	2	3	6.44656	3.04467	4.57132	2.14465
	0.15	1	2	1	2	3.50832	2.25184	2.49572	1.58893
	0.3	1	2	1	2	3.50832	2.25184	2.49572	1.58893
0.05	0.1	1	26	1	26	1.54762	3.01253	1.10093	2.09113
	0.2	1	7	1	7	1.54762	2.05566	1.10093	1.44073
	0.25	1	5	1	5	1.54762	1.77879	1.10093	1.24941
	0.3	1	4	1	4	1.54762	1.59027	1.10093	1.11848
	0.5	1	2	1	2	1.54762	0.99335	1.10093	0.70092
0.1	0.2	---	---	---	---	---	---	---	---
	0.4	4	6	3	5	3.88860	1.34056	2.04328	0.86782
	0.5	2	4	2	4	1.97524	1.10458	1.40066	0.77688

Table 6: Design Parameters of LFCLTSP of Methods –I and II for $\alpha = 4$, $\alpha^* = 0.05$ and $\beta = 0.1$

p_0	p_1	m				c			
		n = 5		n = 10		n = 5		n = 10	
		M - I	M - II	M - I	M - II	M - I	M - II	M - I	M - II
0.001	0.002	---	---	---	---	---	---	---	---
	0.004	5	9	5	8	50.24410	16.13503	3.58623	10.86280
	0.005	4	6	4	6	40.14558	13.82315	4.48279	9.71723
	0.01	2	3	2	3	20.39790	9.63880	8.96558	6.79606
	0.05	1	2	1	2	11.11654	7.13506	11.11654	5.03726
	0.1	1	2	1	2	11.11654	7.13506	11.11654	5.03726
0.005	0.01	---	---	---	---	---	---	---	---
	0.015	8	18	8	16	36.69867	8.85398	2.24140	6.00257
	0.02	5	9	5	8	22.44170	7.20677	2.22331	4.85191
	0.025	4	6	4	5	17.93116	6.17416	2.77914	4.00596
	0.05	2	3	2	3	9.11079	4.30521	5.55827	3.03548
	0.25	1	2	1	2	4.96524	3.18690	11.11654	2.24991
0.01	0.02	---	---	---	---	---	---	---	---
	0.04	5	8	5	8	15.84374	4.87990	2.22331	3.42542
	0.05	4	6	4	5	12.65932	4.35893	2.77914	2.82819
	0.1	2	3	2	3	6.43218	3.03946	5.55827	2.14304
	0.15	1	2	1	2	3.50544	2.24994	11.11654	1.58843
	0.3	1	2	1	2	3.50544	2.24994	11.11654	1.58843
0.05	0.1	1	26	1	26	1.54768	2.98790	11.11654	2.08378
	0.2	1	7	1	7	1.54768	2.04874	11.11654	1.43909
	0.25	1	5	1	5	1.54768	1.77475	11.11654	1.24867
	0.3	1	4	1	4	1.54768	1.58771	11.11654	1.11818
	0.5	1	2	1	2	1.54768	0.99337	#N/A	0.70130
0.1	0.2	---	---	---	---	---	---	---	---
	0.4	3	6	3	5	2.91060	1.33825	3.70551	0.86829
	0.5	2	4	2	4	1.97477	1.10405	5.55827	0.77755

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