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Optimization of Continuous Acceptance Sampling Plans for Truncated Nadarajah-Haghighi Distribution

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Abstract: - Acceptance sampling plans are used primarily to accept or reject lots of finished products. There are several methods for controlling the quality. It is impossible to perform a 100% inspection of crackers, bullets, batteries, bulbs and so forth which can be tested using some of these techniques. The paper presents CASP-CUSUM Schemes that take into account a truncated Nadarajah-Haghighi distribution as the continuous variable under consideration. Nadarajah-Haghighi distributions are generally used in the Life-time Analysis of products, especially in estimating reliability by considering their distributions. The analysis of CASP-CUSUM Schemes is based on numerical results obtained by solving the integral equations by the Lobatto method of integration and by altering the values of the parameters of the Nadarajah and Haghighi distributions. We then determine the maximum values for the Average Run Length and Acceptance Probability based on the obtained results.

Keywords: CASP-CUSUM Schemes, Optimal Truncated Point, Truncated Nadarajah-Haghighi Distribution.

I. INTRODUCTION

Customers' satisfaction determines the success of a new product, and only products of high value meet the needs of clients who expect them to perform correctly throughout their entire life cycle. To meet such requirements, a minimum of variation should be assured within the manufacturing processes and the product itself.

A product or service is said to be of high quality if it possesses several desirable characteristics. Quality has become one of the most important factors in consumer decisions to select among competing products and services. Several areas within a company can be improved by using quality improvement methods, including the manufacturing process, development, engineering design, finance and accounting, marketing, distribution and logistics, customer service, and field service of products.

An acceptance sampling plan is a key tool in Statistical Quality Control. Most statistical quality control experiments cannot perform hundred percent inspections for a variety of reasons. During World War II, the acceptance sampling plan was the first used by the US military to test bullets. For example, if every bullet were tested in advance, there would be no bullets to ship, and on the other hand, if no bullets were tested, then disaster may occur on the battlefield during a crucial time. An acceptance sampling plan represents a middle ground between 100% inspection and no inspection`

Consumers refer to quality items as items that meet the quality specifications they require. An item's quality is influenced by its reliability; one should adopt various measures such as life testing through various probability models, preventing measures, sampling inspections, and CUSUM schemes. To improve the quality of products, it is important to determine if the items produced are fulfilling their intended function or not. In terms of customer satisfaction, as long as an item is within its warranty period

`Hawkins, D. M. [4] proposed a fast accurate approximation for ARL"s of a CUSUM Control Charts. An approximation can be used to calculate the ARL*s for specific parameter values and to calculate the out-of-control ARL"s location and scale CUSUM Charts.

Kakoty. S., Chakravaborthy A.B. developed CASP-CUSUM charts assuming a Truncated Normal Distribution. Truncated distributions are generally used when there is a constraint on the upper and lower limits of the variable under study. As an example, the sorting procedure eliminates production engineering items that exceed or fall below the specified

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tolerance limits. It is worthwhile to note that any continuous variable should be first approximated by an exponential

Vardaman's, Di-ou Ray [10] introduced CUSUM control charts under the restriction that the values are regard to quality are exponentially distributed. Another phenomenon under study is the occurrence of rare events and inter-arriving times for the homogenous poison process. The variables in both cases are identically and independently distributed exponential random variables

Lonnie. C. Vance [7], considered Average Run Length in Cumulative Sum Control Charts for controlling normal means and determining the parameters of a CUSUM chart. In determining the parameters of the CUSUM Chart, the acceptable and rejectable quality levels, along with desired respective ARLs, are considered.

Mohammed Riaz, Nasir Abbas and Ronald J.M.M Does propose two Runs rule schemes for the CUSUM Charts. The CUSUM and EWMA Charts are compared with the usual CUSUM and weighted CUSUM, the first initial response CUSUM is compared with the usual EWMA Schemes. Based on this comparison, the proposed schemes perform better for small and moderate shifts.

Mohammed Akhtar. P and Sarma K.L.A.P [1] analyse and optimizes CASP-CUSUM schemes based on two parametric gamma distributions and evaluate L(0), L*(O) and probability of acceptance, as well as optimize CASP-CUSUM schemes based on numerical results.

Narayana Murthy, B.R. and Mohammed Akhtar.P[11] study CASP CUSUM schemes by optimizing truncated log-logistic distributions and evaluating the probability of acceptance for different parameter values.

Sainath.B and Mohammed Akhtar. P [13] studied the optimization of CASP-CUSUM schemes based on truncated Burr distributions and tested the results at different parameter values.

The Truncated Gompertz Distribution and its Optimization of CASP-CUSUM Schemes were determined by Venkatesulu.G and Mohammed Akhtar.P[1] by changing some parameters of the schemes. Finally, critical comparisons were made based on the numerical results.

Adisekhara Reddy. P and P. Mohamed Akhtar [14] presented a paper in which they determined Type-C OC curves of CASP-CUSUM schemes when the variable under study follows a truncated Nadarajah-Haghighi distribution.

In the present paper, we present various Type-C OC curves for CASP-CUSUM schemes when the variable under study follows a Truncated Nadarajah-Haghighi Distribution and compare the Probability of Acceptance with Lobatto integration. Hence, it is more worthwhile to explore some interesting characteristics of Type-C OC curves concerning this distribution.

II. NADARAJAH -HAGHIGHI DISTRIBUTION

Nadarajah-Haghighi distribution is an extension of the exponential distribution. Nadarajah-Haghighi is also a special case of the generalized power Weibull distribution. The new distribution is quite competitive with other popular lifetime distributions and has the advantage of being very suitable for modelling lifetime data.

Def:

A continuous random variable X assuming non-negative values is said to have Nadarajah-Haghighi distribution with shape and scale parameters $\alpha > 0$, $\lambda > 0$ 0 and its probability density function is given by

$$f(x) = \alpha\lambda(1+\lambda x)^{\alpha-1}.\exp\{1-(1+\lambda x)^{\alpha}\}$$

$x>0$; $\alpha > 0$, $\lambda >0$ ...... (2.1)

2.2. TRUNCATED NADARAJAH-HAGHIGHI DISTRIBUTION

The probability density function ratio of Nadarajah-Haghighi distribution is described in relation to its cumulate distribution at a point T. A random variable x follows the following definition when it is in a truncated Nadarajah-Haghighi distribution.

$$F_T(x) = \frac{\alpha\lambda(1+\lambda x)^{\alpha-1}.\exp\{1-(1+\lambda x)^{\alpha}}{1-\exp\{1-(1+\lambda T)^{\alpha}\}} \quad \text{...... (2.2)}$$

Where "T' is the Upper Truncated point of the Nadarajah-Haghighi distribution.

III. DESCRIPTION OF THE PLAN AND TYPE- C OC CURVE

Beattie [2] has suggested the method for constructing continuous acceptance sampling plans. The procedure, suggested by him consists of a chosen decision interval namely, "Return interval" with the length h', above the decision line is taken.

We plot on the chart the sum $S_m = \sum (X_i - k_1) X_i 's (i = 1,2,3........)$ is distributed independently and k_1 is the reference value. If the sum lies in the area of the normal chart, the product is accepted and if it lies on the return chart, then the product is rejected, subject to the following assumptions.

1. When the recently plotted point on the chart touches the decision line, then the next point is plotted at the maximum, i.e., h+h'.
2. When the decision line is reached or crossed from above, the next point on the chart is to be plotted from the baseline.
   When the CUSUM falls in the return chart, network or a change of specification may be employed rather than outright rejection.
   The procedure, in brief, is given below.
1. Start plotting the CUSUM at 0.

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2. The product is accepted $S_m = \sum (X_i - k) < h$; when $S_m < 0$, return cumulative to 0.
3. When h <S_m<h+h' the product is rejected: when S_m crossed h, i.e., when S_m>h+h' and continues rejecting the product until S_m>h+h' return cumulative to h+h'.

The Type-C, OC function represents how likely an item is to be accepted based on its quality, when the sampling rate within acceptance and rejection areas differs. Therefore, the probability of acceptance P (A) is given by

$$P(A) = \frac{L(0)}{L(0) + L'(0)}$$

…… (3.1)

Where L (0) = Average Run Length in acceptance zone and

L' (0) = Average Run Length in rejection zone.

Page E.S. [8] has introduced the formulae for L (0) and L' (0) as

$$L(0) = \frac{N(0)}{1 - P(0)} \qquad \text{…… (3.2)}$$

$$L'(0) = \frac{N'(0)}{1 - P'(0)} \qquad \text{…… (3.3)}$$

Where P (0) =Probability for the test starting from zero on the normal chart,

N (0) = ASN for the test starting from zero on the normal chart,

P' (0) = Probability for the test on the return chart and

N' (0) = ASN for the test on the return chart

He further obtained integral equations for the quantities P (0), N (0), P' (0), N' (0) as follows

$$P(z) = F(k_1 - z) + \int_0^h P(y) f(y + k_1 - z) dy \qquad \text{…. (3.4)}$$

$$N(z) = 1 + \int_0^h N(y) f(y + k_1 - z) dy, \qquad \text{…… (3.4)}$$

$$P'(z) = \int_{k_1+z}^{B} f(y) dy + \int_0^h P'(y) f(-y + k_1 + z) dy$$

…… (3.5)

$$N'(z) = 1 + \int_0^h N'(y) f(-y + k_1 + z) dy, \qquad \text{.. …. (3.6)}$$

$$F(x) = 1 + \int_A^h f(x) dx$$

$$F(k_1 - z) = 1 + \int_A^{k_1 - z} f(y) dy$$

and z is the distance of the starting of the test in the normal chart from zero.

The equations (3.3), (3.4), (3.5) & (3.6) are evaluated by the iterative procedure explained in Jain M.K and et.al [5] by using the Lobatto Method of Integration.

IV. COMPUTATION OF ARL AND P (A)

By using the Lobatto integration method, we calculate the integral equations that are related to the probability of acceptance and the average sample number values are estimated, which are useful in estimating the value of the probability of acceptance and the average run length of the corresponding distribution.

TABLE 4.1

λ=0.4, α=0.1, k=1, h=0.04, h'= 0.04			
T	**L(0)**	**L'(0)**	**P(A)**
1.5	3.78292	1.0482491	0.7830238
1.4	4.42245	1.0473859	0.8085158
1.3	5.49728	1.0465649	0.8400689
1.2	7.67930	1.0457958	0.8801393
1.1	14.48831	1.0450919	0.9327197

TABLE 4.2

λ=0.5, α=0.1, k=2, h=0.04, h'=0.04			
T	**L(0)**	**L'(0)**	**P(A)**
2.5	7.74984	1.0645127	0.8792297
2.4	9.34778	1.0631697	0.8978797
2.3	12.05520	1.0618392	0.9190488
2.2	17.63884	1.0605222	0.9432856
2.1	35.86115	1.0592200	0.9713107

TABLE 4.3

λ=0.5, α=0.10, k=1, h=0.04, h'=0.04			
T	**L(0)**	**L'(0)**	**P(A)**
1.5	3.95284	1.0518216	0.7898317
1.4	4.62163	1.0506873	0.8147692
1.3	5.74713	1.0495956	0.8455733
1.2	8.03698	1.0485561	0.8845907
1.1	15.22264	1.0475816	0.9356136

TABLE 4.4

λ=0.4, α=0.15, k=2, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
2.5	7.25899	1.0583555	0.8727533
2.4	8.74790	1.0572813	0.8921711
2.3	11.26277	1.0562185	0.9142609
2.2	16.41936	1.0551684	0.9396168
2.1	32.97583	1.0541320	0.9690234

TABLE 4.5

λ=0.4, α=0.15, k=1, h=0.04, h'=0.04			
T	**L(0)**	**L'(0)**	**P(A)**
1.5	3.78547	1.0483143	0.7831276
1.4	4.42531	1.0474422	0.8086078
1.3	5.50072	1.0466127	0.8401466
1.2	7.68398	1.0458359	0.8801995
1.1	14.49734	1.0451247	0.9327568

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TABLE 4.6

λ=0.5, α=0.15, k=2, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
2.5	7.77194	1.0648036	0.8795028
2.4	9.37417	1.0634373	0.8981149
2.3	12.08922	1.0620843	0.9192411
2.2	17.68987	1.0607458	0.9434288
2.1	35.97868	1.0594231	0.9713964

TABLE 4.7

λ=0.5, α=0.15, k=1, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
1.5	3.95673	1.0519217	0.7899792
1.4	4.62600	1.0507737	0.8148996
1.3	5.75238	1.0496690	0.8456835
1.2	8.04417	1.0486175	0.8846759
1.1	15.23671	1.0476319	0.9356663

TABLE 4.8

λ=0.4, α=0.1, k=3, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
3.5	11.38322	1.0692135	0.9141362
3.4	13.91894	1.0680780	0.9287331
3.3	18.23122	1.06417085	0.9447125
3.2	27.19148	1.0658252	0.9622814
3.1	57.08697	1.0647085	0.9816908

TABLE 4.9

λ=0.04, α=0.10, k=2, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
2.5	7.24465	1.0581665	0.8725533
2.4	8.73082	1.0571074	0.8919988
2.3	11.24086	1.0560594	0.9141200
2.2	16.38689	1.0550231	0.9395122
2.1	32.90386	1.0539999	0.9689615

TABLE 4.10

λ=0.5, α=0.1, k=3, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
3.5	12.40374	1.0784957	0.9200062
3.4	15.19665	1.0770583	0.9338161
3.3	19.97590	1.0756286	0.9489050
3.2	30.02580	1.0742074	0.9654596
3.1	64.76335	1.0727943	0.9837051

TABLE 4.11

λ=0.4, α=0.15, k=3, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
3.5	11.42499	1.0695883	0.9143958
3.4	13.97011	1.0684314	0.9289538
3.3	18.29921	1.0672810	0.9448903
3.2	27.29757	1.0661376	0.9624119
3.1	57.35044	1.0650014	0.9817685

TABLE 4.12

λ= 0.5, α=0.15, k=4, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
4.5	18.09479	1.0942461	0.9429755
4.4	22.42656	1.0926927	0.9535405
4.3	29.94366	1.0911472	0.9648412
4.2	46.19655	1.0896096	0.9769571
4.1	107.50316	1.0880799	0.9899800

TABLE 4.13

λ=0.5, α=0.15, k=3, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
3.5	12.46886	1.0790753	0.9203513
3.4	15.27694	1.0776044	0.9341098
3.3	20.08376	1.0761425	0.9491424
3.2	30.19822	1.0746897	0.9656351
3.1	65.22517	1.0732465	0.9838119

TABLE 4.14

λ=0.4, α =0.1, k=5, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
5.5	21.70747	1.0929837	0.9520631
5.4	27.02431	1.0917521	0.9611698
5.3	36.24783	1.0905248	0.9707934
5.2	56.18065	1.0893016	0.9809795
5.1	131.26978	1.0880829	0.9917792

TABLE 4.15

λ=0.4, α=0.1, k=4, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
4.5	16.19418	1.0808636	0.9374321
4.4	19.99677	1.0796763	0.9487733
4.3	26.52094	1.0784937	0.9609233
4.2	40.31403	1.0773159	0.9739724
4.1	88.78817	1.0761429	0.9880248

TABLE 4.16

λ=0.5, α=0.1, k=5, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
5.5	24.48087	1.1087384	0.9566723
5.4	30.65168	1.1071625	0.9651384
5.3	41.53799	1.1055930	0.9740736
5.2	65.88023	1.1040301	0.9835181
5.1	168.94286	1.1024737	0.9935166

TABLE 4.17

λ=0.5, α=0.1, k=4, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
4.5	17.94897	1.0932754	0.9425868
4.4	22.24209	1.0917660	0.9532111
4.3	29.68653	1.0902631	0.9645752
4.2	45.75836	1.0887673	0.9767591
4.1	106.09193	1.0872784	0.9898555

TABLE 4.18

λ=0.4, α=0.15, k=5, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
5.5	21.88017	1.0939267	0.9523844
5.4	27.24462	1.0926602	0.9614409
5.3	36.55780	1.0913987	0.9710113
5.2	56.71462	1.0901420	0.9811410
5.1	133.01852	1.0888906	0.9918805

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TABLE 4.19

λ=0.4, α=0.15, k=4,h = 0.04,h'= 0.04			
T	L(0)	L'(0)	P(A)
4.5	16.28587	1.0814890	0.93777286
4.4	20.11152	1.0802736	0.9490240
4.3	26.67789	1.0790637	0.9611245
4.2	40.57091	1.0778592	0.9741203
4.1	89.51167	1.0766602	0.9881148

TABLE 4.20

λ=0.5, α=0.15, k=5, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
5.5	24.76296	1.1102086	0.9570903
5.4	31.01767	1.1085775	0.9654931
5.3	42.06829	1.1069542	0.9743614
5.2	66.85292	1.1053386	0.9837350
5.1	172.94334	1.1037308	0.9936584

TABLE 4.21

λ=0.4, α=0.05, k=4, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
4.5	16.14104	1.0805005	0.9372588
4.4	19.93025	1.0793291	0.9486268
4.3	26.42999	1.0781623	0.9608057
4.2	40.16520	1.0769998	0.9738860
4.1	88.37048	1.0758418	0.9879722

TABLE 4.22

λ=0.5, α=0.05, k=4, h=0.04, h'=0.04			
T	L(0)	L'(0)	P(A)
4.5	17.86513	1.0927154	0.9423608
4.4	22.13603	1.0912306	0.9530194
4.3	29.53870	1.0897523	0.9644203
4.2	45.50694	1.0882803	0.9766439
4.1	105.28711	1.0868146	0.9897830

V. CONCLUSIONS

At the hypothetical values of the parameters, λ, α, k, h and h'are given at the top of each table, we determined optimum truncated point T at which P (A) the probability of accepting an item is maximum and also obtained ARL's values which represent the acceptance zone L(0) and rejection zone L'(0) values. The values of truncated point T of random variable X, L(0), L'(0) and the values for Type-C Curve, i.e., P (A) are given in columns I, II, III, and IV respectively.

i). By observing the above tables, we see that h, h' increases and the related value of L(0)

increases. Therefore, the size of accepted and rejected zones is inversely related to L(0).

ii) By observing the above tables, we notice that as h,h' increases, then related values of P(A) increases. P (A) is inversely related to the sizes of rejected zone.

(iii) By observing the above table, we can see that as the value of parameter a of Nadarajah-Haghighi distribution changes, P(A) changes along with it.

(iv) It is observed that the Table - 4.1 values of Maximum Probabilities increased as the increased values of 'k' as shown below the Figure-4.

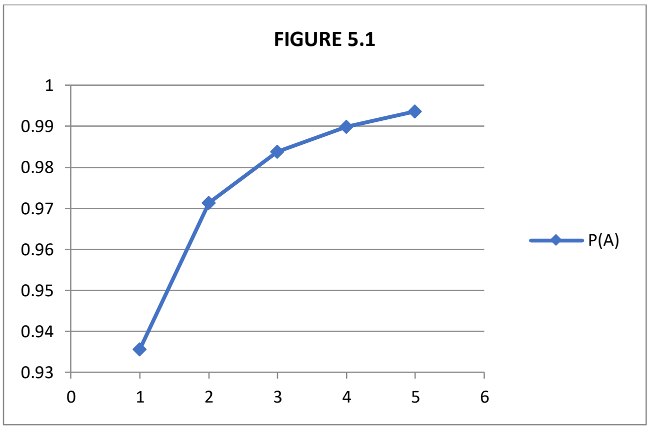

TABLE 5.1

k	P(A)
1	0.935663
2	0.971394
3	0.983812
4	0.98998
5	0.993658

v). The various relations exhibited among the ARLs and Type-C OC Curves with the parameters of the CASP - CUSUM based on the above table 4.1 to 4.22 are observed from the following. Table 4.2.

TABLE - 5.2 CONSOLIDATED TABLE

T	λ	α	h	h'	k	L(0)	P(A)
1.1	0.4	0.1	0.04	0.04	1	14.48831	0.9327197
2.1	0.4	0.1	0.04	0.04	2	32.90386	0.9689615
3.1	0.4	0.1	0.04	0.04	3	57.08697	0.9816908
4.1	0.4	0.1	0.01	0.04	4	88.78817	0.9880248
5.1	0.4	0.1	0.04	0.04	5	131.26978	0.9917792
1.1	0.5	0.1	0.04	0.04	1	15.2224	0.9356136
2.1	0.5	0.1	0.04	0.04	2	35.86115	0.9713107
3.1	0.5	0.1	0.04	0.04	3	64.76335	0.9837051
4.1	0.5	0.1	0.04	0.04	4	106.09193	0.9898555
5.1	0.5	0.1	0.04	0.04	5	168.94286	0.9935166
1.1	0.5	0.15	0.04	0.04	1	15.23671	0.9356663
2.1	0.5	0.15	0.04	0.04	2	35.97868	0.9713964
3.1	0.5	0.15	0.04	0.04	3	65.22517	0.9838119
4.1	0.4	0.15	0.04	0.04	4	107.5016	0.9899800
5.1	***0.4***	***0.15***	***0.04***	***0.04***	***5***	***172.94334***	***0.9936584***
1.1	0.4	0.15	0.04	0.04	1	14.49734	0.9327568

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2.1	0.4	0.15	0.04	0.04	2	32.97583	0.960234
3.1	0.5	0.15	0.04	0.04	3	57.35044	0.9817685
4.1	0.5	0.15	0.04	0.042	4	89.1167	0.9881148
5.1	0.5	0.15	0.04	0.04	5	133.01852	0.9918805
4.1	0.4	0.05	0.04	0.04	4	88.37048	0.9879722
4.1	0.5	0.05	0.04	0.04	4	105.28711	0.9897830

From the Table No.5.2 we can observe the different relationships between the ARL's and Type-C OC Curves with the parameters of the CASP-CUSUM is

$$\begin{bmatrix} T = 5.1 \\ \alpha = 0.15 \\ \gamma = 0.4 \\ k = 0.5 \\ h = 0.04 \\ h' = 0.04 \end{bmatrix}$$

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