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Research Article

Designing Of Double Sampling Plan Indexed Through Six Sigma Quality Level – 1 Using Truncated Binomial Distribution

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ARTICLE INFO	ABSTRACT

Among the various probability distributions utilized to characterize situations where an observational apparatus becomes active only upon the occurrence of at least one event, the Zero Truncated Poisson Distribution (ZTPD) stands out. Shanmugam (1985) demonstrated the applicability of the ZTPD in modeling scenarios such as second quality lots, where there exists the possibility of at least one defective item in the sample. In this paper, a systematic procedure for constructing Double Sampling Plans, indexed through Six Sigma Quality Level – 1 (SSQL - 1), is presented. The methodology employs the Truncated Binomial Distribution (TBD) as the baseline distribution. Furthermore, to facilitate the selection of these plans, tables generated using an Excel packages are provided, ensuring ease of use and accessibility.

Keywords: Six Sigma Quality Level, Operating Characteristic Curve, Double Sampling Plan, Truncated Binomial Distribution.

1. Introduction

R – Forge Distribution Core Team University (2008 – 2009) suggested a Truncated Binomial Distribution, which can also be used in designing sampling plans.

Shilling (1982) provides valuable insights into the benefits and performance measures related to Acceptance sampling within the domain of Quality Control. Several tables are available for designing double sampling plans, including those by Dodge and Romig (1959), which prioritize plans with minimum Average Total Inspection. Additionally, Shilling and Johnson (1980) have devised a table for constructing and evaluating matched sets of single, double, and multiple sampling plans. Moreover, Soundararajan and Arumainayagam (1990) have provided tables for the convenient selection of double sampling plans, indexed by Acceptable Quality Level (AQL), Average Outgoing Quality Level (AOQL), and Limiting Quality Level (LQL).

Radhakrishnan (2002) devised Double, Link, Chain, and Continuous sampling plans indexed by Maximum Allowable Average Outgoing Quality (MAAOQ). Radhakrishnan and Sampathkumar (2007) formulated mixed sampling plans indexed through Maximum Allowable Proportion Defective (MAPD) and Acceptable Quality Level (AQL), with the double sampling plan as the attribute Plans. Furthermore, Radhakrishnan and Ravishankar (2009) developed Three – Class Attribute Double Sampling plans indexed by AQL and Limiting Quality Level (LQL) on the Operating Characteristic (OC) Surface.

Radhakrishnan and Pratheeba (2011) introduced a Double Sampling Plan indexed by the Indifference Quality Level (IQL) utilizing the Truncated Binomial Distribution as its fundamental statistical framework. In continuation, Radhakrishnan and Pratheeba (2012) elaborated on their earlier work by introducing a Double Sampling Plan linked to the Average Quality Level (AQL), maintaining its underlying basis in the Truncated Binomial Distribution.

Said Hofan Alkarni (2013) constructed a new lifetime class with decreasing failure rate is introduced by compounding Truncated Binomial Distribution with any proper continuous lifetime distribution.

The sampling plans can also be constructed by assuming the probability of acceptance of the lot, $P_a(p)$ as 1-3.4 x 10^{-6} in the concept of Six Sigma quality levels. The proportion defective corresponding to this probability on the OC curve is termed as Six Sigma Quality Level-1 (SSQL-1). This new sampling plan is constructed with a point on the OC curve (SSQL-1, 1-α_1), where α_1 = 3.4 x 10^{-6} suggested by Radhakrishnan and Sivakumaran (2008) similar to (AQL, 1- α) suggested by Dodge and Romig (1942). Further the proportion defective

corresponding to the probability $2\alpha_1$ on the OC curve is termed as Six Sigma Quality Level-2 (SSQL-2, $2\alpha_1$) suggested by Radhakrishnan and Sivakumaran (2008) similar to (LQL,β) suggested by Dodge and Romig (1942). Radhakrishnan and Sivakumaran (2008) provided a procedure to construct Sampling Plans using SSQL-1 and SSQL-2 with Poisson distribution as the base line Distribution.
Using these Six Sigma Quality Levels, Radhakrishnan (2009) has given a procedure to construct Single Sampling Plans (SSP) with base line distributions such as Poisson, Weighted Poisson and Intervened Random Effect Poisson Distributions. Moreover, Pratheeba and Radhakrishnan (2014) formulated a Single Sampling Plan indexed by Six Sigma Quality Level – 1 (SSQL -1), utilizing the Truncated Binomial Distribution as the underlying baseline distribution, with provisions for simplified sample selection.
In this Paper a double sampling plan is constructed by fixing the probability of acceptance $P_a(p)$ as $\beta_1 = 2\alpha_1$ where $\alpha_1 = 1\text{-}3.4 \times 10^{-6}$, the proportion defective corresponding to this probability of acceptance in the OC (Operating Characteristic) curve is termed as Six Sigma Quality Level - 1 using Truncated Binomial distribution as the base line distribution.
This paper outlines the construction of a double sampling plan by setting the probability of acceptance Pa(p) as $\beta_1 = 2\alpha_1$ where $\alpha_1 = 1\text{-}3.4 \times 10^{-6}$. The proportion defective corresponding to this acceptance probability on the Operating Characteristic (OC) curve is referred to as Six Sigma Quality Level - 1. The Truncated Binomial distribution serves as the baseline distribution for this construction.

2. Conditions for Application

- Production is Continuous, so that results of the past, present and future lots are broadly the indicative of a continuous process.
- Lots are submitted sequentially.
- Inspection is by attributes, with the lot quality is the level defined as the proportion defective.

3. Operating procedure of Double Sampling Plan

The operating procedure of Double Sampling Plan is as follows

- **Step 1**: Select a random sample of size n_1 from the lot (N) and count the number of non -conformities (d_1).
- **Step 2**: If $d_1 \leq c_1$, accept the lot.
- **Step 3**: If $d_1 > c_2$, reject the lot.
- **Step 4:** If $c_1 < d_1 \leq c_2$, take a second sample of size n_2 from the remaining lot and count the number of non-conformities (d_2).
- **Step 5:** If $d_1+d_2 \leq c_2$, accept the lot.
- **Step 6:** If $d_1+d_2 > c_2$, reject the lot.

3.1. Operating Characteristic Function

The Operating Characteristic (OC) function of the Double Sampling Plan (DSP) is given

$$Pa(p) = \sum_{i=1}^{c_1} p_i + \sum_{j=c_1+1}^{c_2} p_j \sum_{i=1}^{c_2-j} q_i \quad \ldots\ldots\ldots\ldots (1)$$

$$\text{where} \qquad P_i = \frac{\binom{n_1}{x} p^x q^{n_1-x}}{(1-q^{n_1})} \quad ,$$

$$q_i = \frac{\binom{n_2}{x} p^x q^{n_2-x}}{(1-q^{n_2})} \quad ; \quad (n_1 = n_2)$$

3.2. Construction of Double sampling plan indexed through SSQL – 1

By fixing the probability of acceptance of the lot, Pa(p) as $1 - 3.4 \times 10^{-6}$ with Truncated Binomial Distribution as the basic distribution and from equation (1), the values of the SSQL-1 are obtained for the various combinations of 'n_1', 'n_2', 'c_1' and 'c_2'using an Excel package and are presented in Table 1. The parameters of the Double Sampling Plan, 'n_1', 'n_2', 'c_1' and 'c_2'are recorded for various combinations of SSQL-1.
The sigma levels of the process are calculated using the Process Sigma Calculator by providing the sample size and the acceptance number.

3.2.1. Example

For a given SSQL-1 = 0.0000001, the value of n_1, n_2, c_1 and c_2 are obtained from table 1 as $n_1 = 5500$, $n_2 = 5500$, $c_1 = 3$ and $c_2 = 4$ which are associated with 4.77 and 4.68. Hence the parameters of Double Sampling Plan are $n_1 = 5500$, $n_2 = 5500$, $c_1 = 3$ and $c_2 = 4$ with the specified SSQL-1 = 0.0000001. The OC curve for this plan is presented in figure 1.

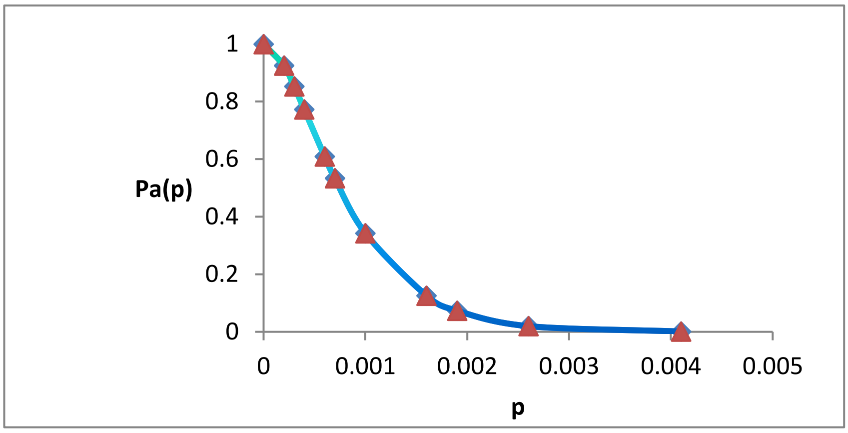

Figure 1: OC curve of the DSP using TBD for n_1= 5500, n_2=5500 c_1= 3 & c_2 =4

Practical Application

In a health drink supplying company, if the distributor fixes the SSQL-1 as 0.0000001 (1 non-confirming item out of 1 Crore bottles supplied in a day/week) for a lot, then take a sample 5500 bottles from the lot of a particular day/week and count the number of non-confirming bottles (d_1). If $d_1 \leq 3$ accept the lot supplied in that day/week and if $d_1 > 4$, reject the lot supplied in that day/week and suggest for an improvement in the quality. If $d_1 = 4$, take a second sample of 5500 bottles from the remaining lot supplied and count the number of non-confirming bottles (d_2). If $d_1+d_2 \leq 4$ accepts the lot, supplied in the same day/week, otherwise reject the lot and inform the management for the quality improvement.

3.2.2. Example

For a given SSQL-1 = 0.00000007, the value of n_1, n_2, c_1 and c_2 are obtained from table 1 as n_1 = 5000, n_2 = 5000, c_1 = 1 and c_2 = 2 which are associated with 5.04 and 4.85. Hence the parameters of Double Sampling Plan are n_1 = 5000, n_2 = 5000, c_1 = 1 and c_2 = 2 with the specified SSQL-1 = 0.00000007. The OC curve for this plan is presented in figure 2.

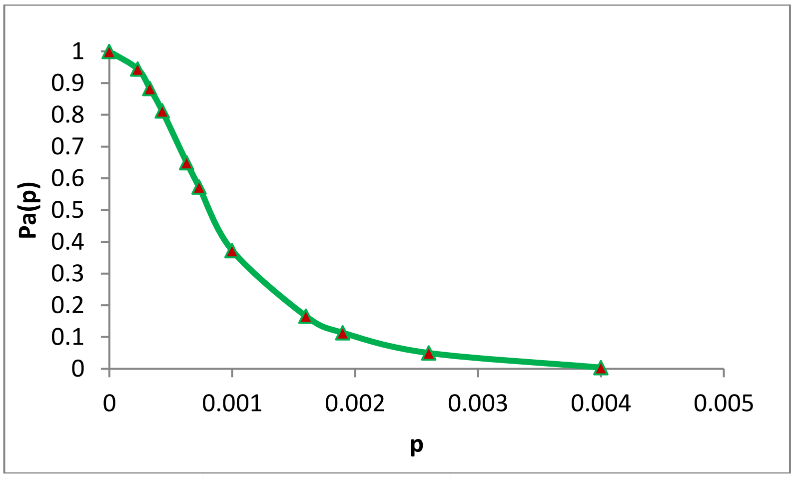

Figure 2: OC curve of the DSP using TBD for n_1=5000, n_2=5000, c_1=1 & c_2 =2

Practical Application

In a digital cameras manufacturing company, if the manufacturer fixes the SSQL-1 as 0.00000007 (7 non-confirming items out of 10 Crore digital cameras) for a lot, then take a sample 5000 digital cameras from the manufactured lot of a particular day/week and count the number of non-confirming items (d_1). If $d_1 \leq 1$ accept the lot manufactured during a day/week and if $d_1 > 2$, reject the lot manufactured during a day/week and suggest for an improvement in the quality. If $d_1 = 2$, take a second sample of 5000 digital cameras from the remaining lot and count the number of non-confirming items (d_2). If $d_1+d_2 \leq 2$ accepts the lot, manufactured in the same day/week, otherwise reject the lot and inform the management for the quality improvement.

4. Conclusion

In recent days of technological advancement in production, manufacturing, service and other sectors achieving zero defectives, theoretically possible but practically very difficult because of the presence of chance causes and a smaller percentage of assignable causes.
In this paper a procedure is given for constructing a Double Sampling Plan indexed through SSQL - 1 using Truncated Binomial Distribution, truncated at x = 0 and a table is also provided for the easy selection of the plans. These plans are very useful for the companies which have at least one defective unit in their lot and also useful to the companies which are using second - quality lots. These sampling plans impose an obligation on producers to uphold quality standards even in their second quality lots.
If the industries were to adopt the procedures delineated in this paper, both producers and consumers would reap significant benefits.

Table 1: Parameters of Double Sampling Plan for a specified SSQL-1 Using Truncated Binomial Distribution

n_1	n_2	c_1	c_2	SSQL-1
5500	5500	1	2	0.000000019853
5500	5500	2	3	0.000000580608
5500	5500	3	4	0.000000100901
5500	5500	4	5	0.000000099616
5500	5500	5	6	0.000000119962
5250	5250	1	2	0.000000685697
5250	5250	2	3	0.000000080258
5250	5250	3	4	0.000000137138
5250	5250	4	5	0.000000018909
5250	5250	5	6	0.000000159349
5000	5000	1	2	0.000000079840
5000	5000	2	3	0.000000926661
5000	5000	3	4	0.000000158435
5000	5000	4	5	0.000000170270
5000	5000	5	6	0.000000184507
4750	4750	1	2	0.000000095914
4750	4750	2	3	0.000000458827
4750	4750	3	4	0.000000154429
4750	4750	4	5	0.000000139174
4750	4750	5	6	0.000000269071
4500	4500	1	2	0.000000119872
4500	4500	2	3	0.000000146347
4500	4500	3	4	0.000001659702
4500	4500	4	5	0.000000202812
4500	4500	5	6	0.000000460851
4250	4250	1	2	0.000000015979
4250	4250	2	3	0.000000082686
4250	4250	3	4	0.000000245449
4250	4250	4	5	0.000000269977
4250	4250	5	6	0.000000306423

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