CONSTRUCTION OF MIXED SAMPLING PLANS INDEXED THROUGH SIX SIGMA QUALITY LEVELS WITH TNT-(n_1, n_2; C) PLAN AS ATTRIBUTE PLAN

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ABSTRACT

Six Sigma is a concept, a process, a measurement, a tool, a quality philosophy, a culture and a management strategy for the improvement in the system of an organization, in order to reduce wastages and increase the profit to the management and satisfaction to the customers. Six Sigma is a business improvement approach and management philosophy that seeks to find and remove causes of defects/errors in management processes by focusing on customer requirements, processes, and outputs that are of critical importance to constituent Six Sigma to be "a program for the near-elimination of defects from every product, process and transaction. Six Sigma is a strategic weapon that works across all processes, products, company functions and industries. Motorola [1] first adopted the concept of six sigma in their organization and established that it can produce less than 3.4 defects per million opportunities. Focusing on reduction of defects will result in more profit to the producer and enhanced satisfaction for the consumer. The concept of Six Sigma can be applied in the process of quality control in general and Acceptance sampling in particular. In this paper a procedure for the construction and selection of Mixed Sampling Plan indexed through Six Sigma Quality level having Tightened – Normal – Tightened plan of the type TNT-(n_1, n_2; c) plan as attribute plan is presented. The plans are constructed using SSQL-1 and SSQL-2 as indexing parameters. Tables are constructed for easy selection of the plan.

KEYWORDS: *Six Sigma Quality Levels, Operating Characteristic Curve, Mixed Sampling Plan, Tightened – Normal – Tightened plan*

I. INTRODUCTION

Mixed sampling plan is a two stage sampling procedure involving variables inspection in the first stage and attributes inspection in the second stage if the variables inspection of the first sample does not lead to acceptance. Mixed sampling plans are of two types, namely independent and dependent plans. Independent mixed sampling plans do not incorporate first sample results in the assessment of the second sample. Dependent mixed plans combine the results of the first and second samples in making a decision if a second sample is necessary.

The mixed sampling has been designed under two cases of significant interest. In the first case the sample size n_1 is fixed and a point on the OC curve is given. In the second case plans are designed when two points on the OC curve are given.

The mixed sampling plans are initially introduced by Dodge [2] and later developed by Bowker and Goode [3]. Schilling [4] has given a method for determining the operating characteristics for mixed variables-attributes sampling plans. Tightened-Normal-Tightened (TNT) sampling scheme was first developed by Calvin [5]. Radhakrishnan and Sampath Kumar [6-11] have made contributions to mixed sampling plans for independent case. Radhakrishnan and Sivakumaran [12] introduced SSQL in the construction of sampling plans. Radhakrishnan and Sivakumaran [13] constructed Tightened-Normal-Tightened schemes indexed through Six Sigma Quality Levels. Radhakrishnan [14] constructed Six Sigma based sampling plan using Weighted Poisson Distribution and Intervened Random Effect Poisson Distribution as the base line distributions.. Radhakrishnan and Saravanan [15-16] constructed dependent mixed sampling plan with single sampling and chain sampling plan as attribute plan. Radhakrishnan, Sampath Kumar and M. Malathi [17] have studied Mixed Sampling Plan with TNT - (n_1, n_2 ; 0) Plan as Attribute Plan Indexed through MAPD and MAAOQ. Radhakrishnan and Glorypersial [18-23] constructed mixed sampling plans indexed through six sigma quality levels with Double Sampling Plan, Conditional Double Sampling Plan, Chain Sampling Plan – (0,1), Link Sampling Plan, Conditional Repetitive Group Sampling, and TNT – (n; c_1, c_2) Plan as Attribute Plan.

This paper deals with the construction of mixed variables – attributes sampling plan (independent case) using TNT-(n_1, n_2; c) plan as attribute plan indexed through Six Sigma Quality levels. Tables are constructed for easy selection of the plan and illustrations are also provided.

II. Glossary of Symbols

The symbols used in this paper are as follows:

P : submitted quality of lot or process
$P_a(p)$: probability of acceptance for given quality p
P_1 : Probability of acceptance under tightened inspection
P_2 : Probability of acceptance under normal inspection
$n_{1,1}$: sample size for variable sampling plan
$n_{1,2}$: tightened (larger) sample size for attribute sampling plan
$n_{2,2}$: normal (smaller) sample size for attribute sampling plan
s : criterion for switching to tightened inspection
t : criterion for switching to normal inspection
β_j : probability of acceptance for lot quality p_j
β_j' : probability of acceptance assigned to first stage for percent defective p_j
β_j'' : probability of acceptance assigned to second stage for percent defective pj
k : variable factor such that a lot is accepted if $\bar{X} \leq A = U - k\sigma$

III. Operating Procedure of Mixed Sampling Plan with TNT - (n1, n2; c) Plan as attribute plan

In this paper only independent mixed sampling plans are considered. The development of mixed sampling plans and the subsequent discussions are limited only to the upper specification limit U. By symmetry a parallel discussion can be made use for lower specification limits. Also it is suggested that the mixed sampling plan with TNT-(n_1, n_2; 0) in the case of single sided specification (U), S.D (σ) known can be formulated by the parameters $n_{1,2}$, $n_{2,2}$, and c. By giving the values for the parameters an independent plan for single sided specification, σ known would be carried out as follows:

1. Determine the parameters with reference to ASN and OC curves
2. Take a random sample of size $n_{1,1}$ from the lot assumed to be large
3. If a sample average $\bar{X} \leq A = U - k\sigma$, accept the lot

   If the sample average $\bar{X} > A = U - k\sigma$, take another sample of size $n_{1,2}$
   (i) inspect using tightened inspection with a larger sample size $n_{1,2}$ and c = 0.
   (ii) switch to normal inspection when 't' lots in a row are accepted under tightened inspection.
   (iii) inspect using normal inspection with smaller sample size $n_{2,2}$ and c=0.
   (iv) switch to tightened inspection after a rejection if an additional lot is rejected in the next 's' lots

When σ is not known, simply substitute the sample standard deviation (s_1) where $s_1 = \sqrt{\dfrac{\sum_{i=1}^{n}(X_i - \bar{X})^2}{n-1}}$ for σ in the known standard deviation procedure by choosing an appropriate value of 'k' and sample size 'n' for the unknown standard deviation case.

IV. CONDITIONS FOR APPLICATIONS

(i) Production process should be steady and continuous
(ii) Lots are submitted sequentially in the order of their production
(iii) Inspection is by variable in the first stage and attribute in the second stage with quality defined as the fraction defective
(iv) Human involvement should be less in the process

V. DEFINITION OF SSQL-1 AND SSQL-2

The proportion defective corresponding to the probability of acceptance of the lot as 1-3.4 x 10^{-6}, (the concept of six sigma quality suggested by Motorola [1] in 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, β_1), where $\beta_1 = 1-\alpha_1$ and $\alpha_1 = 3.4 \times 10^{-6}$ suggested by Radhakrishnan and Sivakumaran [12]. Further the proportion defective corresponding to the probability $2\alpha_1$ in the OC curve is termed as Six Sigma Quality Level-2 (SSQL-2). This new sampling plan is constructed with a point on the OC curve (SSQL-2, β_2), where $\beta_2=2\alpha_1$ suggested by Radhakrishnan and Sivakumaran [12].

VI. DESIGNING THE MIXED SAMPLING PLAN WHEN A SINGLE POINT ON THE OC CURVE IS KNOWN

The procedure for the construction of mixed variables – attributes sampling plans is provided by Schilling [4] for a given 'n_1' and a point 'p_1' on the OC curve. A modified procedure for the construction of independent mixed variables – attributes sampling plan for a given SSQL-1, SSQL-2 and 'n_1' is given below.

- Split the probability of acceptance (β_j) determining the probability of acceptance that will be assigned to the first stage. Let it be β_j'.
- Decide the sample size n_1 (for variable sampling plan) to be used
- Calculate the acceptance limit for the variable sampling plan as
  $A = U - k\sigma = U - [z(p_j) + \{z(\beta_j')/\sqrt{n_1}\}]\sigma$, where z (t) is the standard normal variate corresponding to 't' such that $t = \int_{z(t)}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-u^2/2}\,du$
- Determine the sample average $\bar{X}$. If a sample average $\bar{X} > A = U - k\sigma$, take a second stage sample of size 'n_2' using attribute sampling plan.
- determine β_j'', the probability of acceptance assigned to the attributes plan associated with the second stage sample as $\beta_j'' = (\beta_j - \beta_j') / (1-\beta_j')$
- Determine the appropriate second stage sample of size '$n_{2,2}$' from $Pa(p) = \beta_j''$ for $p = p_j$.
- Now determine β_1'', the probability of acceptance assigned to the attributes plan associated with the second stage sample as $\beta_1'' = (\beta_1 - \beta_1') / (1-\beta_1')$.
- Determine the appropriate second stage sample of size '$n_{2,2}$' and 'c' from $P_a(p) = \beta_1''$ for p=SSQL-1.
- Determine β_2'', the probability of acceptance assigned to the attributes plan associated with the second stage sample as $\beta_2'' = (\beta_2 - \beta_2') / (1-\beta_2')$.

- Determine the appropriate second stage sample of size '$n_{2,2}$' and 'c' from $P_a(p) = \beta_2''$ for p=SSQL-2.

Using the above procedure tables can be constructed to facilitate easy selection of mixed sampling plan with TNT-(n_1, n_2; c) plan as attribute plan indexed through SSQL-1 and SSQL-2.

VII. Operating Characteristic Function

Under the assumption of Poisson model, the OC function of the independent mixed sampling plan having TNT-(n_1, n_2; c) Plan is given by

$$Pa(p) = P(\overline{X} \le A) + [1 - P(\overline{X} \le A)] \frac{P_1(1-P_2^s)(1-P_1^t)(1-P_2) + P_2P_1^t(1-P_1)(2-P_2^s)}{(1-P_2^s)(1-P_1^t)(1-P_2) + P_1^t(1-P_1)(2-P_2^s)} \quad (1)$$

$$\text{Where } P_1 = \sum_{x=0}^{c} \frac{e^{-n_1 p}(n_1 p)^x}{x!} \quad (2)$$

$$P_2 = \sum_{x=0}^{c} \frac{e^{-n_2 p}(n_2 p)^x}{x!} \quad (3)$$

P_1 = Probability of acceptance under tightened inspection

P_2 = Probability of acceptance under normal inspection

Since $n_{1,2} > n_{2,2}$, we set $n_{1,2}$ equal to some multiple of $n_{2,2}$ say, $kn_{2,2}$.

VIII. Construction of MSP with TNT- (n1, n2; c) Plan as Attribute Plan Indexed Through SSQL-1

In this section the mixed sampling plan indexed through SSQL-1 is constructed. A point on the OC curve can be fixed such that the probability of acceptance of fraction defective SSQL-1 is β_1. The general procedure given by Schilling [4] is used for constructing the mixed sampling plan as attribute plan indexed through SSQL-1 [for $\beta_1'' = (\beta_1 - \beta_1') / (1-\beta_1')$] with β_1=0.9999966 and β_1'=0.50, the $n_{2,2}$SSQL-1 values are calculated for different values of c and k using visual basic program and is presented in Table1. The sample size '$n_{1,2} = n_{2,2}$' of the normal plan is obtained as $n_{2,2} = n_{2,2}$SSQL-2/SSQL-2 and then the sample size '$n_{1,2}$' of the tightened plan is found as $n_{1,2} = kn_{2,2}$ (k >1). Hence the parameters of the TNT-(n_1, n_2; c) schemes $n_{1,2}$, $n_{2,2}$ and c are obtained for various values of SSQL-1.

The sigma level of the process [24] is calculated using the Process Sigma Calculator by providing the sample size and acceptance number.

8.1 Selection of the plan

Table 1 is used to construct the plans when SSQL-1, s and t are given. For any given values of SSQL-1, c and k one can determine $n_{2,2}$ value using $n_{2,2} = n_{2,2}$SSQL-1/SSQL-1.

8.2 Example

Given SSQL-1=0.00000002, c = 1, k = 2.0 and β_1'=0.50, the value of SSQL-1 is selected from Table 1 as 0.0000068 and the corresponding sample size of normal plan $n_{2,2}$ is computed as $n_{2,2} = n_{2,2}$SSQL-1/SSQL-1=0.0000068 /0.00000002=340 and the sample size of tightened plan $n_{1,2}$ is computed as $n_{1,2}$ = (2.0)(340) = 680, which are associated with 4.3 and 4.5 sigma levels respectively. For a fixed β_1'=0.50, the Mixed Sampling Plan with TNT-(n_1, n_2; c) Plan as attribute plan are $n_{1,2}$=680, $n_{2,2}$=340 and c = 1 for a specified SSQL-1=0.00000002.

8.3 Practical Application

Suppose the plan with n_1 = 10, c=1 and k=2.0 is to be applied to the lot-by-lot acceptance inspection of solar mobile phone charger. The characteristic to be inspected is the "weight of the solar mobile phone charger in g" for which there is a specified upper limit (U) of 90 g with a known standard deviation (σ) of 0.002 g. In this example, U=90 g, σ = 0.002 g and k = 2.0

Now, in applying the variable inspection first, take a random sample of size n_1=10 from the lot. Record the sample results and find $\overline{X}$. If $\overline{X} \leq A = U - k\sigma$=89.96 g, accept the lot otherwise take a random sample of size 680 and apply attribute inspection.

Under attribute inspection, the TNT-(n_1, n_2; c) plan as attribute plan, if the manufacturer of solar mobile phone charger fixes the quality of cell phones as SSQL-1 = 0.00000002 (2 non-conforming solar mobile phone chargers out of 10 crore items), then inspect under tightened inspection with sample of size 680 solar mobile phone chargers and acceptance number c = 1 from the manufactured lot of a particular month. If 5 lots in a row are accepted under tightened inspection, then switch to normal inspection. Then inspect under normal inspection with a sample of 340 solar mobile phone chargers and acceptance number c = 1 from the manufactured lot of a particular month. Switch to tightened inspection, after a rejection, if an additional lot is rejected in the next 4 lots and inform the management for corrective action. The OC curve of the plan in Example 8.2 is presented in the Figure 1.

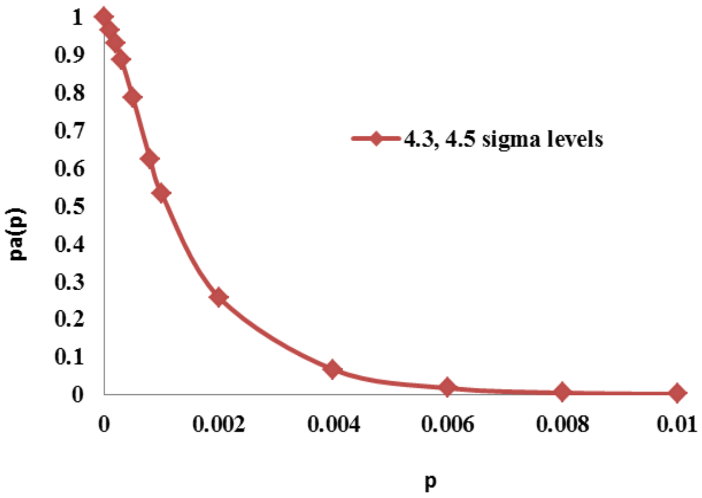

Figure 1. OC curve for the plan $n_{1,2}$=680, $n_{2,2}$=340 and c = 1

Table 1: Various characteristics of the MSP when (SSQL-1, β_1) is known with

β_1 = 0.9999966, β_1' = 0.50.

c	k	$n_{2,2}$SSQL-1
0	1.25	0.0000068
0	1.50	0.0000068
1	1.25	0.0000068
1	1.50	0.0000068
1	1.75	0.0000068
1	2.00	0.0000068
1	2.25	0.0000068
1	2.50	0.0000068
1	2.75	0.0000068
1	3.00	0.0000068
2	2.00	0.0000068
2	2.25	0.0000068
2	2.50	0.0000068
2	2.75	0.0000068
2	3.00	0.0000068
3	2.25	0.0000068
3	2.50	0.0000068
3	2.75	0.0000068

3	3.00	0.0000068
4	2.50	0.0000068
4	2.75	0.0000068
4	3.00	0.0000068
5	2.50	0.0000068
5	2.75	0.0000068
5	3.00	0.0000068

IX. CONSTRUCTION OF MSP WITH TNT- (N1, N2; C) PLAN AS ATTRIBUTE PLAN INDEXED THROUGH SSQL-2

In this section the mixed sampling plan indexed through SSQL-2 is constructed. A point on the OC curve can be fixed such that the probability of acceptance of fraction defective SSQL-2 is β_2. The general procedure given by Schilling [4] is used for constructing the mixed sampling plan as attribute plan indexed through SSQL-2 [for $\beta_2'' = (\beta_2 - \beta_2') / (1-\beta_2')$] with $\beta_2 = 0.0000068$ and $\beta_2' = 0.0000034$, the n_2SSQL-2 values are calculated for different values of c and k using visual basic program and is presented in Table2. The sample size '$n_{1,2} = n_{2,2}$' of the normal plan is obtained as $n_{2,2} = n_{2,2}$SSQL-2/SSQL-2 and then the sample size '$n_{1,2}$' of the tightened plan is found as $n_{1,2} = kn_{2,2}$ (k >1). Hence the parameters of the TNT-(n_1, n_2; c) schemes $n_{1,2}$, $n_{2,2}$ and c are obtained for various values of SSQL-2.

9.1 Example

Given SSQL-2=0.008, c = 2, k = 2.0 and β_1'=0.50, the value of SSQL-2 is selected from Table 2 as 7.4418576 and the corresponding sample size of normal plan $n_{2,2}$ is computed as $n_{2,2} = n_{2,2}$SSQL-2/SSQL-2=7.4418576 /0.008 =930 and the sample size of tightened plan $n_{1,2}$ is computed as $n_{1,2}$ = (2.0)(930) = 1860, which are associated with 4.4 and 4.6 sigma levels respectively. For a fixed β_1'=0.50, the Mixed Sampling Plan with TNT-(n_1, n_2; c) Plan as attribute plan are $n_{1,2}$=1860, $n_{2,2}$=930 and c = 2 for a specified SSQL-2=0.008.

9.2 Practical Application

Suppose the plan with n_1 = 10, c=2 and k=2.0 is to be applied to the lot-by-lot acceptance inspection of solar mobile phone charger. The characteristic to be inspected is the "weight of the handy mobile phone charger in g" for which there is a specified upper limit (U) of 104 g with a known standard deviation (σ) of 0.002 g. In this example, U=104 g, σ = 0.002 g and k = 2.0
Now, in applying the variable inspection first, take a random sample of size n_1=10 from the lot. Record the sample results and find $\overline{X}$. If $\overline{X} \leq A = U - k\sigma$=103.96 g, accept the lot otherwise take a random sample of size 1860 and apply attribute inspection.
Under attribute inspection, the TNT-(n_1, n_2; c) plan as attribute plan, if the distributor of handy mobile phone charger fixes the quality of mobile phone chargers as SSQL-2 = 0.008 (8 non-conforming handy mobile phone chargers out of 1 thousand items), then inspect under tightened inspection with sample of size 1860 handy mobile phone chargers and acceptance number c = 2 from the manufactured lot of a particular month. If 5 lots in a row are accepted under tightened inspection, then switch to normal inspection. Then inspect under normal inspection with a sample of 930 handy mobile phone chargers and acceptance number c = 2 from the manufactured lot of a particular month. Switch to tightened inspection, after a rejection, if an additional lot is rejected in the next 4 lots and inform the management for corrective action. The OC curve of the plan in Example 9.1 is presented in the Figure 2.

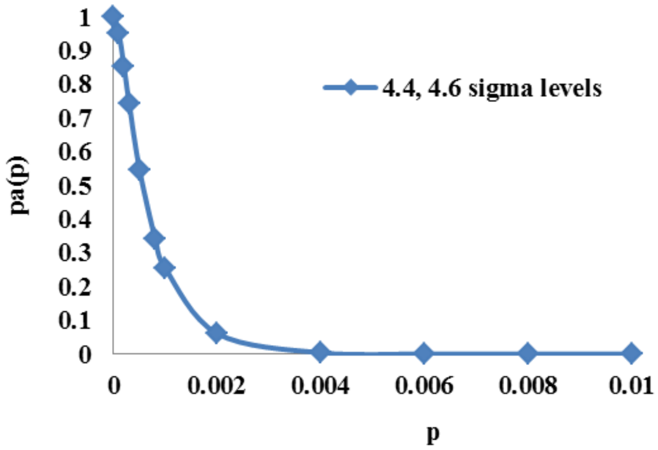

Figure 2. OC curve for the plan $n_{1,2}$=930, $n_{2,2}$=1860 and c = 2

Table2: Various characteristics of the MSP when (SSQL-2, β_2) is known with β_2 = 0.0000068 and β_2' = 0.0000034.

c	k	$n_{2,2}$SSQL-2
0	1.25	11.907999
0	1.50	9.9262777
1	1.25	11.920999
1	1.50	9.9220569
1	1.75	8.5156965
1	2.00	7.4411228
1	2.25	6.6254328
1	2.50	5.9590028
1	2.75	5.4200999
1	3.00	4.9659991
2	2.00	7.4418576
2	2.25	6.6206966
2	2.50	5.9596899
2	2.75	5.4200899
2	3.00	4.9685499
3	2.25	6.6209512
3	2.50	5.9550512
3	2.75	5.4120512
3	3.00	4.9685547
4	2.50	5.9600692
4	2.75	5.4200061
4	3.00	4.9685988
5	2.50	5.9565923
5	2.75	5.4205999
5	3.00	4.9696999

X. Conclusion

This paper provides a procedure to engineers for the selection of Mixed Sampling Plan through Six Sigma Quality Levels having TNT-(n_1, n_2; c) Plan as attribute plan. These plans are very effective in place of classical plans indexed through SSQL-1 and SSQL-2 and these plans are useful for the companies in developed and developing countries which are practicing six sigma quality initiatives in their process. The use of SSQL-1 and SSQL-2 schemes results in savings in the companies reduce costs related to scrap, rework, inspection, and customer dissatisfaction, when compared with single-sampling plan. These schemes are suitable when we have a without break stream of batches or lots, where quality shifts slowly and when the submitted lots are expected to be of in essence the same quality. The procedure outlined in this paper can be used for other plans also.

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