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Economic Reliability Acceptance Sampling Plan Design with Zero Acceptance Number

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ABSTRACT

This paper presents a double acceptance sampling plan where the first sampling assumes zero as the acceptance number. In zero acceptance number sampling plans, the sample items of an incoming lot are inspected one at a time. The projected method in this paper follows these rules: if the number of nonconforming items in the first sample is equal to zero, the lot is accepted but if the number of nonconforming items exceeds zero, i.e is equal to one, then second sample is taken and the rule of zero acceptance number would be applied for the second sample. In this paper, a mathematical model is developed to design single stage and double stage sampling plans. This model can be used to determine the optimal tolerance limits and sample size. In addition, an analysis is carried out to illustrate the effect of some important parameters on the objective function (total loss function). The results show that the two stage sampling plan has better performance than single stage sampling plan in terms of total loss function and sample size.

Keywords: Quality control, Acceptance sampling, Optimal design, Producer's loss, Consumer's loss, Loss Function

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1. INTRODUCTION

An acceptance sampling plan is the overall system for accepting or rejecting a lot based on sample information. The acceptance plan identifies both the sample size and other criteria which are used to accept or reject the lot. Sampling plans can be classified as single, double, multiple, chain, sequential plans e.t.c. Acceptance sampling plan is very significance in the area of quality control/management and it can be applied when its requirements is satisfied. For instance, in single acceptance sampling plans, decision about in-coming lot is taken based on the results of inspection. If the number of defective items are larger than the acceptance number (*c*) then the lot is rejected, or else the lot is accepted.

Double acceptance sampling plan is an extension of single sampling plans, based on the fact that the producer might be psychologically dissatisfied if his products are rejected on the basis of just a single inspection. The double sampling plans are more efficient than the single sampling plans in terms of sample size. Double sampling plans are generally used when final decision cannot be reached by the inspectors based on the result of inspecting the first lot. The process of double sampling plans can be found in [3 and 4]. Whenever the incoming quality level is particularly good or particularly poor, double sampling plan will reach an acceptance or rejection decision faster; therefore the average sample size will reduce.

Acceptance sampling plan uses statistical methods to determine whether to accept or reject an incoming lot. Two approaches are proposed for designing the acceptance sampling models. In the Firstly, the sampling plan is designed based on two-point method. In this method, the designer specifies two points on the operating characteristic (OC) Curve. These two points define the acceptable and unacceptable quality levels for acceptance sampling [5, 12 and 17]. Secondly, the optimal acceptance sampling method is determined by minimizing the total loss function, which consists of the producer's loss and the consumer's loss [7, 10, 11, 14 and 15].

Literatures revealed that many approaches have been proposed for designing sampling plans. One approach is to design economically optimal sampling system. The other approach is to design a statistically optimal sampling system. Furthermore, some studies have considered the combination of these two approaches. The model used in this study can be categorized as an economic model for sampling plan. This approach has been employed by many authors recently. [11] presented an economical acceptance sampling plan. Their plan has three options, namely:

1. They used continuous loss function.
2. Inspection error is considered in their sampling plan.
3. Their model can be used for designing close to optimal sampling plan.

[8] proposed an economical acceptance sampling plan based on Bayesian analysis. [6] proposed an economic design of control chart. They used Taguchi continuous quadratic loss function. Their objective was to minimize the total quality cost and to determine the optimal parameters of control chart. [13] used Taguchi quadratic loss function for economical operation of control chart. They considered sampling cost and the loss function in order to obtain total operation cost. [1] presented variable sampling plan for normal distribution based on Taguchi loss function. [10] recently proposed an optimization model for obtaining the optimal control tolerances and the corresponding critical acceptance and rejection thresholds based on the geometric distribution which minimizes the loss function for both producers and consumers.

It is assumed that the rejected lots are 100% inspected, that means all items would be inspected. This concept is used in developing the objective functions where the cost of inspected items in the case of rejecting the lot involves both the producer loss and consumer loss. The single sampling plan is a decision rule to accept or reject a lot based on the results of one random sample from the lot. The procedure is to take a random sample of size (n) and inspect each item. If the number of defects does not exceed a specified acceptance number (c), the consumer accepts the entire lot. This is the most common plan commonly used, although this plan is not the most efficient in terms of the average number of inspected items.

In double sampling plan, after inspecting the first sample, there are three possibilities:

1. Accept the lot
2. Reject the lot
3. Take a second sample

In a double sampling plan, experimenter specifies two sample sizes (n_1 and n_2) and two acceptance numbers ($c_1$and c_2). If the quality of the lot is very good or very bad, the consumer can make a decision to accept or reject the lot on the basis of the first sample, which is smaller than in the single sampling plan. To use the plan, the consumer takes a random sample of size n_1. If the number of defective items is less than or equal to c_1, the consumer accepts the lot. If the number of defective items is greater than c_2, the consumer rejects the lot. If the number of defective items is between c_1 and c_2, the consumer takes a second sample of size n_2. If the combined number of defective items in the two samples is less than or equal to c_2, the consumer accepts the lot. Otherwise, it is rejected.

In Electronic especially Hard Disk Drive (*HDD*) industry, the use of zero acceptance single sampling plans is widely adopted, particularly for a six sigma process where the quality of product is practically controlled under very low fraction defective level, i.e., in part per million basis. These days, manufacturers are directing toward the implementation of lean production system, which is strongly compelling for the smaller lot sizing to eliminate unnecessary wastes or losses and to minimize the production cycle time. However, the zero acceptance single sampling plans have been implemented as a protection to re-assure the quality of supplied product. The zero acceptance number plans were originally designed and used to provide over all equal or greater consumer protection with less inspection than the corresponding MIL-STD-105 sampling plans. In addition to economic advantages, these plans are simple to use and administer. Because of these advantages and because greater emphasize is now being placed on zero defects and product liability prevention, these plans have found their place in many commercial industries, although they were originally developed for military products.

There is no specific sampling plan or procedure that can be considered the best suited for all applications. It is not practical to cite all of the applications in which these $c=0$ plans are used. Regardless of the products, wherever the potential for lot-by-lot sampling exists, the $c=0$ plans may be applicable. This model is therefore to improve the performance of sampling designs with zero acceptance number which has many applications in the industrial environments. The zero acceptance number single sampling plans have some advantageous over classical sampling plans. For example, it leads the customer to psychologically justify the quality level of their suppliers.

When it is used under two stages, it possess the minimum average total inspection if only a prescribed single point on the operating characteristics (*OC*) curve requirement must be achieved. For small lot sizes, this will also help the manufacturer to minimize the average total inspection as well as the production lead time. To design the zero acceptance single-sampling plans, the sampling distribution of the observed defective must be taken into account, with respect to lot size for greater accuracy.

In this paper, an economic double (two -stage) sampling plan is designed. This model develops an economic model for the sampling plan. The results of the plan are compared with the other models of acceptance sampling plan which were studied by other authors.

1.1 Process Flowchart for Single and Double Stages Acceptance Sampling Plan

The following are the operating procedure for single and double sampling plans

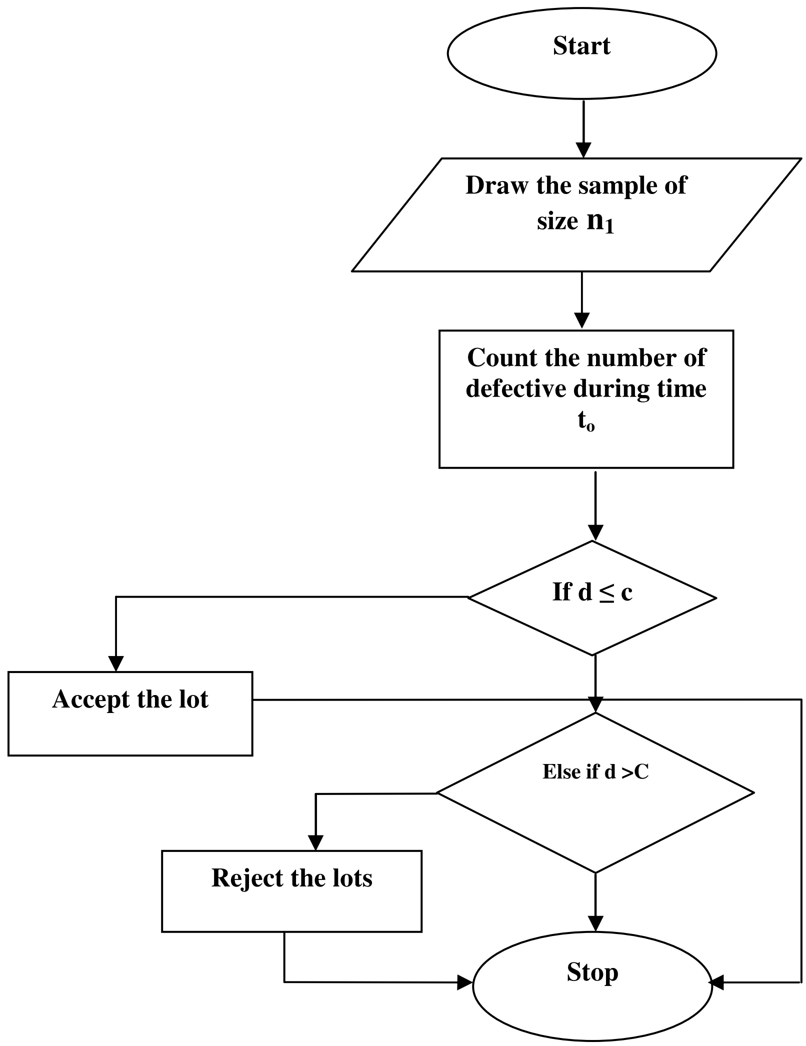

Fig. 1: Flowchart Process for Single Acceptance Sampling Inspection

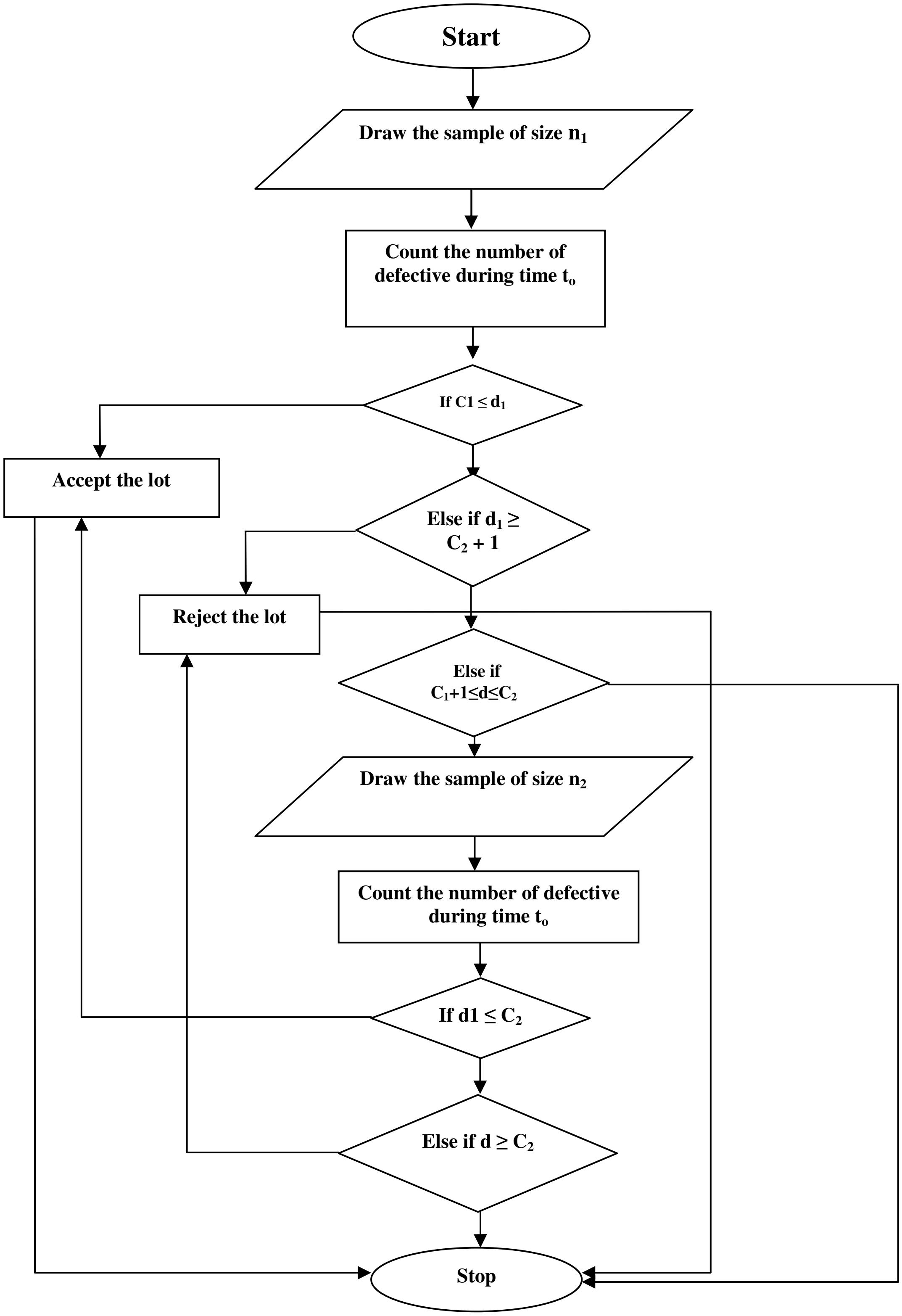

Fig. 2: Flowchart Process for Double Acceptance Sampling Inspection

Notations and Definitions
The following notations and definitions will be used in the rest of the paper

Table 1: Notations

Notation	Definition
Δ	Half the specification width
τ	Target of the quality characteristics
$C_{p(x)}$	Producer's loss
$C_{c(x)}$	Consumer's loss
A	Coefficient of consumer loss function
B	The cost spending by producer to repair or replace a rejected item
N	Lot size
I	Inspection cost per item
n_1	Sample size for first sampling stage
n_2	Sample size for second sampling stage
c	Specified acceptance threshold of nonconforming items in the second sampling stage
δ	Specified acceptance threshold of nonconforming items in the second sampling stage

2. MATERIALS AND METHODS

This paper centers on economic design of sampling system, thus the inspection cost, producer loss and consumer loss are explicitly considered in the model. The main concept considered here deals with the product design that we have determined the optimal value of tolerance for product quality inspection. This model does not consider statistical measures like type I and type II errors because these risks are mostly considered in contracts between producer and consumer based on quality standards. This model can be applied at the final inspection station in production lines where minimizing the cost is important.

It is assumed that the consumer's cost associated with a product is incurred when the quality characteristics fall within the specification limits, and the producer's loss to replace an item is incurred when the quality characteristics exceed the specification limits. A quadratic function is assumed to represent the consumer's cost when quality characteristics fall within the specification limits. The graphical solution to this problem is depicted in figure 1. The producer's loss to repair or replace an item, regardless of the values of the quality characteristics, is *B*. The consumer must spend *A* to repair or replace the item if the quality characteristics exceed $\tau \pm \Delta$ where Δ is half the specification width and τ is the target of the quality characteristics [11]. Therefore the probability of accepting an item P_σ is determined as follows:

$$P_\sigma = \int_{-\delta}^{\delta} f(x)dx \qquad \textbf{(1)}$$

$\tau \pm \Delta$ is specification limits that denote when the values of quality characteristics fall within these limits, then the item is conforming but if we want to consider the consumer loss in the optimization then the tolerance limits change to $\tau \pm \delta$ because larger deviations from target value leads to increasing the consumer's loss. $\tau \pm \delta$ are the tolerance limits and similar to specification limits. They are applied for inspection process and when the values of quality characteristics fall within the tolerance limits, the item is conforming. This figure shows continuous quadratic function between the specifications, while the function passing through zero at the target. The intersection of loss functions for consumer and producer's the inspection

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tolerance that minimizes the total loss. Suppose $C_{p(x)}$ be the producer's loss and $C_{c(x)}$ be the consumer's loss as shown in equation (2) and (3) respectively.

$$C_p(x) = B \qquad (2)$$

$$C_c(x) = \frac{A}{\Delta^2}(x - \Delta)^2 \qquad (3)$$

The loss associated with one inspected item is determined as follows:

$$K = I + \int_{-\infty}^{-\delta} Bf(x)dx + \int_{-\delta}^{\delta} A(x-\mu)^2 f(x)dx + \int_{\sigma}^{\infty} Bf(x)dx \qquad (4)$$

where I is inspection cost per item, $\int_{-\infty}^{\infty} A(x-\tau)^2 f(x)dx$ is cost of the accepted item without inspection. [11] also proposed the following model for designing a single sampling plan model. They assumed a sample size of n items is taken from the process and if the number of defective item in this sample was more than zero then the lot is rejected otherwise it is accepted.

Therefore, the loss model is determined as follows:

$$E(L_1)n_1K + p(N-n_1)\int_{-\infty}^{\infty} A(x-\tau)^2 f(x)dx + (1-p)(N-n_1)K \qquad (5)$$

Where n_1K is the expected loss of item in sample one and $p(N-n_1)\int_{-\infty}^{\infty} A(x-\tau)^2 f(x)dx$ is the expected loss of accepted items without inspection and $(1\text{-}p)(N\text{-}n1)K$ is the expected loss of inspected items, $(N\text{-}n_1)K$ multiplied with probability of rejecting the lot (inspecting all items of the lot) $1\text{-}p$. Since the concept of zero acceptance number is utilized in sampling process thus p is determined as follows:

$$p = \sum_{i=0}^{0}\binom{n}{i}p_\delta^i(1-p_\delta)^{n-i} = (1-p_\delta)^n \qquad (6)$$

It is supposed that a lot with size N is received. The concept of zero acceptance number is utilized in the second sampling stages. Suppose that first sample with size of n_1 items is inspected. For the received lot with N items, if the number of defective items in the first stage of inspection was equal to zero then the lot is accepted but if one defective item was found in the first sample of inspection, then second sample size of n_2 items will be taken. If there were more than one nonconforming item in the first stage of sampling, then the lot would be rejected. Again, if the number of the defective items in second sample was equal to zero, then the lot would be accepted otherwise the lot would be rejected. Therefore, the total loss function used in this study is determined as follows:

$$E(L_2) = n_1K + n_2p_2K + p_1(N-n_1)\int_{-\infty}^{\infty} A(x-\tau)^2 f(x)dx + p_2p_3(N-n_1-n_2)\int_{-\infty}^{\infty} A(x-\tau)^2 f(x)dx + (1-p_1-p_2)K + p_2\,p_4(N-n_1n_2)K \qquad (7)$$

where n_1K is the expected loss of inspected items in first sample and n_2p_2K is the expected loss of inspected items in the second sample, $p_1(N-n_1)\int_{-\infty}^{\infty} A(x-\tau)^2 f(x)dx$ is the expected loss of accepted items without inspection, $p_2p_3(N-n_1-n_2)\int_{-\infty}^{\infty} A(x-\tau)^2 f(x)dx$ is the expected loss of accepted items without inspection, $(N-n_1-n_2)\int_{-\infty}^{\infty} A(x-\tau)^2 f(x)dx$ multiplied with the probability of taking the second sample p_2 and probability of accepting the lot in the second sample, p_3, $(1-p_1p_2)(N-n_1)K$ is the expected value of accepting all remained items in the lot.

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$(N-n_1)K$ multiplied with probability of rejecting the lot in first sampling stage $(1-p_1-p_2)p_2p_4(N-n_1-n_2)K$ is the expected loss of inspecting all remained items in the lot. $(N-n_1-n_2)K$ multiplied with probability of taking the second sample, p_2 multiplied with the probability of rejecting the lot in second sampling stage, p_4. Also p_1 denotes the acceptance probability in the first sampling stage and p_2 denotes the probability of taking the second sample as shown in equation (8).

$$p_1 = \sum_{i=0}^{0}\binom{n}{i} p_\delta^i (1-p_\delta)^{n_1-i} = (1-p_\delta)^{n_1},$$
$$p_2 = \sum_{i=1}^{1}\binom{n}{i} p_\delta^i (1-p_\delta)^{n_1-i} = \binom{n_1}{1} p_\delta (1-p_\delta)^{n_1-1} \qquad \textbf{(8)}$$

Also p_3 denotes the acceptance probability in the second sampling stage and p_4 denotes the probability of rejecting the lot and inspecting all items in the lot (incurring the loss K for each item),

$$p_3 = \sum_{i=0}^{0}\binom{n_1}{1} p_\delta^i (1-p_\delta)^{n_2-i} = (1-p_\delta)^{n_2} \qquad \textbf{(9)}$$
$$p_4 = 1 - p_3$$

Comparing the total loss of two sampling methods, the following result is obtained:

$$E(L_1) - E(L_2) = \binom{n_1}{1} p_\delta (1-p_\delta)^{n_1-1} (1-p_\delta)^{n_1} (N-n_1-n_2)(K-A) \qquad \textbf{(10)}$$

Therefore, the following decision making method is obtained.

If $K<A$, then single sampling plan is preferred, otherwise, double sampling plan would be better. It is of note that all items are inspected after rejecting the lot and the objective function is designed based on rectified sampling. The model is used to simulate existing values using statistical software (R) so as to compare the obtained result with existing ones.
Producer and consumer risks are not being considered in the optimization model. Adding these risks as constraints in the model is possible where it is important to design an optimized economic statistical sampling method. The loss function of double sampling plan is minimized separately. Also, the loss function of single-sampling plan is minimized separately. The difference between these two objective functions are computed in order to find out which one is less and optimal.

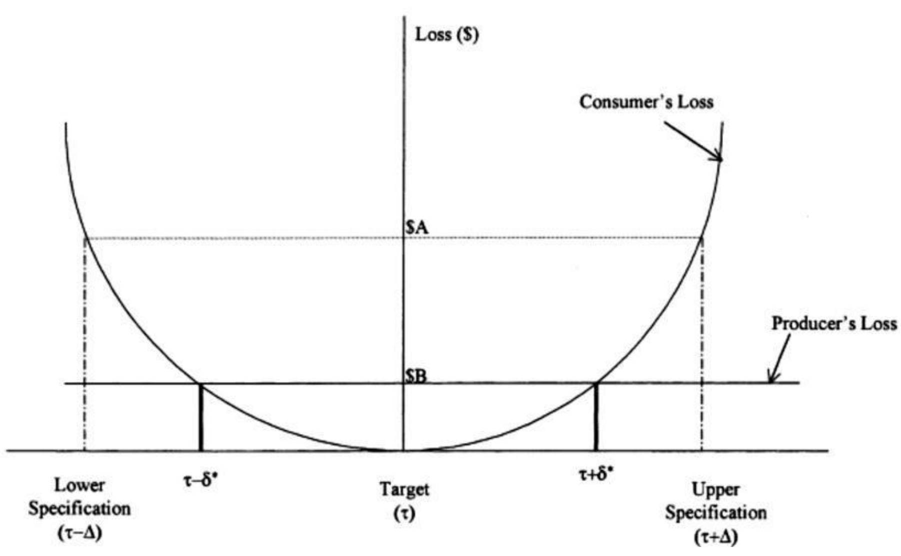

Fig. 3: Graphical quadratic function. Source: [9].

3. RESULTS AND ANALYSIS

In this section, a statistical example is presented to illustrate the performance of this model. This example shows how the model can be applied to obtain the optimal values of parameters n_1, n_2, δ in order to minimize producer's and consumer's loss. In this example, the lot size is equal to 50000, and $\Delta=1$, $\tau=0$, $I=10$, $B=50$. The minimum total losses for two stages sampling plan and single stage sampling plan are obtained by solving optimization model with mentioned input parameters. The different combination of alternative values for n_1, n_2, δ is used together and their corresponding loss objective functions are determined. Since the search space is limited thus, numerical simulation method was used to solve the model. First, 104 set of alternative values for n_1, n_2, δ are generated in logical intervals. Then, this model and classical models have been solved with these input values. To illustrate the performance and statistical advantages of this sampling method, the average sample number (*ASN*) for each set of parameters was calculated, [16]

Since statistical measures (i.e risks) are not included in the optimization model, thus analyzing power of sampling system is not needed the risks at AQL and LQL points was obtained to see the behavior of the sampling plan. The results have been summarized and displayed in table 1 and 2. From these table, it is observed that the risk of producer (1-Pa(AQL)) and the risk of consumer (Pa(LQL)) in the two stage method is less than classical one stage method in most of the cases.

It can be seen that the optimal sampling design in two stages method is $n_1=4$, $n_2=13$, $\delta=4.2$ and its minimum loss is equal to 1857344. It can be seen that the optimal sampling design in single stage method is $n=6$, $\delta=4.2$ and its minimum loss is equal to 1859660. The value of objective function in two stages sampling model is less than single stage sampling model. This result was expected because $K=37.34>A=36$ in this system. Also, ASN in two stages sampling method is 6 and it is equal to sample size of single stage method. Also, producer and consumer risks in two stages sampling model is 0.010 and 0.02, respectively where the values of these risk in single stage method are 0.04 and 0.05, respectively that denote the better performance of the proposed method considering risk values.

Table 1: The value of cost function for alternative values of n_1, n_2, δ in two stages (double acceptance sampling) plan

n_1	n_2	*ASN*	δ	$1-p_a(AQL)$	$1-p_a(LQL)$	Total
3	11	14	1.0000	0.0300	0.0500	2591667
9	13	11	1.2000	0.0500	0.0400	2514176
3	13	11	1.4000	0.0400	0.0300	2439532
4	12	13	1.6000	0.0400	0.0300	2367466
3	12	4	1.8000	0.0400	0.0300	2298591
3	9	6	2.0000	0.0400	0.0500	2217475
7	14	19	2.2000	0.0300	0.0500	2172051
3	7	5	2.4000	0.0200	0.0400	2112036
7	9	7	2.6000	0.0300	0.0100	2059190
3	9	11	2.8000	0.0100	0.0500	2016165
5	14	9	3.0000	0.0100	0.0500	1974670
6	10	11	3.2000	0.0300	0.1000	1938065
3	8	7	3.4000	0.0200	0.0400	1904513
7	13	14	3.6000	0.0100	0.0200	1881900
4	10	12	3.8000	0.0300	0.0200	1872067
5	8	8	4.0000	0.0100	0.0200	1862808
5	7	8	4.2000	0.0400	0.0500	1861693
6	14	14	4.4000	0.0200	0.0200	1851188
7	14	12	4.6000	0.0400	0.0600	1882929
7	13	8	4.8000	0.0100	0.0300	1887367
6	8	12	5.0000	0.0200	0.0200	1920637
8	15	16	1.0000	0.0200	0.0200	2591666
4	9	6	1.2000	0.0200	0.0400	2514176
7	17	21	1.4000	0.0200	0.0600	2439533
7	15	14	1.6000	0.0100	0.0300	2366717
6	11	8	1.8000	0.0300	0.0400	2298597
4	13	10	2.0000	0.0100	0.0300	2231583
3	6	4	2.2000	0.0500	0.0500	2169650
3	14	10	2.4000	0.0600	0.0300	2114698
6	11	12	2.6000	0.0300	0.0200	2062817
3	6	4	2.8000	0.0600	0.0500	2016165
8	14	17	3.0000	0.0300	0.0300	1974338
5	11	15	3.2000	0.0300	0.0600	1938846
3	13	8	3.4000	0.0300	0.0300	1898984
5	12	9	3.6000	0.0400	0.0300	1884736
6	14	6	3.8000	0.0400	0.0300	1873185
6	14	11	4.0000	0.0400	0.0500	1844612
4	17	5	4.2000	0.0600	0.0200	1841142
4	19	8	4.4000	0.0300	0.0600	1871954
6	10	13	4.6000	0.0100	0.0400	1879755
5	10	8	4.8000	0.0400	0.0400	1864467
4	14	11	5.0000	0.0200	0.0300	1899777
7	10	8	1.0000	0.0400	0.0200	2591664
6	13	13	1.2000	0.0600	0.0200	2513275
5	15	11	1.4000	0.0100	0.0300	2431506
7	17	15	1.6000	0.0100	0.0400	2367466
9	14	15	1.8000	0.0200	0.0200	2285233
5	13	8	2.0000	0.0600	0.0500	2233269
7	13	16	2.2000	0.0300	0.0200	2153935
9	19	23	2.4000	0.0500	0.0300	2115120
7	15	16	2.6000	0.0500	0.0200	2063074

5	14	19	2.8000	0.0600	0.0500	2014071
4	12	8	3.0000	0.0300	0.0200	1969639
9	12	15	3.2000	0.0400	0.0300	1938842
9	16	17	3.4000	0.0300	0.0500	1910503
5	14	14	3.6000	0.0300	0.0300	1888283
8	15	19	3.8000	0.0500	0.0300	1866464
5	10	5	4.0000	0.0400	0.0200	1857903
4	14	13	4.2000	0.0100	0.0100	1861898
4	13	12	4.4000	0.0100	0.0800	1867942
9	18	18	4.6000	0.0500	0.0500	1842268
6	16	17	4.8000	0.0200	0.0300	1856221
9	16	21	5.0000	0.0200	0.0600	1892069
3	11	7	1.0000	0.0500	0.0600	2591664
4	6	8	1.2000	0.0200	0.0500	2514355
3	10	11	1.4000	0.0500	0.0200	2439433
6	16	21	1.6000	0.0300	0.0700	2364643
8	14	13	1.8000	0.0200	0.0700	2298591
9	14	14	2.0000	0.0400	0.0200	2232752
6	9	14	2.2000	0.0200	0.0200	2171949
6	10	15	2.4000	0.0100	0.0100	2113940
4	11	8	2.6000	0.0500	0.0500	2062399
7	16	11	2.8000	0.0100	0.0200	2015796
6	16	10	3.0000	0.0600	0.0400	1974337
7	12	17	3.2000	0.0200	0.0600	1916445
8	10	15	3.4000	0.0300	0.0300	1907280
4	9	8	3.6000	0.0600	0.0500	1877179
9	14	21	3.8000	0.0300	0.0200	1866516
4	12	8	4.0000	0.0200	0.0400	1860869
4	14	7	4.2000	0.0500	0.0200	1855842
6	8	6	4.4000	0.0200	0.0400	1869544
5	9	13	4.6000	0.0200	0.0700	1857755
7	14	14	4.8000	0.0700	0.0200	1876103
7	13	7	5.0000	0.0600	0.0500	1866495
4	6	5	1.0000	0.0200	0.0900	2591664
4	13	16	1.2000	0.0400	0.0600	2514400
6	16	18	1.4000	0.0300	0.0300	2439533
6	15	13	1.6000	0.0300	0.0100	2366717
4	13	6	1.8000	0.0300	0.0500	2298245
5	11	11	2.0000	0.0200	0.0600	2217434
3	14	11	2.2000	0.0400	0.0600	2171184
5	11	6	2.4000	0.0200	0.0300	2115120
4	14	17	2.6000	0.0300	0.0500	2063074
5	17	14	2.8000	0.0400	0.0300	2006152
3	12	5	3.0000	0.0300	0.0400	1974336
5	12	12	3.2000	0.0400	0.0400	1933817
4	17	19	3.4000	0.0200	0.0300	1908833
6	9	12	3.6000	0.0500	0.0500	1887355
6	14	13	3.8000	0.0400	0.0500	1873196
6	11	17	4.0000	0.0300	0.0400	1857956
4	13	6	4.2000	0.0100	0.0200	1843997
6	12	15	4.4000	0.0500	0.0600	1859357
6	6	6	4.6000	0.0500	0.0100	1873398
7	16	9	4.8000	0.0100	0.0400	1895342

Table 2: The value of cost function for alternative values of n, $\hat{\delta}$ in single stage sampling plan

n_1	δ	$1-p_a(AQL)$	$1-p_a(LQL)$	Total
7	1.0000	0.0400	0.0200	2591664
7	1.2000	0.0300	0.0300	2514391
7	1.4000	0.0400	0.0800	2439510
7	1.6000	0.0200	0.0700	2367414
7	1.8000	0.0600	0.0200	2298494
7	2.0000	0.0500	0.0700	2233141
7	2.2000	0.0700	0.0300	2171744
7	2.4000	0.0800	0.0700	2114698
7	2.6000	0.0400	0.0300	2062399
7	2.8000	0.0600	0.0800	2015253
7	3.0000	0.0200	0.0800	1973671
7	3.2000	0.0700	0.0400	1938066
7	3.4000	0.0800	0.1200	1908844
7	3.6000	0.0600	0.0900	1886383
7	3.8000	0.0900	0.0700	1870996
7	4.0000	0.0800	0.0400	1862873
7	4.2000	0.0500	0.0900	1862004
7	4.4000	0.0600	0.0500	1868047
7	4.6000	0.0200	0.0400	1880169
7	4.8000	0.0300	0.1200	1896808
7	5.0000	0.0200	0.1000	1915374
8	1.0000	0.0700	0.0700	2591666
8	1.2000	0.0300	0.1100	2514398
8	1.4000	0.0300	0.0700	2439528
8	1.6000	0.0400	0.0200	2367453
8	1.8000	0.0900	0.0900	2298568
8	2.0000	0.0300	0.0000	2233269
8	2.2000	0.0400	0.0800	2171949
8	2.4000	0.0000	0.0400	2115000
8	2.6000	0.0300	0.1000	2062817
8	2.8000	0.0300	0.0400	2015796
8	3.0000	0.0600	0.0200	1974338
8	3.2000	0.0100	0.0800	1938848
8	3.4000	0.0200	0.0800	1909725
8	3.6000	0.0200	0.0700	1887356
8	3.8000	0.0300	0.0700	1872080
8	4.0000	0.0700	0.0100	1864148
8	4.2000	0.0600	0.0500	1863638
8	4.4000	0.0300	-0.0600	1870335
8	4.6000	0.0300	0.0600	1883549
8	4.8000	0.0600	0.0000	1901846
8	5.0000	0.0300	0.0400	1922678
9	1.0000	0.0100	0.0200	2591667
9	1.2000	0.0200	0.1100	2514400
9	1.4000	0.0000	0.0700	2439532
9	1.6000	0.0900	0.0100	2367463
9	1.8000	0.1100	0.1400	2298591
9	2.0000	0.0700	0.1400	2233312
9	2.2000	0.0600	0.0600	2172024
9	2.4000	0.0600	0.1000	2115120
9	2.6000	0.0800	0.0400	2062997

9	2.8000	0.0500	0.1000	2016048
9	3.0000	0.0200	0.0200	1974670
9	3.2000	0.0800	0.0100	1939263
9	3.4000	0.1000	0.0400	1910222
9	3.6000	0.0600	0.0400	1887937
9	3.8000	0.1100	0.0500	1872764
9	4.0000	0.0100	0.0700	1864994
9	4.2000	0.0300	0.1100	1864777
9	4.4000	0.0100	0.1000	1872006
9	4.6000	0.0300	0.0300	1886130
9	4.8000	0.0800	0.0800	1905860
9	5.0000	0.0300	0.0800	1928740
10	1.0000	0.0200	0.0800	2591667
10	1.2000	0.0200	0.0900	2514400
10	1.4000	0.0600	0.0400	2439533
10	1.6000	0.0400	0.0700	2367466
10	1.8000	0.0200	0.0600	2298597
10	2.0000	0.0500	0.0900	2233326
10	2.2000	0.0800	0.0800	2172051
10	2.4000	0.0300	0.0400	2115168
10	2.6000	0.0500	0.0400	2063074
10	2.8000	0.1000	0.1000	2016165
10	3.0000	0.0300	0.0700	1974836
10	3.2000	0.0300	0.0800	1939483
10	3.4000	0.0600	0.0900	1910503
10	3.6000	0.0100	0.1200	1888284
10	3.8000	0.0100	0.0200	1873196
10	4.0000	0.0400	0.1100	1865556
10	4.2000	0.0400	0.1600	1865571
10	4.4000	0.0300	0.0400	1873227
10	4.6000	0.0700	0.0100	1888101
10	4.8000	0.0100	0.0400	1909059
10	5.0000	0.0600	0.0800	1933771
6	1.0000	0.0500	0.0400	2591650
6	1.2000	0.0400	0.0300	2514355
6	1.4000	0.0800	0.0600	2439433
6	1.6000	0.0700	0.0900	2367267
6	1.8000	0.1000	0.0600	2298245
6	2.0000	0.0800	0.0500	2232753
6	2.2000	0.0700	0.0200	2171184
6	2.4000	0.0700	0.0600	2113940
6	2.6000	0.0800	0.0400	2061433
6	2.8000	0.0100	0.1500	2014086
6	3.0000	0.0400	0.0400	1972331
6	3.2000	0.0600	0.1400	1936594
6	3.4000	0.0200	0.0800	1907283
6	3.6000	0.0200	0.1000	1884756
6	3.8000	0.0700	0.0400	1869276
6	4.0000	0.0500	0.1200	1860954
6	4.2000	0.0400	0.0500	1859660
6	4.4000	0.0500	0.0400	1864914
6	4.6000	0.0400	0.0700	1875742
6	4.8000	0.0500	0.1100	1890484

4. SENSITIVITY STUDY

The effects of some important input parameters like:

1. Coefficient of consumer loss function (A),
2. Producer's cost to repair or replace a rejected item (B) and
3. Lot sizes (N) on the objective function were examined.

Figure 4 shows the variation of the objective function with respect to the lot size. It is observed that objective function increases by increasing the lot size. This means that it is better to provide a small value of lot size for lot acceptance model in order to decrease the expected loss for each item in quality inspection plan. Also, a sensitivity study is performed in order to rejected item (*B*) on the objective function. According to figure 5 and 6, it is observed that the objective function increases by increasing the value of *B* and *A* respectively with fewer slope rather than figure 4. Conclusively, figure 4 shows that total loss function increases considerably by increasing the lot size, which is in line with [16].

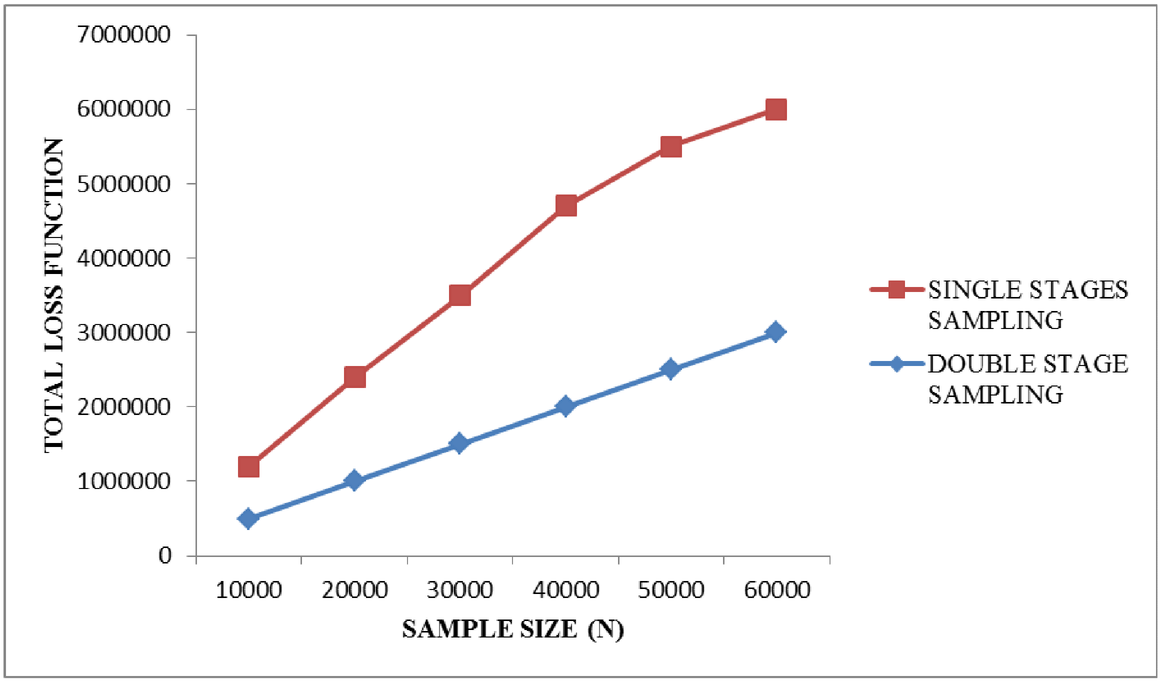

Fig. 4: Lot size (N) versus Objective function

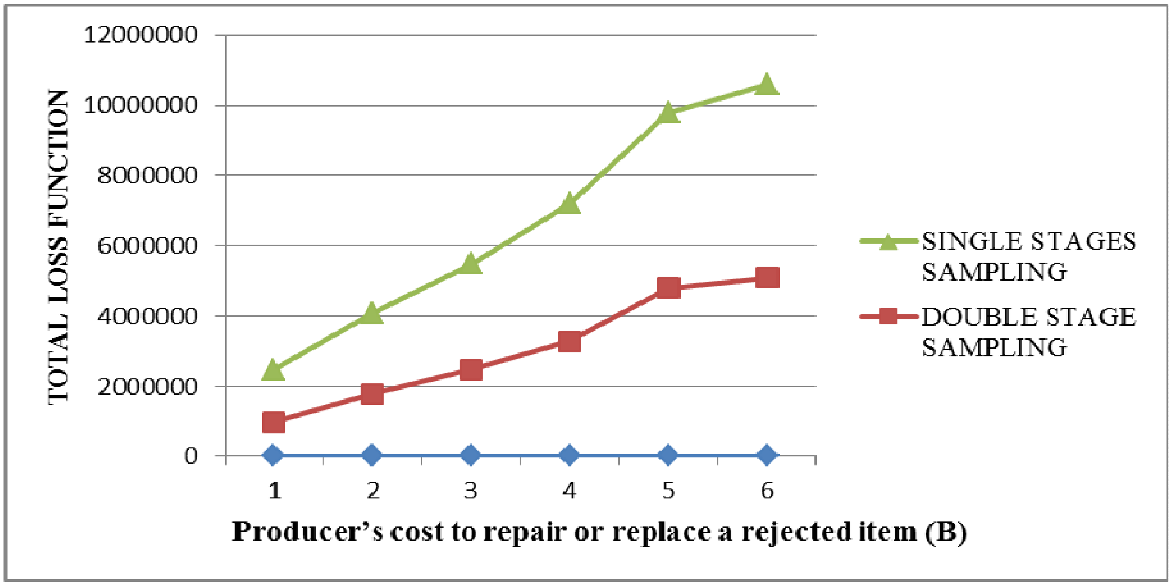

Fig. 5: Producer's cost to repair or replace a rejected item (B) versus Objective function

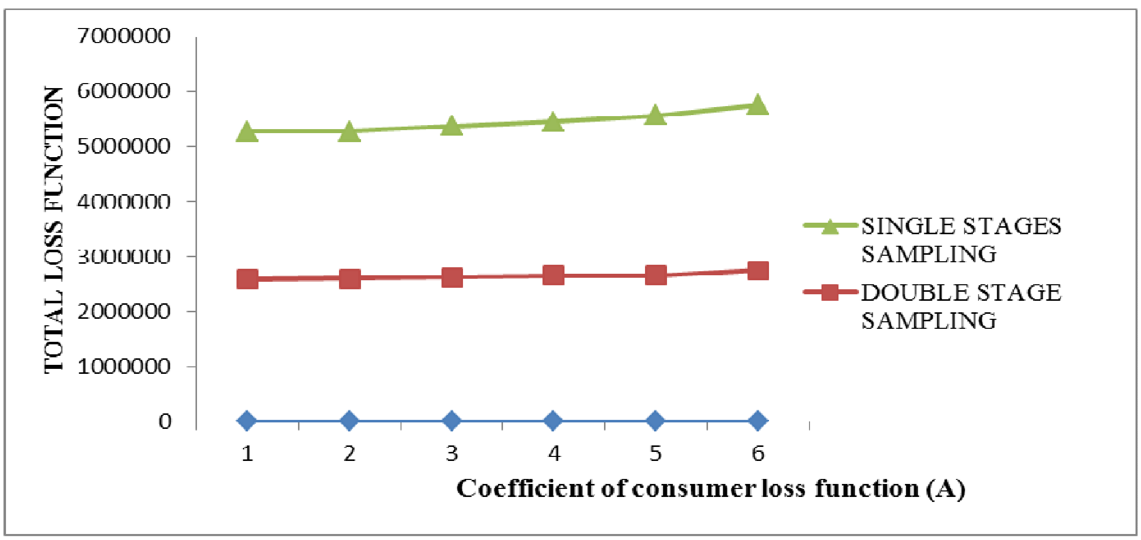

Fig. 6: Coefficient of consumer loss function (A) versus Objective function

5. DISCUSSION AND CONCLUSION

A comparison study is performed between single stage sampling model and double-sampling model based on loss objective function for plans with zero acceptance number. This method provides the protection for both producer and consumer by minimizing the summation of loss for each one. The double sampling plan was compared with classical single sampling plan and a sensitivity analysis was carried out to compare the model performance under different scenarios of parameters selection. The advantages of this model rather than the existing traditional ones is to help decision maker to select the optimal sampling parameters in the case that zero acceptance number policy is employed in order to decrease the total loss for both producer and consumer.

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REFERENCES

[1] Arizono, I., Kanagawa, A., Ohta H., Watakabe K., & Tateishi K. (1997). "Variable sampling plans for by Taguchi's *Naval* loss*Research* function", *Logistics* 44(6) pp.591-603.

[2] Aslam, M., Jun, C.H, Ahmad, M. (2009) Double acceptance sampling plans based on truncated life tests in the weibull model *Journal of Statistical Theory and Applications,* 8(2) pp. 191- 206.

[3] Aslam, M. & Jun, C.H. (2010). A double acceptance sampling plan for generalized log-logistic distributions with known shape parameters, *Journal of Applied Statistics,* 37(3) pp. 405-414.

[4] Aslam, M., Yasir, M., Lio, Y.L., Tsai, T.R., Khan, M.A. (2011). Double acceptance sampling plans for burr type XII distribution percentiles under the truncated life test, *Journal of the Operational Research Society,* 63(7) pp.1010- 1017.

[5] Aslam, M., Niaki, S.T.A.., Rasool, M., Fallahnezhad, M.S. (2012). Decision rule of repetitive acceptance sampling plans assuring percentile life, *Scientia Iranica*, 19(3) pp.879-884.

[6] Elsayed, E. A. & Chen, A. (1994). An economic design of control *International Journal of Production Research*, 32(4) pp. 873-887.

[7] Fallahnezhad, M.S., Niaki, S.T.A., VahdatZad, M.A. (2012). A new acceptance sampling design using bayesian modeling and backwards induction, *International Journal of Engineering, Transactions C: Aspects*, 25(1) pp. 45-54.

[8] Fallahnezhad, M.S., Aslam, M. (2013). Anew economical design of acceptance sampling models using bayesian inference, *Accreditation and Quality Assurance*, 18(3) pp.187-195.

[9] Fallahnezhad, M.S., HosseiniNasab, H. (2011). Designing a single stage acceptance sampling plan based on the control threshold policy, *International Journal of Industrial Engineering & Production Research*, 22(3) pp. 143-150.

[10] Fallahnezhad, M.S., Ahmadi Yazdi, A. (2015). Economic acceptance design sampling of plans based on conforming run lengths using loss functions, *Journal of Testing and Evaluation*, 44(1) pp. 1-8.

[11] Ferrell, W. G., Chhoker, Jr. A. (2002). Design of economically optimal acceptance sampling plans with inspection error, *Computers & Operations Research*, 29(1) pp. 1283-1300.

[12] Govindaraju, K. (2005). Design minimum of average total inspection sampling plans, *Communications in Statistics - Simulation and Computation*, 34(2) pp. 85-493

[13] Hailey W.A. (1980). Minimum sample size single sampling plans: a computerized *Journal of Quality Technology* approach", 12(4) pp. 230–5.

[14] Kobayashia, J., Arizonoa, I. & Takemotoa, Y. (2003), Economical operation of cont function, *International Journal of Production Research*, 41(6) pp. 1115-1132.

[15] Moskowitz, H. and Tang, K. (1992). Bayesian variables acceptance-sampling plans: quadratic loss function and step loss function, *Technometrics*, 34(3) pp. 340-347.

[16] Niaki, S.T.A., Fallahnezhad, M.S (2009). Designing an optimum acceptance plan using bayesian inference and stochastic dynamic programming, *Scientia Iranica*, 16(1) pp. 19-25.

[17] Mohammad S. F. N, Ahmad A. Y, Parvin A and Muhammad A (2015). Design of Economic Optimal Double Sampling Design with Zero Acceptance Numbers, *Journal of Quality Engineering and Production Optimization,* 1(2), pp. 45-56.

[18] Pearn, W.L., Wu. C.W. (2006). Critical acceptance values and sample sizes of a variables sampling plan for very low fraction of nonconforming, *Omega* 34(1) pp.90 –101.