Scheming and Economic Analysis of SkSP-3 involving Destructive and Non- Destructive Testing of Cross Member Automotive Spare Parts

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Short Report

Keywords: Destructive testing, Efficiency, Non-destructive testing, Optimal plan, Stochastic transition, Skip-lot sampling plan

Posted Date: August 14th, 2024

DOI: https://doi.org/10.21203/rs.3.rs-4760062/v1

Additional Declarations: No competing interests reported.

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ABSTRACT

This paper demonstrates the development of an economic designing and evaluating procedure for the Skip-lot sampling plan-3 under the conditions of Poisson distribution. The designing of feasible cost model under certain conditions imposed in essential construction of single sampling plan to study the economic designing of special purpose plan such as SkSP-3 at various stages of inspection of lots at the production unit is emphasized. The cost behaviour of spare parts with respect to plan parameters through the sensitivity analysis and furthermore, cost curves deals with determining the optimal plan parameters are presented in a tailor made tables for the Industrialist. Efficiency gain is exclusively given for the stochastic representation of the cost function in destructive and non-destructive testing.

Key Words: Destructive testing, Efficiency, Non-destructive testing, Optimal plan, Stochastic transition, Skip-lot sampling plan.

1 Introduction

Acceptance sampling plan plays an essential role for the industrialist to improve their quality of the raw material or finished goods in achieving minimizing risks of both producer and consumer with minimum cost. Skip-lot sampling is considered to be a good and useful acceptance sampling procedure is a lot-by-lot sampling inspection plans well qualify as a standard system of reduced inspection has a provision to inspect only a fraction of submitted lots when the quality of the products is excellent examined by the producer's quality history. These plans are in general transferring the Continuous Sampling Plan (CSP) of Dodge (1943) for continuous series of units' principle to inspection of lots. Skip-lot sampling plan of type SkSP-1 Dodge (1955b) concerns the bulk sampling of lots in which every incoming lot is inspected until certain successive i lots are accepted. The plan switches between sampling inspection and screening. SkSP-2 procedure is proposed by Dodge and Perry (1971) for a skip lot system is specified by i and k of a SkSP-1 plan and a reference plan. The skip-lot sampling plans uses the method of attribute sampling plans (SSP) to inspect the lots is called the reference plan. Further, Perry (1973) tabulated unity values of SkSP-2 under the conditions of Poisson distribution for the specified producer's risk at *5%* and consumer's risk at *10%*. Suresh (1993) designed a methodology based on relative slopes, Vijayaraghavan (2000), Vijayaraghavan (2009), Balamurali and Subramani (2010) constructed tables for the selection of SkSP–3 and suggested important techniques for arriving performance measures and plan parameters

The scheming of cost optimization for SkSP-3 plan by attributes in the case of destructive and costly testing, non-destructive testing for fixed lot size and variable lot size under Poisson distribution is introduced in Section 2, which is a generalization of the cost function considered by Hsu (1977), Hsu (1979) developed skip-lot cost model for destructive sampling and non-destructive sampling that minimizes the average cost per good unit under various lot size characterized by n, c and the inspection interval. Hsu (1980) extended the skip-lot cost model to skip-lot sampling plan. Under the assumption of cost model, this work considered the confidence level (1-α) and β for the product being in good state and degraded state. It is evident from the literature survey that no attempts are found in designing of feasible cost model under certain conditions imposed in essential construction of single sampling plan.

Thus, the probability distribution for number of defectives under Poisson model for the SSP is given by

$$P_k = P_a(\delta_k) = \sum_{x=0}^{c} \frac{e^{-np(1-\alpha)}(np(1-\alpha))^x}{x!} \quad (1)$$

$$P_j = P_a(\delta_j) = \sum_{x=0}^{c} \frac{e^{-np\beta}(np\beta)^x}{x!} , \quad (2)$$

where P_k and P_j are the Probability of acceptance of lot under good state k and Probability of acceptance of lots under degraded state j respectively. The (1) and (2) is used to study the economic designing of special purpose plans such as SkSP-3 at various stages of inspection of lots at the production unit is emphasized. Romboski (1969) derived OC function of QSS (Quick Switching System) for related approaches.

Horsnell (1957) considered the choice of the risk points and the associated risks for the cost parameters to accept lots of quality on 95 percent and nature of curves are shown for destructive and non-destructive inspection which minimizes the effective costs. Cyris Martin (1964) formulated combined-cost equation for a breakeven point to compute a critical point in case of destructive sampling and non-destructive sampling keeping the lot size N constant. Moreover, Brown and Rutemiller (1974) considered and framed to calculate the long run cost of sampling inspection. Therefore, most literature has focused on minimizing the total sampling cost through Bayesian approach and Monte carlo simulation (Wetherill and Chiu, 1975; Lenz and Wilrich, 1977; Hald, 1981; Phelps, 1982; Cox, 1982; Chen and Chou, 2002 for CSP-1; Haji and Haji, 2004; Sampath kumar et al., 2004; Chen and Chou, 2006; Chen, 2009).

However, few papers were made contributions on cost optimization as Fallahnezhad and Niaki (2010), developed absorbing Markov chain models to determine the optimum process mean levels and various costs for both stage of production with rework and scrapping. Fallahnezhad and Aslam (2013) proposed an economical design for the optimal decision using the Bayesian inference along with backward induction is utilized to analyse the expected cost of different decisions. Chen. et. al., (2015) including the Taguchi's quadratic quality loss of conforming products associated with raw material and production process sustains the optimal parameters under the minimization of the expected total relevant cost of product per unit time. However, these approaches are limited to Balamurali et.al (2015) proposed an economic design of SkSP-R for both destructive and non-destructive testing by considering various cost items in order to reduce sampling costs and inspection efforts. Balamurali and Subramani (2017) introduced an optimal design of a skip-lot sampling plan of type SkSP-2 when the quality characteristic under inspection follows a normal distribution to minimize the inspection cost of the final lots, the average sample number subject to satisfying the producer's and consumer's risks at the AQL and LQL respectively.

Riemann (1982) insisted that Hsu optimal model is sub-optimal for independent fraction defective. Recently, Balamurali and Subramani (2010); Balamurali and Jun (2011) formulated SkSP-3 and SkSP-V procedure through Markov chain and derived its performance measure. Also, certain cost models are framed for the economic design of SkSP-3 and SkSP-V plan. Kokila and Pradeepa Veerakumari (2018) gave an economic design of TNT plan; a key advantage of our cost model is a non-Bayesian approach because of the simplicity of Hsu (1977) economic design and model that the optimal plan is obtained by choosing the minimum cost through the sensitivity analysis. The prior probabilities are chosen for various states of product quality are fixed and the cost function is derived in order to satisfy the conditions of the sampling plan. The tailor-made tables are presented for selection of optimal plan parameters.

The remainder of this paper is structured as follows. In Section 2, the scheming of SSP plan is introduced. In Section 3, procedures and evaluation of cost function for destructive testing item with numerical illustration is given. In Section 4, procedures and feasible cost model for non-destructive testing item of fixed lot size is presented with real data example. In Section 5, procedures and feasible cost model for non-destructive testing item of variable lot size is presented with real data example. In Section 6, presents a comparative study which is carried out through the experimental cost curve analysis and simulation studies for the skip-lot sampling plans involved in this study.

2 Scheming of single sampling plan under the conditions of Poisson distribution

The Single Sampling Plan (SSP) is the popularly used form of sampling plan for the industrial purposes. The SSP is used for count data in which only one sample is selected characterized by three parameters namely, the lot size (*N*), sample size (*n*) and acceptance number (*c*). If the total num ber of defective units d_e does not exceed the critical value *c* accept the lot, otherwise reject the lot.

Before administering a plan, it is important to find out which of these acceptance number and rejection number is being used satisfying both the stake holders. The sampling plans are developed under the assumptions that the manufactured products in each lot are comes out under the homogeneous conditions. The OC function of SSP is defined as,

$$P_a(p) = P[x \leq c] \tag{3}$$

In this regard, Hald (1981) pointed out that the Poisson approximation to the Binomial B(n, p, c) ≈ P(np, c) when $p < 0.1$, offers great advantages theoretical as well as numerical, since the two parameters n and p are replaced by the one parameter $\lambda = np$. Here *p* symbolizes the lot proportion defectives. Schilling (1982) also prescribes out that when $n/N \leq 0.10$, *n* is large and *p* is small such that $np < 5$, then the suitable model for number of nonconformity units is Poisson distribution with parameter *np*. In general, the values of $P_a(p)$, the probability of accepting the lot can be determined for various values of *p* using the probability models (Poisson model). In the production process, the lot is submitted for inspection in the order of their production process. There may be two states k and j where there are changes in the process fraction defective when the lots are produced in each inspection interval observed from the past records according to Hsu (1977). There may be transition from one state to another per lot. Then the mean of the rare event np may be altered. Here np is replaced by considering risks np(1-α) for good state k, δ_k=0.01 and npβ for degraded state j, δ_j= 0.10 without violating the assumptions of Poisson distribution improvising the model as Romboski (1969) derived OC function for QSS-2 using single sampling plan as reference plan in which k times the samp le size is multiplied. In such situation the probability distributions

$$P_a(p) = \sum_{x=0}^{c} \frac{e^{-np}(np)^x}{x!} \tag{4}$$

be unsuccessful to study this kind of transition. Thus, the probability distribution for number of defectives under Poisson model for the SSP for given values of *n, c* and p is given by (1) and (2).

Hence the probability of acceptance on different state Pa_k (good state) and Pa_j (degraded state) of SkSP-3 are obtained using equation (1) and (2). The Single Sampling Plan is used as a reference plan for special purpose plans.

2.1 *Numerical Illustration*

Let us assume that the production process may have two states k and j where in the incoming inspection lot during normal and skipping process has the fraction defective is in good state δ_k=0.01 and the other proportion defective are considered as the degraded state δ_j=0.10. Assuming under the conditions that the incoming quality of the spare parts to follow Poisson distribution. Given the lot size N=1000, the number of products to be inspected is n=25 having acceptance number c=1. Suppose that, the required plan should have the sets of strength $\delta_k=0.01$, $\alpha=0.05$, $\delta_j=0.10$ and $\beta=0.10$, to achieve this, first let us calculate probability of acceptance of lots in a good state and in degraded state using single sampling plan of modified np value is given in Table 1 by applying a search procedure,

3 The operating procedure of SkSP-3

In this section, explains the operating procedure of SkSP-3.

Further, Soundararajan and Vijayaraghavan (1989) has developed and extended the procedure of SkSP-2 with single sampling plan under the conditions of Poisson distribution another plan named SkSP-3 under the principles of CSP-2 characterized by i lots, f sampling frequency and k reduced inspection where 0< f< 1, k and i are positive integers and the flow chart for SkSP-3 is represented in Figure 1,

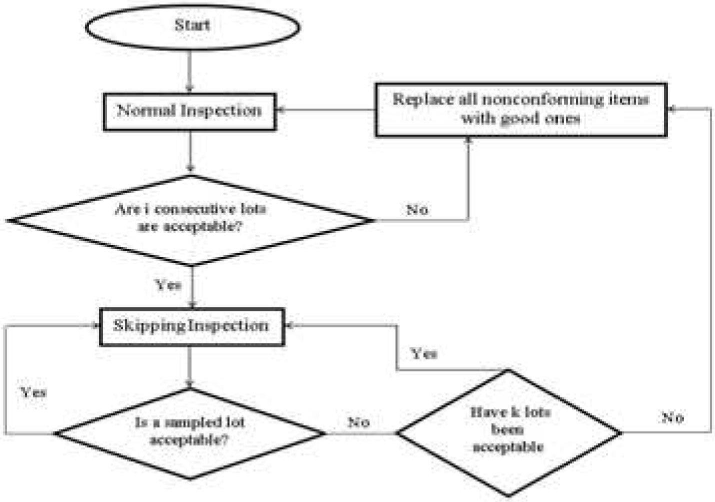

Figure 1 Flow chart for operating procedure of SkSP-3 plan

1. Start with normal inspection proceeding with i consecutive lots using single sampling plan as reference plan.
2. If the screening inspection i is found acceptable, then the skipping inspection (fraction f of the lots) is in effect.
3. If any lot is rejected in the normal inspection, replace all the nonconforming units with the conforming units.
4. In the skipping inspection, if any lot is rejected then the inspection is carried out for next k lots under skipping inspection.
5. The skipping inspection is continued if all the lots are accepted in the 1/k lots.
6. If all the lots are accepted in the next k lots then the skipping inspection is preceded further. Otherwise, the lots are replaced and move for normal inspection.

3.1 Determination and implementation of optimal parameters for SkSP-3 with SSP under the conditions of Poisson distribution

According to Soundararajan and Devaraj Arumainayagam (1992) indicates that the parameters of QSS-r (r = 1, 2, 3 and 4) for defects using Poisson model for given values of p_1 (α=0.05) and p_2 (β=0.10) satisfying the conditions (i) P_r (accepting the lot of quality $p \leq p_1$) $\geq 1-\alpha$ and (ii) P_r (rejecting the lot of quality $p \geq p_2$) $\leq \beta$. This can be obtained using the search procedure in this paper for the proposed plan SkSP-3 with SSP as a reference plan in the objective of obtaining optimum parameters (i, f, k) and tabulated in Table 1. Here the excellent quality is considered as good state and the quality next to that is considered as the degraded state so the probability of rejecting the second quality by the consumer is less than or equal to 10%. The average number of lots inspected in screening stage for SkSP-3 during one period of inspection is,

$$U = \frac{1 - P^i}{P^i(1 - P)} \tag{5}$$

Hence, V is the average number of lots passed under sampling fraction on one inspection cycle.

$$V = \frac{fQ}{Q^2 f^2} \tag{6}$$

The measure of SkSP-3 for the probability of acceptance is

$$P_a(p) = \frac{fP(1 - P^i)(1 - P^k) + (1 - f)P^i(2 - P^k) + fP^{i+1}(2 - P^k)}{f(1 - P^i)(1 - P^k) + P^i(2 - P^k)} \tag{7}$$

The strength of the sampling plan is obtained by satisfying the following conditions

$$P_a(p_1) \geq 1 - \alpha \ \& \ P_r(p_2) \leq \beta \tag{8}$$

This condition helps the producer and the consumer economically and also quality of the product is up to the satisfactory level.

3.2 Procedures for evaluating and obtaining optimum plan and minimum cost of SkSP-3:

The quality cost system determined is a function which satisfies the quality of the product assuring costs involved economically. In the inspection of destructive items, rejected lots are not sorted but scrapped or reprocessed. The various costs associated with defects discovered before and after the product has been shipped to the customers. The costs are of two types internal and external costs regarding failure include waste, rework costs, scrapping cost, returns of rejected lots plans for quality, reliability, operations, production, and inspection in case of non-destructive product. Manufacturing costs includes the cost of the direct material, factory overhead charges and wages of labour become a part of the finished product. Appraisal costs incurred includes verification, quality audits and supplier rating to find the degree of conformance to the satisfactory level evaluated by the dealer and customer of purchased materials, products, and services to ensure that they conform to the standard.

The optimization problem for SkSP-3 is to consider the parameters n, i, k, f and c.

Objective function is to

Minimize E(C)

Subject to $P_a(\delta_k) \geq 1-\alpha$

$$\Pr(\delta_j) \leq \beta \tag{9}$$

and the non-negative constraints are

$n \geq 1, c > 0, i > 0, k > 0$ and $0 < f < 1$.

The Average cost behaviour is calculated for each n, c, i, k and f. The algorithm is as Hsu (1977) follows and constructs a model which differs in the following steps.

1. Given the values of δ_k, δ_j, μ_k and μ_j.
2. Initially, set i = 1, k=1, f=1/2.
3. Set c = 0. Gradually increase n by a fixed quantity and hold c, i constant, the lowest average cost is obtained. Repeat the process for various values of f.
4. Increase c by one and again search for a minimum by increasing n and keeping i, k constant repeating the steps 2 and 3. When the minimum cost for a given c indicates that the minimum point for n and c together has been reached, the best plan is obtained for i and k.
5. Increase i, k by 1 and set f, c constant and varying n. Repeat steps 2, 3 and 4 to find the best i, k and n for SkSP-3 and a good estimate of the plan in the new interval.
6. Determine the optimal inspection plan of SkSP-3 characterized by n, c, i, f and k by repeating step 5 until the minimum E(C) has been reached.

3.3 Procedure of economic designing of SkSP-3 plan in the case of destructive testing

In this section, introduces the cost function of destructive testing of cross member parts.

The various costs are included and their relationship is carried out to show the effectiveness of the SkSP-3 plan. The cost function assuming that there is a linear relationship between the cost parameters.

Manufacturing Costs is given by

$$MC = NC_m(i+k) \tag{10}$$

Appraisal Costs: The states δ_k and δ_j assuming the prior probabilities as (1-α) and β and (N-n)p refers to the average number of units shipped to the buyer without inspection (passed).

$$APC = n(i+k)C_i + C_k \quad (11)$$

Total Failure Costs:

$$TFC = (N(i+k) - n(i+k))(C_d(\mu_k \delta_k Pa_k (1-\alpha) + \mu_j \delta_j Pa_j \beta) - S(\mu_k \Pr_k + \mu_j \Pr_j)) \quad (12)$$

After the inspection is over, the i lots containing number of good units is shipped to the customer is $G = (N(i+k) - n(i+k))(1 - \mu_k \delta_k (\Pr_k) + \mu_j \delta_j (\Pr_j)) + (1 - (\mu_k \Pr_k + \mu_j \Pr_j))$ (13)

Total cost in a screening and sampling inspection under SkSP-2 plan is

$$TC = MC + APC + TFC$$

Here follows Hsu (1977) procedure as the long run minimum average unit cost subject to i, f, k and n

$$E(C) = \frac{MC + APC + TFC}{G} \quad (14)$$

The average cost per unit is calculated by (14) evaluated for obtaining minimum average cost and are given in Tables with numerical illustration and sensitivity analysis.

3.4 *Numerical Illustration & Sensitivity Analysis*

Consider the industry is manufacturing automobile spare parts (component) in which the production is a continuous process the sampled items which are taken for inspection as a destructive one. For instance, the cross member is an automobile spare part taken to identify its welding strength and thickness which supports the pillion handle component is expressed in Figure 2. This strip contains 46 blanks with 204mm length but here needed only one blank for manufacturing a cross member.

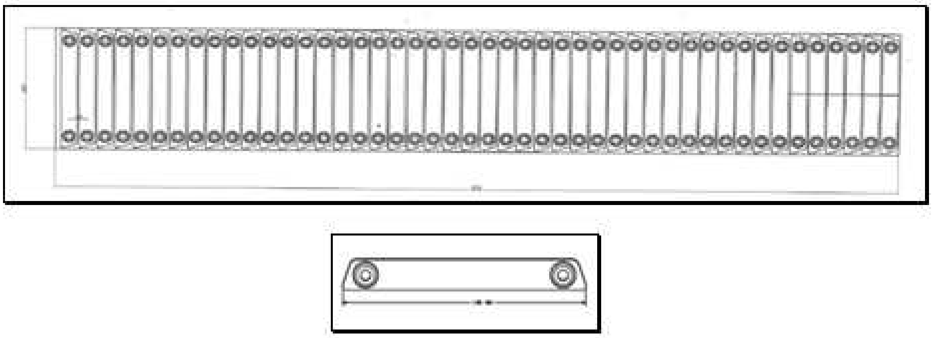

Figure 2 Source: SKI-Component Costing sheet, M/s Hi Tech industries, Hosur, Tamil Nadu

This destructive testing item comprises of two types of units-namely usable units and recycling units in the lots manufactured by the company. Usable units are utilized by the company in different lots throughout the manufacturing process of the product. Recycling units are not utilized by the company for the current manufacturing but are used in a different schedule because of its raw material value.

The raw material specification cost for the company with regard to the Pillion Handle Component comprises of the production cost for the raw materials utilized and also the penalty cost for replacing defective units in the manufacturing lots at different stages of manufacturing process. Therefore, it is inferred that since the total material specification cost involves penalty cost for replacement, constant check of the quality of raw materials and finished product by the Quality Control department are essential for the component.

The lot of size N=1000 are submitted for inspection in the order of their production process assuming the quality is homogeneous throughout the lot. The inspection is carried on go-no-go basis after the specification is tested by the production engineer. The program manager suggests that the manufacturing cost of cross member is c_m=₹4.10, the cost of inspecting is c_i=₹ 0.05, penalty cost for replacing a defective unit shipped to consumer is c_d=₹ 1.6, cost per inspection and reset the equipment before starting the manufacture the pre-checking is done with c_k=₹ 0.83. The salvage value or scrap cost per unit for the rejected lot is S = 0.02.

There may be two possible states k with least proportion defective δ_k=0.01 and j with allowable maximum proportion defective δ_j=0.10 where there are changes in the process fraction defective as it is continuous production of lots in each inspection interval. Observing from the past records there may be transition from one state (good) to another (degrade) per lot holding average rate of transition μ_k=0.09 and μ_j=0.01. If the sample size n and the acceptance number c exceeded as per the SSP reference plan, the measurement is stopped and the lot is rejected. The acceptance and rejection of lot is based on the Skip-lot sampling plan-3.

The Figure 3 expressed when i=4, k=1and c=1are fixed and the sampling fraction f varies, then E(C) is increased up to certain values of n and decreases at particular sample size. The minimum average cost exist for the optimum plan is i=4, c=1, f=1/8. If the program manager inspects only n=5, then the optimum plan is n=5, i=4, c=1, k=1, f=1/8 with G=4964 units, MC=₹ 20500, E(C)=₹ 4.161, APC=₹ 2.08 and TFC=₹ 154.99 satisfying $P_a(\delta_k)$=0.99, which in turn satisfies the customer shown in Table 2.

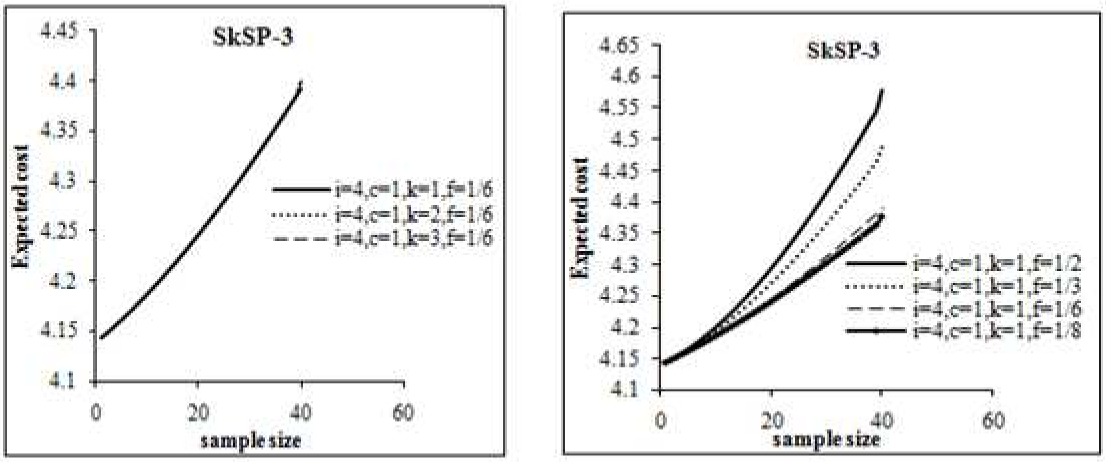

Figure 3 The optimum cost for the plan keeping i, c fixed and f vary (left) and keeping i, c and f fixed and k vary (right)

(i) Here E(C) is a decreasing function as f increases to f=0.50.

(ii) Here E(C) is a decreasing function when the acceptance number c increases.

(iii) As n and f are fixed, c=1 and k varies then E(C) is a decreasing function of reduced clearance interval k when increases.

(iv) Here E(C) is a decreasing function of i as the clearance interval increases.

From the study the minimum mean cost obtained for the optimum plan is i=4, k=3, c=1, f=1/6, n=5 with G= 6949, E(C) =₹ 4.16 is given in the Table 3.

4. Procedure of economic designing of SkSP-3 plan in the case of non-destructive testing: constant lot size

In this section, introduces the cost function of non-destructive testing of cross member parts from fixed lot size. The cost function assuming that there is a linear relationship between the cost parameter.

Manufacturing Costs is given by

$$MC = NC_m(i+k) \tag{15}$$

Appraisal Costs: The states δ_k and δ_j assuming the prior probabilities as (1-α) and β and (N-n) p refers to the average number of units shipped to the buyer without inspection (passed).

$$APC = \frac{C_k + C_i\lfloor n(i+k) + (N(i+k) - n(i+k))(\Pr_k \mu_k + (\Pr_j \mu_j) + (N(i+k) - n(i+k))(\mu_k\delta_k Pa_k + \mu_j\delta_j Pa_j)\rfloor}{1-(\mu_k\delta_k + \mu_j\delta_j)} \tag{16}$$

Total Failure Costs:

$$TFC = C_d\,(N(i+k) - n(i+k))(\mu_k \delta_k Pa_k (1-\alpha) + \mu_j \delta_j Pa_j \beta) + \\ C_r\left[n(i+k)(\mu_k \delta_k + \mu_j \delta_j) + (N(i+k) - n(i+k))(\Pr_k)\mu_k \delta_k + (\Pr_j)\mu_j \delta_j\right] \quad (17)$$

After the inspection is over, the lots containing number of good units is shipped to the customer is

$$G = N(i+k) \quad (18)$$

Total cost in a screening and sampling inspection under SkSP-3 plan is

$$TC = MC + APC + TFC$$

Here follows Hsu (1979) procedure as the long run minimum average unit cost subject to n, i, f, k and c is given by

$$E(C) = \frac{MC + APC + TFC}{G} \quad (19)$$

The average cost per unit is calculated and evaluated for obtaining minimum average cost and are given in Tables with numerical illustrations and sensitivity analysis.

4.1 *Numerical illustrations and sensitivity analysis*

For instance, the cross member is an automobile spare part needs conducting magnetic particle testing can be considered as a combination of two non-destructive test for magnetic flux leakage testing and visual testing as expressed in Figure 2. The non-destructive testing for this child part for detecting surface and shallow subsurface discontinuities in the cross member to identify a leak evaluated to determine the properties of a material, component or system without causing damage. The lot of size N=1000 are submitted for inspection in the order of their production process assuming the quality is homogeneous throughout the lot. The inspection is carried on go-no-go basis after the specification is tested by the production engineer. The program manager suggests that the manufacturing cost of cross member (child part) is c_m=₹ 4.10, the cost of inspecting is c_i=₹ 0.05, penalty cost for replacing a discrepancy unit shipped to consumer is c_d=₹ 1.12, cost per inspection and reset the equipment before starting the manufacture the pre-checking is done with c_k=₹ 0.83. The corrective cost of a discrepant unit during the sampling and the screening process is c_r=₹ 0.67. There may be two states k and j where there are changes in the process fraction defective is continuous as the lots are produced in each inspection interval from the past records as dictated in section 3.4. There may be transition from one state to another per lot. The acceptance and rejection is based on skip-lot sampling plan-3.

It is well expressed in Figure 4 that let i=4, k=1and c=1 are fixed and the sampling fraction f varies, then E(C) is increased up to certain values of n and decreases at particular sample size. The minimum average cost exist for the optimum plan is i=4, k=1, c=1, f=1/8, If the program manager inspects only n=5, then the optimum plan is n=5, i=4, k=1, c=1, f=1/8 with G=5000 units, MC=₹ 20500, E(C)=₹ 4.1015, APC=₹ 2.55 and TFC=₹ 5.35 satisfying $P_a(\delta_k)$=0.99, which in turn satisfies the customer. It is noticed that E(C) is a decreasing function as f decreases to 0.13 is displayed in Table 4.

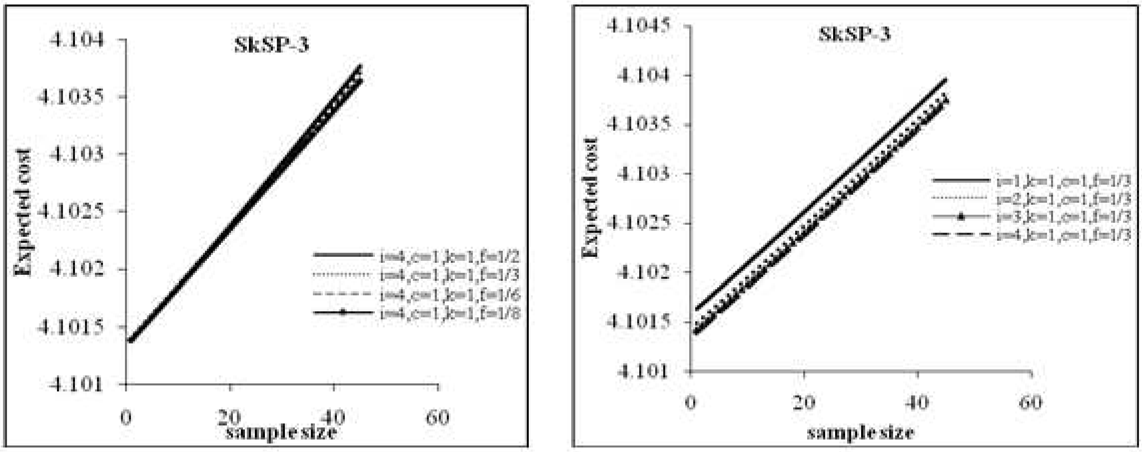

Figure 4 Optimum cost for the plan keeping i, c and k fixed and f vary (left) and keeping c=1 fixed and i, f vary (right)

(i) As c=1 fixed and i, f vary, E(C) is a decreasing function of i when the clearance interval i increases.

(ii) To know the effect of the changing reduced interval k, keeping n, c and f are fixed then E(C) is a decreasing function of k when the reduced clearance interval increases.

(iii) When i, k and f are fixed and the acceptance number c varies then E(C) is a decreasing function of c as the acceptance number increases.

(iv) Here E(C) is a decreasing function as f decreases to 0.13.

From the study the minimum mean cost obtained for the optimum plan is n=5, i=4, k=1, c=1, f=1/8 with G=5000, MC=₹ 20500 and E(C)=₹ 4.1015 is in Table 4.

5. Procedure of economic designing of SkSP-3 plan in the case of non-destructive testing: variable lot size:

In this section, introduces the cost function of non-destructive testing (variable lot size N) of cross member spare parts.

Manufacturing Costs is given by

$$MC = NC_m(i+k) \tag{20}$$

Appraisal Costs: The states δ_k and δ_j assuming the prior probabilities as (1-α) and β and (N-n) p refers to the average number of units shipped to the buyer without inspection (passed).

$$APC = C_k + C_i\left[\frac{n(i+k)+(N(i+k)-n(i+k))(\Pr_k \mu_k + \Pr_j \mu_j)+(N(i+k)-n(i+k))(\mu_k\delta_k Pa_k + \mu_j\delta_j Pa_j)}{1-(\mu_k\delta_k + \mu_j\delta_j)}\right] \tag{21}$$

Total Failure Costs:

$$TFC = C_d(N(i+k)-n(i+k))(\mu_k\delta_k Pa_k(1-\alpha)+\mu_j\delta_j Pa_j\beta) \tag{22}$$

After the inspection is over, the lots containing number of good units is shipped to the customer is

$$G = (N(i+k)-n(i+k))(1-(\mu_k\delta_k \Pr_k + \mu_j\delta_j \Pr_j)) + n(i+k)(1-(\mu_k\delta_k + \mu_j\delta_j)) \tag{23}$$

The shipped discrepant units will be replaced by good and the discrepant units found in sampling and screening process is discarded and not replaced.

Total cost in a screening and sampling inspection under SkSP-3 plan is

$$TC = MC + APC + TFC$$

Here follows Hsu (1979) procedure as the long run minimum average unit cost subject to n, c, i, f and k is given by

$$E(C) = \frac{MC + APC + TFC}{G} \tag{24}$$

The Skip-lot sampling plan helps in reduced inspections which automatically signify the minimum average unit cost is safeguard to the customer from accepting the unsatisfactory lot and favours the producer. There may be two states k and j in the production process where in inspection lot during switching process the one is good state k having very least proportion defective and the other proportion defective are considered as the degraded state j. Numerical illustrations and sensitivity analysis for the optimal inspection plan that minimizes the average cost is given in the following Section 5.1.

5.1 Numerical illustration and sensitivity analysis

Consider the sampled items in the numerical illustration 4.1 are taken for inspection as a non-destructive one in which the production unit has variable lot size N. It is observed from Figure 5 that let f=1/3, k=1 and c=1 are fixed and the sampling fraction i varies, the E(C) is increased up to certain values of N and decreases as lot size increases. The minimum average cost exist for the optimum plan is N=5000, n=5, i=4, k=1, c=1, f=1/3. If the program manager inspects only n=5, then the optimum plan is n=5, i=4, c=1, f=1/3 with G=25000, MC=₹ 102500, E(C)=₹ 4.1013, APC=₹ 4.52 and TFC=₹ 26.7 satisfying $P_a(\delta_k)$=0.99 which in turn satisfies the customers requirement. It is noted that E(C) is a decreasing function of i is shown in Table 5.

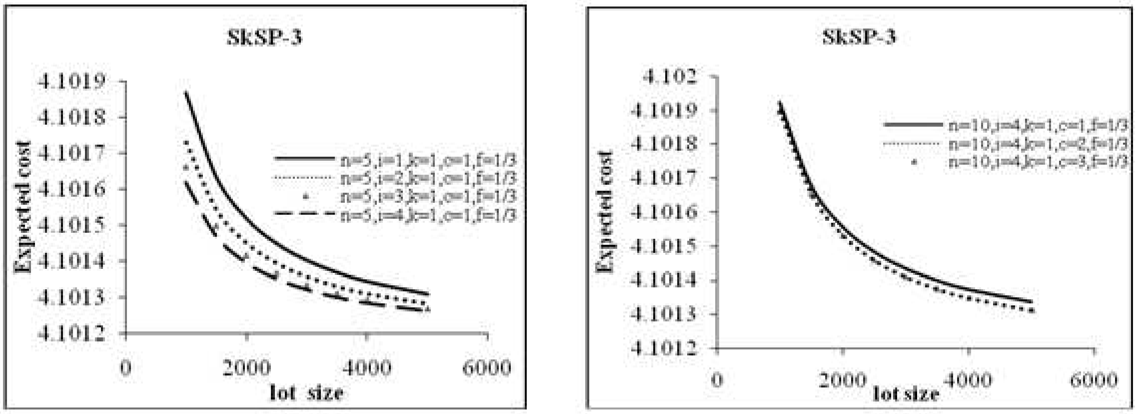

Figure 5 The optimum cost for the plan keeping k, f and c are fixed and i vary (left) and keeping i, f and k fixed and c vary (right) for varied lot size N.

(i) As k, f, c fixed and i vary, then E(C) is a decreasing function of i while lot size N increases.

(ii) To know the cost effectiveness as the sampling frequency f varies assuming c, i and k are fixed, then E(C) is a decreasing function of f when the sampling frequency decreases.

(iii) When i, k and f are fixed and the acceptance number c varies then E(C) is a decreasing function of c as the acceptance number increases.

(iv) Here E(C) is a decreasing function as f decreases to 0.13.

If we relax the acceptance number c the cost decreases in the case of non-destructive testing item and obviously the program manager decides to select the optimum plan n=10, c=2, i=4, f=1/3 and E(C)=₹ 4.101 gives more protection to the consumer from accepting unsatisfactory item providing good units is G=25000 with E(C)=₹ 4.1013, MC=₹ 102500, APC=₹ 4.52 and TFC=₹ 26.69. It is displayed in Table 6. Even though the cost and sample size n in some situation of inspection changes the minimum mean cost is obtained and it protects the producer as well as the consumer with the consideration of required plan with strength (δ_k, 1-α) and (δ_j, β). i.e., $P_a(\delta_k)$=0.99. The saturation point exists to obtain the optimal plan.

6 Comparative study

In this section 6, efficiency of cost is analysed among skip-lot sampling plans under the conditions of Poisson distribution with respect to producer's and consumer's risk. This comparison is illustrated through a sensitivity analysis and cost curve analysis. The usual method of comparing cost efficiency among the plans is the ratio of variance of cost of one plan to variance of cost of another plan. If '$e < 1$' then the existing plan is more efficient than the other plan.

6.1 Comparison of optimal cost among SkSP-2 and SkSP-3 plans in the case of destructive testing

Suppose in a continuous production process, say for one hour production the lot of size 1000 is produced and kept for quality checking. The attribute inspection is carried out by the quality inspector after the destructive testing on an item is approved by the production engineer for checking and specification for the conformance of an item given in the numerical illustration 3.4. If the inspector decides to inspect the lot i=4 following the procedure of skip-lot sampling plan-2 (SkSP-2) given by PradeepaVeerakumari and Kokila (2017) under the single sampling plan (n, c) as a reference plan following Poisson distribution with the acceptance number c=1 having the skipping inspection f=1/2 from the production process. The average cost of an item by SkSP-2 is compared among SkSP-3. The quality inspector decides to inspect the lot i=4 under SkSP-3 and if all the lots are accepted then reduced clearance interval k=1 is inspected with acceptance number c=1 switching to the sampling fraction f=1/2 from the production process. The cost and the plan is found using the procedure in the section 3.2. The minimum expected cost of a product is obtained for particular optimum plan satisfying the probability of accepting good lot δk=0.99 which safeguard producer as well as the consumer in accepting good lot. The quality manager likes to implement suitable plan for their quality improvement and cost reduction. It necessitates comparing the plans based on the cost obtained in each plans is given in Table 7.

Here the quality inspector according to single sampling plan chooses the sample size n=5, then the average cost of SkSP-2, E(C)=₹ 4.174. The cost obtained for SkSP-3 is E(C)=₹ 4.165. As the sample size increases the cost also increases. Here SkSP-3 and SkSP-2 has similar effect but by comparing the cost among the plans, SkSP-3 is more efficient as shown in the figure 6. But the efficiency, 'e' of SkSP-3 among SkSP-2 is calculated as,

$$e=\frac{\text{Variance (cost of SkSP-3)}}{\text{Variance (cost of SkSP-2)}}=\frac{0.000845}{0.002733}=0.31<1. \tag{25}$$

This shows that SkSP-3 is more efficient than SkSP-2 in the case of destructive testing item.

6.2 Comparison of optimal cost among SkSP-2 and SkSP-3 in the case of non-destructive testing item

The attribute inspection is carried out by the quality inspector after the non-destructive testing on an item is approved by the production engineer for checking and specification for the conformance of an item given in the numerical illustration 4.1. It necessitates comparing the plans based on the cost obtained in each plan is given in Table 8. The average cost of an item by SkSP-2 is compared among SkSP-3 for the non-destructive testing item as mentioned in the previous section 6.1.

Here the quality inspector according to single sampling plan chooses the sample size n=5, then the average cost of SkSP-2, E(C) =₹ 4.1016 and the cost obtained for SkSP-3 is E(C)=₹ 4.1015. As the sample size increases the cost also increases. SkSP-3 is more efficient is shown in the Figure 6. But the efficiency, 'e' of SkSP-3 among SkSP-2 is calculated as,

$$e=\frac{\text{Variance (cost of SkSP-3)}}{\text{Variance (cost of SkSP-2)}}=\frac{0.000000047}{0.000000053}=0.887<1. \tag{26}$$

This shows that SkSP-3 is more efficient than SkSP-2 in the case of non-destructive testing item.

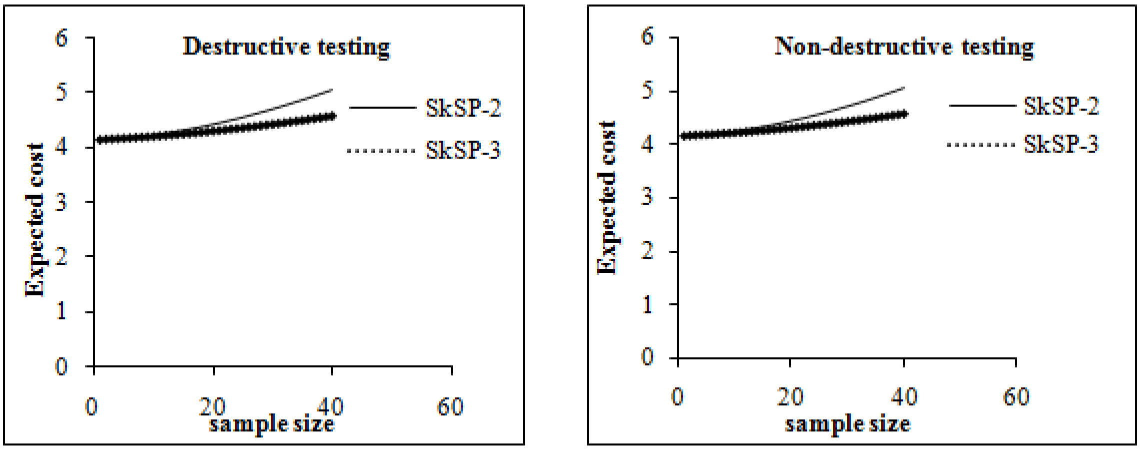

Figure 6 Comparison of optimal cost for SkSP-2 and SkSP-3 in the case of destructive testing item (left) and non-destructive testing item (right)

7 Final Remarks

The primary objective of this paper is to model an appropriate function for the expected costs in the case of non-destructive testing item involving strength of the plan (δ_j, 1-α) and (δ_k, β) points with acceptance probabilities of lots with different state of quality which is most economical for the producer and also delivering the quality goods to the consumer at a satisfactory cost. This shows that SkSP-3 is more efficient than SkSP-2 in the case of destructive and non-destructive testing item. The proposed method has an advantage that it includes the confidence level of being a good state and satisfactory level for being a degrade state in a lot. The cost variation obtained through this model is less than 1% which suits the model. Thus, the modified unity value in the SSP under the conditions of Poisson distribution will address the prevalence of transition of states. It also reveals the aspect that the cost obtained in the case of non-destructive testing item is lesser than the cost of destructive testing item. Thus, the proposed cost model gives better precision and favours the producer as well as consumer. It is very economical and time consumer for the shop-floor industrialist.

Conflict-of-interest statement

The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript. We certify that the submission is original work and is not under review at any other publication.

Ethical Conduct

We certify that the submission is original work and is not under review at any other publication.

Funding Details

There is no funding was received.

Data availability statement

It is confirming that all data generated and analysed during this study are included in this article.

References:

1. Balamurali, S., & Subramani, J. (2010). Economic designs of SkSP-3 skip lot sampling plans. *International Journal of Mathematics and Statistics*, 6, 23-39. DOI: https://www.researchgate.net/publication/264005083

2. Balamurali, S., & Jun, C.H. (2011). A new system of skip-lot sampling plans having a provision for reducing normal inspection. *Applied Stochastic Models in Business and Industry*, 27, 348–363. DOI: 10.1002/asmb.844

3. Balamurali, S., Aslam, M., & Jun, C. H. (2015). Economic Design of SkSP-R Skip-lot Sampling Plan. *Journal of Testing and Evaluation*, 43, 1205-1210. DOI: org/10.1520/JTE20140081.
4. Balamurali, S., & Subramani, J. (2017). Optimal designing of SkSP-2 skip-lot sampling plan for normally distributed quality characteristics. *Transactions of the Institute of Measurement and Control*, 1-9. DOI: full/10.1177/0142331217700466
5. Chen, C. H., & Chou, C. Y. (2002). Economic design of continuous sampling plan under linear inspection cost. *Journal of Applied Statistics*, 29, 1003-1009. DOI: org/10.1080/0266476022000006702.
6. Chen, C.H. (2009). Modified Economic Manufacturing Quantity Model for Product with Quality Loss Function. *Tamkang Journal of Science and Engineering,* 12, 109-112. https://www.semanticscholar.org/paper/4eee17365995e9c11e2b6978c81a454d03fd6170
7. Chen, C.H., Chou, C. Y., & Kan, C. C. (2015). Modified economic production and raw material model with quality loss for conforming product. *Journal of Industrial and Production Engineering,* 32, 196-203. https://doi.org/10.1080/21681015.2015.1029548

8. Chung-Ho Chen & Chao-Yu Chou.(2006). Economic Design of Short-Run Csp-1 Plan Under Linear Inspection Cost. *Tamkang Journal of Science and Engineering*, 9, 19-23. https://www.semanticscholar.org/paper/adcf0813feb4207b92b36190c60d70d47a483794
9. Cox, D. C. (1980). Skip-lot sampling plans. *Quality*, Vol. 21, No. 8, pp. 26–27. View at Google scholar.
10. Dodge, H. F. (1943). A sampling plan for continuous production. *Annals of Mathematical Statistics*, 14, 264–279. https://www.jstor.org/stable/2235805
11. Dodge, H.F. (1955). Skip-lot sampling plan, *Industrial Quality Control*, 11, 3-5.
12. Dodge, H.F., & Perry, R.L. (1971). A system of skip-lot plans for lot-by-lot inspection. *American Society for Quality Control Technical Conference Transactions*, Chicago, Illinois, pp. 469-477.
13. Fallahnezhad, M. S., & Aslam, M. (2013). A new economical design of acceptance sampling models using Bayesian inference. *Accreditation and Quality Assurance*, 18, 187-195. https://link.springer.com/article/10.1007/s00769-013-0984-9
14. Haji, A. & Haji, R. (2004). The optimal policy for a sampling plan in continuous in terms of the clearance number. *Computers and Industrial Engineering*, 472, 141-147. DOI:10.1016/j.cie.21004.06.005.
15. Hald, A. (1981). *Statistical Theory of Sampling Inspection by Attributes*, L.M.S. Monographs, Academic Press, London.
16. Horsnell, G. (1957). Economical Acceptance Sampling Schemes. *Journal of the Royal Statistical Society, Series A*, 120, 148-201. DOI: 10.2307/2342822
17. Hsu, J.I.S. (1977). A cost model for skip-lot destructive sampling. *IEEE Transactions on Reliability*, R-26, 70-72. DOI: 10.1109/TR.1977.5215081
18. Hsu, J.I.S. (1979). A cost model for skip-lot non-destructive. *IEEE Transactions on Reliability*, R-28, 289-291. DOI: 10.1109/TR.1979.5220607
19. Hsu, J. I. (1980). An economic design of skip-lot sampling plans. *Journal of Quality Technology*, 12, 144–149. https://doi.org/10.1080/00224065.1980.11980952
20. Kokila. M & PradeepaVeerakumari. K (2018). Economic Design and Evaluation of Feasible Cost Model for Attribute Sampling Tightened-Normal-Tightened Plan. International Journal of Scientific Research in Mathematical and Statistical Sciences, 5, 338-349. https://doi.org/10.26438/ijsrmss/v5i4.338349
21. Nirmala, V. & Suresh, K.K. (2017). Construction and Selection of Continuous Sampling Plan of type (CSP-T) Indexed through Maximum Allowable Average Outgoing Quality.

Journal of Statistics and Management Systems (IJMS), 20, 441-457. DOI: 10.1080/09720510.2017.1303952.
22. Pandey, R. J. (1974). Bayesian single sampling plan by Attributes with Three Decision Criteria for Discrete Prior Distribution. *Sankhya: The Indian Journal of Statistics*, Series B, 36, 348-390. https://www.jstor.org/stable/25051921
23. PradeepaVeerakumari, K & Kokila. M (2017). Economic Design of Skip-Lot Sampling Plan of Type (SkSP−2) in Reducing Inspection for Destructive Sampling. *International Journal of Pure and Applied Mathematics*, 117(12), 101-111. https://acadpubl.eu/jsi/2017-117-11-14/articles/12/12.pdf
24. Reimann, A. (1982): Skip-lot is not optimal in the case of independent fractions defective comments on a paper by Professor Hsu, *Journal of Quality Technology*, Vol.14, pp. 211–214. DOI:/abs/10.1080/00224065.1982.11978823
25. Romboski, L.D. (1969). An investigation of quick switching acceptance sampling systems (Ph.D. Dissertation), New Brunswick, NJ, Rutgers State University.
26. Schilling, E. G. (1982). *Acceptance Sampling in Quality Control*, Marcel Dekker, Inc., New York.
27. Suresh, K. K. (1993). A Study on Acceptance Sampling using Acceptable and Limiting Quality Levels (Ph.D. Thesis). Department of Statistics, Bharathiar University Coimbatore, Tamil Nadu, India.
28. Vijayaraghavan, R. (2000) Design and evaluation of skip-lot sampling plans of type SkSP-3. *Journal of Applied Statistics*, 27, 901-908. DOI: 10.1080/02664760050120579
29. Vijayaraghavan, R. (2009). Selection of Skip-Lot Sampling Inspection Plans of Type SkSP-3 Indexed by Indifference Quality Level and Maximum Allowable Percent Defective. *Bulletin of Statistics and Economics*, 3, S09, 54-60. http://www.ceser.in/ceserp/index.php/bse/article/view/2077
30. Wetherill, G.B. & Chiu, W.K. (1975). A Review of Acceptance sampling schemes with Emphasis on the Economic Aspect. *International Statistical Review*, 43, 191-210. DOI: 10.2307/1402898

Table 1 Probability of acceptance of lot using single sampling plan

N	n	c	P_k ($\delta_k=0.01$)	P_j($\delta_j=0.10$)
1000	25	1	0.98	0.97
1000	25	3	0.99	0.99

Table 2 Determination of cost for the SkSP-3 Plan

in the case of destructive testing

i=4 c=1 k=1									
n	**f=1/2**	**f=1/3**	**f=1/6**	**f=1/8**	**n**	**f=1/2**	**f=1/3**	**f=1/6**	**f=1/8**
1	4.144	4.144	4.143	4.143	**15**	4.243	4.229	4.216	4.212
2	4.148	4.148	4.148	4.148	**16**	4.252	4.237	4.222	4.218
3	4.153	4.153	4.152	4.152	**17**	4.262	4.245	4.228	4.223
4	4.159	4.158	4.157	4.157	**18**	4.272	4.253	4.234	4.229
5	4.165	4.163	4.162	4.161	**19**	4.283	4.261	4.24	4.235
6	4.171	4.169	4.167	4.166	**20**	4.294	4.27	4.247	4.241
7	4.178	4.175	4.172	4.171	**21**	4.305	4.279	4.253	4.247
8	4.185	4.181	4.177	4.176	**22**	4.316	4.288	4.26	4.253
9	4.192	4.187	4.182	4.181	**23**	4.328	4.297	4.266	4.259
10	4.2	4.193	4.187	4.186	**24**	4.339	4.306	4.273	4.265
12	4.216	4.207	4.198	4.196	**25**	4.352	4.315	4.28	4.271
13	4.224	4.214	4.204	4.201	**35**	4.487	4.419	4.353	4.336
14	4.233	4.222	4.21	4.207	**40**	4.579	4.488	4.392	4.378

Table 3 Determination of cost for the SkSP-3 Plan

in the case of destructive testing

i=4, c=1, f=1/6							
n	**k=1**	**k=2**	**k=3**	**n**	**k=1**	**k=2**	**k=3**
1	4.143	4.143	4.143	**15**	4.216	4.216	4.216
2	4.148	4.148	4.148	**16**	4.222	4.222	4.222
3	4.152	4.152	4.152	**17**	4.228	4.228	4.228
4	4.157	4.157	4.157	**18**	4.234	4.234	4.234
5	4.162	4.162	4.162	**19**	4.24	4.24	4.24
6	4.167	4.167	4.166	**20**	4.247	4.247	4.247
7	4.172	4.171	4.171	**21**	4.253	4.253	4.253
8	4.177	4.177	4.177	**22**	4.26	4.26	4.26
9	4.182	4.182	4.182	**23**	4.266	4.266	4.266
10	4.187	4.187	4.187	**24**	4.273	4.273	4.273
11	4.193	4.193	4.193	**25**	4.28	4.28	4.28
12	4.198	4.198	4.198	**30**	4.315	4.315	4.316
13	4.204	4.204	4.204	**35**	4.353	4.353	4.353
14	4.21	4.21	4.21	**40**	4.392	4.4007	4.4016

Table 4 Determination of cost for the SkSP-3 Plan in the case of non-destructive testing for constant N

i=4, c=1, k=1									
n	**f=1/2**	**f=1/3**	**f=1/6**	**f=1/8**	**n**	**f=1/2**	**f=1/3**	**f=1/6**	**f=1/8**
1	4.101	4.101	4.101	4.101	**16**	4.102	4.102	4.102	4.102
2	4.101	4.101	4.101	4.101	**17**	4.102	4.102	4.102	4.102
3	4.101	4.101	4.101	4.101	**18**	4.102	4.102	4.102	4.102
4	4.102	4.102	4.102	4.102	**19**	4.102	4.102	4.102	4.102
5	4.102	4.102	4.102	4.102	**20**	4.102	4.102	4.102	4.102
6	4.102	4.102	4.102	4.102	**21**	4.102	4.102	4.102	4.102
7	4.102	4.102	4.102	4.102	**22**	4.102	4.102	4.102	4.102
8	4.102	4.102	4.102	4.102	**23**	4.103	4.103	4.103	4.102
9	4.102	4.102	4.102	4.102	**24**	4.103	4.103	4.103	4.103
10	4.102	4.102	4.102	4.102	**25**	4.103	4.103	4.103	4.103
11	4.102	4.102	4.102	4.102	**30**	4.103	4.103	4.103	4.103
12	4.102	4.102	4.102	4.102	**35**	4.103	4.103	4.103	4.103
13	4.102	4.102	4.102	4.102	**40**	4.103	4.103	4.103	4.103
14	4.102	4.102	4.102	4.102	**45**	4.104	4.104	4.104	4.104
15	4.102	4.102	4.102	4.102					

Table 5 Determination of cost for the SkSP-3 Plan in the case of non-destructive testing for varied N

n=5, f=1/3, k=1 c=1					n=20, f=1/3, k=1 c=1				
N	**i=1**	**i=2**	**i=3**	**i=4**	**N**	**i=1**	**i=2**	**i=3**	**i=4**
1000	4.102	4.102	4.102	4.102	**1000**	4.103	4.103	4.103	4.103
1500	4.102	4.102	4.101	4.101	**1500**	4.102	4.102	4.102	4.102
2000	4.102	4.101	4.101	4.101	**2000**	4.102	4.102	4.102	4.102
2500	4.101	4.101	4.101	4.101	**2500**	4.102	4.102	4.102	4.102
3000	4.101	4.101	4.101	4.101	**3000**	4.102	4.102	4.102	4.102
3500	4.101	4.101	4.101	4.101	**3500**	4.102	4.102	4.102	4.102
4000	4.101	4.101	4.101	4.101	**4000**	4.102	4.102	4.102	4.102
5000	4.101	4.101	4.101	4.101	**5000**	4.102	4.102	4.102	4.102
n=10, f=1/3, k=1 c=1					**N**	**n=30, f=1/3, k=1 c=1**			
1000	4.102	4.102	4.102	4.102	**1000**	4.103	4.103	4.103	4.103
1500	4.102	4.102	4.102	4.102	**1500**	4.103	4.103	4.103	4.103
2000	4.102	4.102	4.102	4.102	**2000**	4.102	4.102	4.102	4.102
2500	4.102	4.102	4.101	4.101	**2500**	4.102	4.102	4.102	4.102
3000	4.102	4.101	4.101	4.101	**3000**	4.102	4.102	4.102	4.102
3500	4.101	4.101	4.101	4.101	**3500**	4.102	4.102	4.102	4.102
4000	4.101	4.101	4.101	4.101	**4000**	4.102	4.102	4.102	4.102
5000	4.101	4.101	4.101	4.101	**5000**	4.102	4.102	4.102	4.102

Table 6 Determination of cost for the SkSP-3 Plan in the case of non-destructive testing for varied N

n=5, i=4 k=1 f=1/3				n=10, i=4 k=1 f=1/3			
N	**c=1**	**c=2**	**c=3**	**N**	**c=1**	**c=2**	**c=3**
1000	4.102	4.102	4.102	**1000**	4.102	4.102	4.102
1500	4.101	4.101	4.101	**1500**	4.102	4.102	4.102
2000	4.101	4.101	4.101	**2000**	4.102	4.102	4.102
2500	4.101	4.101	4.101	**2500**	4.101	4.101	4.101
3000	4.101	4.101	4.101	**3000**	4.101	4.101	4.101
3500	4.101	4.101	4.101	**3500**	4.101	4.101	4.101
4000	4.101	4.101	4.101	**4000**	4.101	4.101	4.101
5000	4.101	4.101	4.101	**5000**	4.101	4.101	4.101
N	**n=20, i=4, k=1, f=1/3**				**n=30, i=4, k=1, f=1/3**		
1000	4.103	4.102	4.102	**1000**	4.103	4.103	4.103
1500	4.102	4.102	4.102	**1500**	4.103	4.102	4.102
2000	4.102	4.102	4.102	**2000**	4.102	4.102	4.102
2500	4.102	4.102	4.102	**2500**	4.102	4.102	4.102
3000	4.102	4.102	4.102	**3000**	4.102	4.102	4.102
3500	4.102	4.102	4.102	**3500**	4.102	4.102	4.102
4000	4.102	4.101	4.101	**4000**	4.102	4.102	4.102
5000	4.102	4.101	4.101	**5000**	4.102	4.102	4.102

Table 7 Comparison of cost for SkSP-2 (i=4, c=1, f=1/2) and SkSP-3 (i=4, k=1, c=1, f=1/2) in the case of destructive testing

n	SkSP-2	SkSP-3	n	SkSP-2	SkSP-3
1	4.14397	4.14359	**15**	4.32349	4.24268
2	4.14984	4.14833	**16**	4.34377	4.25225
3	4.15684	4.15346	**17**	4.36497	4.26213
4	4.16496	4.15896	**18**	4.38707	4.2723
5	4.17419	4.16483	**19**	4.41006	4.28278
6	4.18451	4.17107	**20**	4.43391	4.29354
7	4.19589	4.17767	**21**	4.45863	4.30458
8	4.20832	4.18462	**22**	4.48418	4.31591
9	4.22179	4.19191	**23**	4.51056	4.32752
10	4.23628	4.19955	**24**	4.53775	4.33939
11	4.25178	4.20753	**25**	4.56574	4.35153
12	4.26826	4.21583	**30**	4.59451	4.36394
13	4.28571	4.22446	**35**	4.62406	4.37661
14	4.30413	4.23341	**40**	4.65435	4.38953

Table 8 Comparison of cost for SkSP-2 (i=4, c=1, f=1/2) and SkSP-3 (i=4, k=1, c=1, f=1/2) in the case of non-destructive testing

n	SkSP-2	SkSP-3	n	SkSP-2	SkSP-3
1	4.10142	4.10138	**15**	4.102195	4.10211
2	4.10147	4.10143	**16**	4.102255	4.10216
3	4.10153	4.10148	**17**	4.102314	4.10221
4	4.10158	4.10153	**18**	4.102374	4.10227
5	4.10163	4.10158	**19**	4.102435	4.10232
6	4.101686	4.10164	**20**	4.102495	4.10238
7	4.10174	4.10169	**21**	4.102556	4.10243
8	4.101795	4.10174	**22**	4.102618	4.10248
9	4.101851	4.10179	**23**	4.10268	4.10254
10	4.101907	4.10184	**24**	4.102742	4.10259
11	4.101964	4.1019	**25**	4.102804	4.10265
12	4.102021	4.10195	**30**	4.10312	4.10292
13	4.102079	4.102	**35**	4.103441	4.1032
14	4.102137	4.10205	**40**	4.103766	4.10348