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An Adjusted Economic Cost Model for Sampling Inspection Plans

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ABSTRACT: Acceptance sampling inspection performed during inspection of incoming lot of raw materials or finished products where decision is taken either to accept or reject the inspected lot. Defective units of the products detected at the manufacturers' site are either reworked or treated as scrap resulting in Internal failure cost while defective units of the product detected by the consumer after shipment are either returned to the producer or manufacturer or replaced resulting to external failure cost. This study therefore proposed an adjusted economic cost model with inspection error to achieve optimal sampling plan with minimized total cost. The model is tested on Rectifying Sigle sampling (RSS) and Rectifying Double Sampling (RDS) plans and comparison was made with the existing model.

Findings from the study revealed that optimal sampling plan for RSS and RDS with minimal total cost was observed when the adjusted model with inspection error was used than in the existing model. It was also found that thetotal costs (TC) in RSS and RDS using the adjusted model were relatively smaller than in the existing model when the effect of changes in the values of Inspection cost(C_i), Internal failure cost(C_f) and External failure cost(C_o) on the optimal total cost were investigated.

However, the total cost for RSS and RDS were found to be higher in the adjusted model when External failure cost$(C_o) \geq 40$than in the existing model.

This adjusted model therefore performed better and is recommended to be used by all stakeholder in a supply chain.

Keywords: External failure cost, Internal failure cost, Producer's risk, consumer's risk, Rectifying Inspection

I. INTRODUCTION

Acceptance sampling plan plays an important role in the inspection of raw materials; semi-finished products and finished products in the manufacturing industries. It is performed by taking a random sample from a submitted lot for inspection for certain quality characteristics and based on the information in the sample a decision is taken to either accept or reject the lot. In case of rectifying inspection, all the rejected lot is subjected to 100% inspection where all the identified defective units are removed and replaced with non-defective units.

Defective units of the products detected at the manufacturers' site, are either treated as scrap or reworked resulting in Internal failure cost while defective units detected by the consumer after shipment are either returned to the producer or manufacturer or replaced resulting to external failure cost. In acceptance sampling inspection, producer's risk occurs when lot with acceptable quality (AQL) is rejected by the consumer. On the other hand, consumer's risk occurs when lot with poor quality or Lot Tolerant Percent defective (LTPD) units is accepted by the consumer. The choice of an economic cost model that produce optimal sampling plan that minimizes the total cost of inspection and failure costs is imperative. This work focused on the use of an adjusted cost model to minimize total cast and achieve optimal solution in Rectifying Single Sampling (RSS) and Rectifying Double Sampling with inspection errors.

Many researchers have made several contributions in the development of cost model for acceptance sampling inspection, most of the notable ones are as follows[9] proposed Markov chain analysis in a single stage and two stages acceptance sampling plans. [2] proposed a model minimizing cost of inspection and maintaining product quality using novel ABCDE classification of product. [1] used Ant Colony Algorithm to

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optimize quality of manufactured products and the components of the cost of quality.[10] proposed goal programming model to determine the optimal number of inspectors based on skills and also minimize cost of inspection in single sampling plan. [3] developed optimization model to reduce total losses of the producer and the consumer. [8] proposed an optimization model that reduced the producer and consumer losses where cumulative sum of run length of conforming unit was considered manufacturers and the consumers. [4] presented an economic cost model using Maxima Nomination Sampling (MNS) technique to reduce total cost.[7] proposed an economic model for the design of Rectifying double Sampling (RDS) plan via Maxima Nomination Sampling (MNS) with regard to the total loss function.[6] developed an economic cost model for achieving optimal single sampling plan that minimizes total cost and satisfies the producer and consumer quality risk. [5]adjusted the model developed by Kumar to obtain optimal sampling for Rectifying Single Sampling (RSS) plan with the introduction of inspection error. In this work, the adjusted model is extended to double sampling plan and sensitivity analysis is conducted to determine the effect of cost parameters o the plans, comparison with the existig model is also made.

II. MATERIALS AND METHODS

The existing model as well as the adjusted model is as formulated below:

Existing Model

A cost minimization model as proposed by Kumar (2018) us as stated below:

Minimize Total cost $(\mathrm{TC}) = \mathrm{C_i ATI} + \mathrm{C_f Dd} + \mathrm{C_o Dn}$ (1)

Subject to $1 - \mathrm{P_a(AQL)} \leq \alpha$

$\mathrm{P_a(LTPD)} \leq \beta$

where TC is the total cost, $\mathrm{C_i}$ is the cost of inspection per unit, $\mathrm{C_f}$ is the internal failure cost per unit (which include cost of repair, scrap or rework of defective unit) and $\mathrm{C_o}$ is the external failure cost or post sales cost per unit (which include repair or replacement cost). Dd and Dn represent the detected defective units and those not detected respectively. $1 - \mathrm{P_a(AQL)}$ is the probability of rejection of the lot at acceptable quality level, $\mathrm{P_a(LTPD)}$ is the probability of acceptance of the lot given Lot tolerance percent defective. In addition, α and β are the values of producer's risk and consumer's risk respectively.

The Adjusted Economic Cost Model

Kumar's economic cost model stated above is therefore adjusted with the introduction of inspection errors and addition of other objective functions as stated below:

Minimize Total Cost $(\mathrm{TC}) = \mathrm{C_i ATI_e} + \mathrm{C_f Dd_e} + \mathrm{C_o Dn_e}$ (2)

Maximize $\mathrm{P_{a_e}(AQL_e)}$

Minimize $\mathrm{P_{a_e}(LTPD_e)}$

Minimize $\mathrm{P_{a_e}(ATI_e)}$

Subject to $1 - \mathrm{P_{a_e}(AQL_e)} \leq \alpha$

$\mathrm{P_{a_e}(LTPD_e)} \leq \beta$

$\mathrm{AOQ_e} \leq \mathrm{AOQL}$

Where $\mathrm{AQL_e}$ and $\mathrm{LTPD_e}$ denote the apparent (observed) Acceptable Quality Level and apparent (observed) Lot Tolerant Percent Defective respectively. Other parameters are as in Kumar's model though with incorporation of inspection error.

Single Sampling Inspection Plan

In a single sampling inspection, a sample (n) is randomly taken from a lot. N. If the number of defective units in a sample x is less than or equal to acceptance number c the lot is accepted. However, if the number of defective units in the sample is more than the acceptance number, the lot is rejected.

Probability of acceptance $(\mathrm{P_a})$ for single sampling plan is calculated as:

$\mathrm{P_a} = \mathrm{p}(\mathrm{x} \leq \mathrm{c}) = \sum_{\mathrm{x}=0}^{\mathrm{C}} \binom{\mathrm{n}}{\mathrm{x}} \mathrm{p^x}(1-\mathrm{p})^{\mathrm{n-x}}$(3)

where p is the true fraction defective units

If inspection error probability is taken into account the true fraction defective p is replaced by the apparent fraction defective ($\mathrm{p_e}$).Thus equation (1) is rewritten as:

$\mathrm{P_{a_e}} = \sum_{\mathrm{x}=0}^{\mathrm{C}} \binom{\mathrm{n}}{\mathrm{x}} \mathrm{p_e}^{\mathrm{x}}(1-\mathrm{p_e})^{\mathrm{n-x}}$ (4)

In Rectifying Single Sampling, if a lot is rejected all the rejected lots are subjected to 100% inspection and all the defective units are replaced with the units that are not defective.

Average total inspection (ATI) represents the average number of units inspected in the sample and in the rejected lot in a rectifying sampling inspection and is given as:

ATI=n+$(1 - P_a)(N - n)$ (5)

If inspector error is considered, equation (5) is re-written as:

$ATI_e = n + (1 - P_{ae})(N - n)$ (6)

In double sampling plan, the probability that the lot is accepted on the first sample n_1 is only P_{a_1} . Given that it is accepted on the second sample it means that two samples $(n_1 + n_2)$ are inspected

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with the probability of acceptance P_{a_2} and if the whole lot N is rejected, with the probability $(1 - P_{a1} - P_{a2})$,the Average Total Inspection (ATI) is calculated as:

ATI=$n_1 P_{a_1} + (n_1 + n_2)P_{a2} + N(1 - P_{a1} - P_{a2})$(7)

Where

$P_{a_1} = \sum_{x_1=0}^{c_1} \binom{n_1}{x_1} p^{x_1}(1-p)^{n_1-x_1}$ and

$$P_{a_2} = \sum_{x_1=c_1+1}^{c_2} \left\{ \left[\binom{n_1}{x_1} p^{x_1}(1-p)^{n_1-x_1} \right] \times \left[\sum_{x_2=0}^{c_2-x_1} \binom{n_2}{x_2} p^{x_2}(1-p)^{n_2-x_2} \right] \right\}$$

The Average Total Inspection for Double sample inspection when inspector error is considered is:

$ATI_e = n_1 P_{a_{1e}} + (n_1 + n_2)P_{a2e} + N(1 - P_{a_{1e}} - P_{a_{2e}})$(8)

Defective Units in an Inspected Lot

Some defective units exist in the portion of the lot not inspected and are accepted during rectifying sampling inspection. However, during 100% inspection of the rejected lot, some defective are detected and removed. The number of defective units not detected per lot is to be denoted by (D_n) while the number of detected defective units is to be denoted by (D_d).

Defective Units in RSS plan.

The number of defective units not detected for RSS plan is given as

$Dn = (N - n)pP_a$ (9)

It is also to be noted that during 100% inspection of the rejected lots, defective units are detected in the sample and in the remaining portion of the rejected lot which is screened.

So, the number of detected defective units in the rejected lots for RSS plan is stated below as:

$Dd = np + p(1 - P_a)(N - n)$ (10)

In situations where inspection errors are taken into consideration, the error of misclassifying a defective unit as non-defective is denoted as e_2.Thus the number of defective units not detected in accepted lot for RSS plan is:

$Dn_e = npe_2 + p(N - n)P_{a_e} + p(N - n)(1 - Paee2$(11)

In a rectifying inspection, some defective units in a rejected are correctly classified as defective with a probability $1 - e_2$ during 100% inspection. The number of detected defective units in the rejected lots is:

$Dd_e = np(1 - e_2) + p(N - n)(1 - e_2)(1 - P_{a_e})$(12)

Defective units in RDS plan

In rectifying double sampling plan also, some defective units accepted in uninspected portion of the accepted lot while some defective units are detected and removed during 100% inspection of rejected lot.

The number of defective units not detected for RDS plan is stated below as:

$Dn = p[P_{a_1}(N - n_1) + P_{a_2}(N - n_1 - n_2)]$(13)

The number of detected defective units in the rejected lots for RDS plan is therefore stated as:

$Dd = pn_1 + p(N - n_1)(1 - Pa_1) + pn_2 + p(N - n_1 - n_2)(1 - P_{a2})$(14)

The number of defective units not detected in the accepted lots for RDS plan with inspection error is :

$Dn_e = pn_1e_2 + p(N - n_1)P_{a1_e} + p(N - n_1 -$ n2Pa2e+pn2e2+pN−`n11−Pa1ee2+pN−n1−n2e21−Pa2e(15)

Therefore, the number of detected defective units in the rejected lots for RDS plan with inspection error is:

$Dd_e = pn_1(1 - e_2) + p(N - n_1)(1 - P_{a1e})(1 -$ e2+pn21−e2+p(N−n1−n2)(1−Pa2e)1−e2 (16)

Inspection Cost and Failure Cost

We model inspection cost here as the cost of inspecting units in a lot and we multiply it by the average total inspection (ATI) as stated below:

$Ci \times ATI$ (17)The failure cost includes Internal failure cost (Cf) and External failure cost (C_o) .We model internal failure cost here as the rework cost of defective units detected at the producer's siteand we multiplied by units identified as defective (d_e) as stated below:

$Cf \times Dd_e$(18)

External failure cost(C_o) in this work is modeled as repair or replacement cost for a detected defective unit of a product at the customer's site and is given as:

$C_o \times Dn_e$(19)

Design of Single Sampling Plans with specified AQL and LTPD

In the design of acceptance single sampling plan, we chose an appropriate sample size (n) and acceptance number (c). Given the probabilities of acceptance(P_a) with associated quality level $p_1 =$

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AQL, and $p_2 = LTPD$.Probability of lot acceptance is thus given as:

$1-\alpha = P_a(x \le c|n, p_1 = AQL) = \sum_{x=0}^{C}\binom{n}{x} AQL^x(1-AQL)^{n-x}$ (20)

$1 - P_a(AQL) = \alpha$ (21)

When inspection error is considered, the AQL is replaced with observed acceptable quality level (AQL_e). Thus, the probability of acceptance $1-\alpha$ with inspection error for lot with quality level $p_1 = AQL_e$ is given by:

$1-\alpha = P_{ae}(x \le c|n, p_1 = AQL_e) = \sum_{x=0}^{C}\binom{n}{x} AQL_e{}^x(1-AQL_e)^{n-x}$

(22)

$AQL_e = 1-(1-AQL)^n(1-e_2)+e_1(1-AQLn$ (23)

Substituting (23) for AQL_e in (22), now becomes:

$= \sum_{x=0}^{C}\binom{n}{x}\{1-(1-AQL)^n(1-e_2)+$ $e11-AQLnx(1-AQL)n1-e2+e11-AQLnn-x$

(24)

The probability of lot rejection at $p_1 = AQLe$ or producer's risk (α) as stated in the adjusted model is thus:

$1 - P_{ae}(AQL_e) = \alpha$

(25)

On the other hand, if the lot with quality level $p_2 = LTPD$ is accepted, then there is consumer's risk.Thus, the probability of accepting lot with quality level $p_2 = LTPD$ under no inspection error assumed is stated below:

$$\beta = P(x \le c|n.p_2 = LTPD)$$

$$= \sum_{x=0}^{C}\binom{n}{x} p_2{}^x(1-p_2)^{n-x}$$

$$\beta = \sum\nolimits_{x=0}^{c}\binom{n}{x} LTPD^X(1-LTPD)^{n-x}$$

$\beta = P_a(LTPD)$(26)

When inspection error is considered, the probability of acceptance or consumer's risk (β) as stated in the adjusted model above is obtained as shown below:

$\beta = P_{ae}(x \le c|n, p_2 = LTPD_e) = \sum_{x=0}^{C}\binom{n}{x} LTPD_e{}^x(1-LTPD_e)^{n-x}$(27)

Where

$$LTPD_e = \{1-(1-LTPD)^n\}(1-e_2) + e_1(1-LTPD)^n$$

Thus the probability of lot acceptance at $p_2 = LTPD_e$ or consumer's risk (β) is thus:

$\beta = P_{ae}(LTPD_e)$(28)

Design of Double Sampling Plans with specified AQL and LTPD

In the design of Double Sampling Plan, the probabilities of lot acceptance given quality level $p_1 = AQL$ and $p_2 = LTPD$ are determined as shown below:

$1-\alpha \; = P_{a_1} + P_{a_2} = P\big(x_1 \le c_1|n_1, p_1 = AQL\big) + P\big(x_1 + x_2 \le c_2|c_1 < x_1 \le c_2, n_1, n_2, p_1 = AQL\big)$

(29)

Producer's risk is :

$1 - P_a(AQL) = \alpha$ (30)

The Probability of lot acceptance$(1-\alpha)$ in the presence of inspection error is given as:

$1-\alpha = P_{ae1} + P_{ae_2} = P\big(x_1 \le c_1|n_1, p_1 =$ $AQLe+Px1+x2\le c2|c1<x1\le c2,n1,n2,p1=AQLe$

(31)

$= \sum_{x_1=0}^{c_1}\binom{n_1}{x_1} AQL_e{}^{x_1}(1-AQL_e)^{n_1-x_1} +$ $\sum_{x_1=c_1+1}^{c_2}\left\{\left[\binom{n_1}{x_1} AQL_e{}^{x_1}(1-AQL_e)^{n_1-x_1}\right]\times\right.$ $x2=0c2-x1n2x2AQLex21-AQLen2-x2$(32)

Where $AQL_e = \{1-(1-AQL)^{n1}\}(1-e_2) + e_1(1-AQL)^{n1}$

Then (32) becomes:

The probability of rejecting a lot with quality level $p_1 = AQL_e$

$1 - Pa_e(AQL_e) = \alpha$(33)

On the other hand, the probability of accepting the lot with quality level $p_2 = LTPD$ is calculated below:

$\beta = P_{a_1} + P_{a_2} = P\big(x_1 \le c_1|n_1, p_2 = LTPD\big) + P\big(x_1 + x_2 \le c_2|c_1 < x_1 \le c_2, n_1, n_2, p_2 = LTPD\big)$

(34)

$$\beta = \sum_{x_1=0}^{c_1}\binom{n_1}{x_1} LTPD^{x_1}(1-LTPD)^{n_1-x_1} + \sum_{x_1=c_1+1}^{c_2}\left\{\left[\binom{n_1}{x_1} LTPD^{x_1}(1 - LTPD)^{n_1-x_1}\right] \times \left[\sum_{x_2=0}^{c_2-x_1}\binom{n_2}{x_2} LTPD^{x_2}(1 - LTPD)^{n_2-x_2}\right]\right\}$$

Consumer's risk (β) $= P_a(LTPD)$ (35)

When inspection error is considered, the probability of acceptance of the lot is formulated as shown below with $p_2 = LTPD$ is replaced with $p_2 = LTPDe$:

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$\beta = P_{ae1} + P_{ae_2} = P(x_1 \le c_1 | n_{1,} p_2 = LTPD_e) + P(x_1 + x_2 \le c_2 | c_1 < x_1 \le c_2, n_{1,} n_{2,} p_2 = LTPD_e)$ (36)

$= \sum_{x_1=0}^{c_1} \binom{n_1}{x_1} LTPD_e^{\,x_1} (1 - LTPD_e)^{n_1 - x_1} + \sum_{x_1=c_1+1}^{c_2} \left\{ \left[\binom{n_1}{x_1} LTPD_e^{\,x_1} (1 - LTPD_e)^{n_1 - x_1} \right] \times \right.$
$x2{=}0c2{-}x1n2x2LTPDex21{-}LTPDen2{-}x2$ (37)

Where $LTPD_e = \{1 - (1 - LTPD)^{n1}\}(1 - e_2) + e_1(1 - LTPD)^{n1}$

Then (37) becomes
Thus, consumer's risk for Double Sampling at $p_2 = LTPDe$:
$\beta = P_{ae}(LTPD_e)$(38)

III.RESULTS AND DISCUSSION

Comparison of the existing model and the adjusted model in terms of optimal solutions and sensitivity analysis is made as shown in tables and figures below:

Table 1: Sampling plans for RSS Plan in the existing model given the parameters ($N = 1000, AQL = 0.02, LTPD = 0.07$, α=0.05, β=0.1,$AOQL = 0.03$ with$n \le 250$) [adopted from the existing model. (Kumar S.(2018)]

n	c	ATI	D_n	D_d	$1 - P_a(AQL)$	$P_a(LTPD)$	TC
200	8	319.68	20.41	9.59	0.0202	0.0556	542.95
201	8	323.03	20.31	9.69	0.0208	0.0537	545.50
201	**9**	**267.19**	**21.98**	**8.02**	**0.0077**	**0.0979**	**503.07**
202	8	326.40	20.21	9.79	0.0214	0.0518	548.06
202	9	269.78	21.91	8.09	0.0080	0.0947	505.03
205	9	277.68	21.67	8.33	0.0088	0.0859	511.04

Table 2:Sampling plans for RSS Plan in the Adjusted model given the parameters (N=1000, ,$AQL = 0.02, LTPD = 0.07$, α=0.05, β=0.1, $AOQL = 0.03$ with $n \le 250$

n	c	ATI_e	D_{ne}	D_{de}	$1 - P_{ae}(AQL_e)$	$P_{ae}(LTPD_e)$	TC
23	13	204.40	23.83	6.07	0.0138	0.0084	455.84
23	14	115.21	26.58	3.42	0.0044	0.0261	387.83
23	**15**	**71.90**	**27.86**	**2.14**	**0.0012**	**0.0687**	**348.05**
24	13	316.24	20.61	9.39	0.0302	0.0020	541.10
24	14	194.47	24.22	5.78	0.0111	0.0073	448.26
26	15	293.11	21.29	8.71	0.0209	0.0014	523.46
27	15	422.00	17.47	12.53	0.0431	0.0003	621.73

The optimal solutions for RSS using the existing model and the adjusted model are highlighted in tables 1 and 2 above. It can be seen that the values of the sample size $(n) = 23$, Average Total Inspection (ATI) =71.90 and the total cost $(TC) = 348.05$ in the optimal RSS plan of the adjusted model in table 2 are smaller than the optimal values of sample size $(n) = 201$, Average Total Inspection (ATI) =267.19 and the total cost $(TC) = 503.07$. in the existing model as shown in table 1.

Table 3: Sampling plans for RDS Plans using the existing model given the parameters ($N = 1000, AQL = 0.02, LTPD = 0.07$, α=0.05, β=0.1, $AOQL = 0.03$,withn_1 and $n_2 \le 250$)

n_1	n_2	c_1	C_2	ATI	D_n	D_d	$1 - P_a(AQL)$	$P_a(LTPD)$	TC
95	190	3	10	263.69	22.09	35.06	0.0175	0.0972	554.70
96	192	3	10	271.07	21.87	35.25	0.0187	0.0926	560.26
96	**192**	**3**	**11**	**237.32**	**22.88**	**34.24**	**0.0093**	**0.0971**	**534.60**
97	194	3	10	278.10	21.64	35.45	0.0200	0.0882	565.88
97	194	3	11	244.10	22.68	34.41	0.0100	0.0923	539.69
98	196	3	11	250.98	22.47	34.59	0.0108	0.0878	544.87

Table 4: Sampling plans for EDS Plans in the Adjusted Model given the parameters $N = 1000, AQL = 0.02, LTPD = 0.07$, α=0.05, β=0.1, AOQL $= 0.03$,withn_1 and $n_2 \leq 250$

n_1	n_2	c_1	c_2	ATI_e	D_{ne}	D_{de}	$1 - P_{ae}(AQL_e)$	$P_{ae}(LTPD_e)$	TC
9	18	1	8	153.68	25.73	34.00	0.0164	0.0714	479.01
10	20	2	8	266.31	22.39	37.31	0.0437	0.0539	564.81
10	**20**	**2**	**10**	**113.69**	**26.92**	**32.78**	**0.0076**	**0.0800**	**448.45**
11	22	2	10	262,44	22.50	17.17	0.0302	0.0211	561.79
11	22	3	10	196.46	24.46	35.21	0.0214	0.0717	511.49
11	22	3	11	137.86	26.20	33.47	0.0098	0.0763	466.82
12	24	3	11	291.88	21.63	38.01	0.0353	0.0258	584.18
13	26	4	13	241.35	23.13	36.48	0.0210	0.0320	545.59
14	28	4	14	353.55	19.80	39.78	0.0365	0.0099	631.07

The optimal solutions for RDS using the existing model and the adjusted model are highlighted in tables 3 and 4 above. It can be seen that the values of the sample size $(n_1) = 10$, $n_2 = 20$,Average Total Inspection (ATI) =113.32,and the total cost (TC) $= 448.45$ in the optimal RDS plan of the adjusted model in table 4 are smaller than the optimal values of the sample size $(n_1) = 96$, $n_2 = 192$,Average Total Inspection (ATI) =237.32,and the total cost (TC) $= 534.60$ in the existing model shown in table 3.

Effect of Changes in the Cost Parameters on the Total cost (TC)

The effects of inspection **cost** (C_i), Internal failure cost (C_f) and External failure cost on the optimal total cost of the sampling plans is shown in tables and figures below:

Table 5: Effects of $C_i = 1$,$C_f = 2$ and $C_o = 10$ on the optimal TC in RSS Plans

Cost parameters			Optimal Sampling plan for RSS in the Existing Model $(n = 201, c = 9)$	Optimal sampling plan for RSS in the Existing Model $(n = 23, c = 15)$	
C_i	C_f	C_0	TC	TC	%Difference in TC
1.0	2	10	503.07	348.05	30.80%
2.0	2	10	770.26	411.07	46.63%
3.0	2	10	1037.45	474.09	54.30%
4.0	2	10	1304.64	537.11	58.83%
5.0	2	10	1571.84	600.13	61.80%
6.0	2	10	1839.03	663.15	63.94%
7.0	2	10	2106.22	726.17	65.52%
8.0	2	10	2373.41	789.19	66.75%
9.0	2	10	2640.60	852.21	67.73%
10.0	2	10	2907.80	915.24	68.52%
1	2.0	10	503.07	348.05	30.82%
1	4.0	10	519.10	351.79	32.23%
1	6.0	10	535.13	355.53	33.56%
1	8.0	10	551.16	359.28	34.81%
1	10.0	10	567.19	363.02	35.99%
1	2	10	503.07	348.05	30.81%
1	2	20	722.91	629.33	12.95%
1	2	30	942.75	910.61	3.41%
1	2	40	1162.59	1191.90	-2.52%
1	2	50	1382.44	1473.18	-10.56%

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1	2	60	1602.28	1754.46	-9.50%
1	2	70	1822.12	2035.74	-11.72%
1	2	80	2041.96	2317.03	-13.47%
1	2	90	2261.80	2598.31	-14.88%
1	2	100	2481.65	2879.59	-16.04%

Table 6: Effect of $C_i = 1, C_f = 2$ and $C_o = 10$ on the optimal TC of RDS Plans

Cost parameters			Optimal Sampling plan for RDS in the existing model $n_1 = 96, c_1=3, n_2 = 192, c_2 = 11,$	Optimal Sampling plan for RDS in the Adjusted Model $n_1 = 10, c_1=2, n_2 = 20, c_2 = 10,$	
C_i	C_f	C_o	TC	TC	%Difference in TC
1.0	2	10	534.60	448.45	16.11%
2.0	2	10	771.92	562.14	27.18%
3.0	2	10	1009.24	675.82	33.05%
4.0	2	10	1246.56	789.51	36.66%
5.0	2	10	1483.88	903.19	39.13%
6.0	2	10	1721.20	1016.52	40.94%
7.0	2	10	1958.52	1130.56	42.27%
8.0	2	10	2195.84	1244.25	43.34%
9.0	2	10	2433.15	1357.93	44.19%
10.0	2	10	2670.47	1471.62	44.89%
1	2.0	10	534.60	448.45	16.12%
1	4.0	10	603.08	514.01	14.77%
1	6.0	10	671.56	579.57	14.06%
1	8.0	10	740.04	645.13	12.82%
1	10.0	10	808.52	710.69	12.10%
1	2	10	534.60	448.45	16.11%
1	2	20	763.41	717.66	5.99%
1	2	30	992.21	986.86	0.54%
1	2	40	1221.02	1256.07	-2.87%
1	2	50	1449.82	1525.27	-5.20%
1	2	60	1678.62	1794.48	-6.90%
1	2	70	1907.43	2063.68	-8.19%
1	2	80	2136.23	2332.89	-9.21%
1	2	90	2365.04	2602.09	-10.02%
1	2	100	2593.84	2871.30	-10.70%

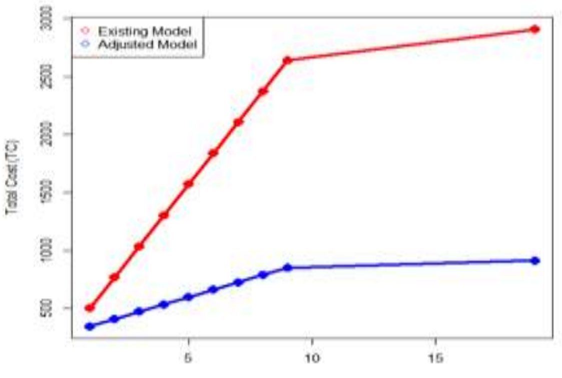

Fig.1: Effect of Increase in Inspection Cost(Ci) on Total Cost (TC) of RSS

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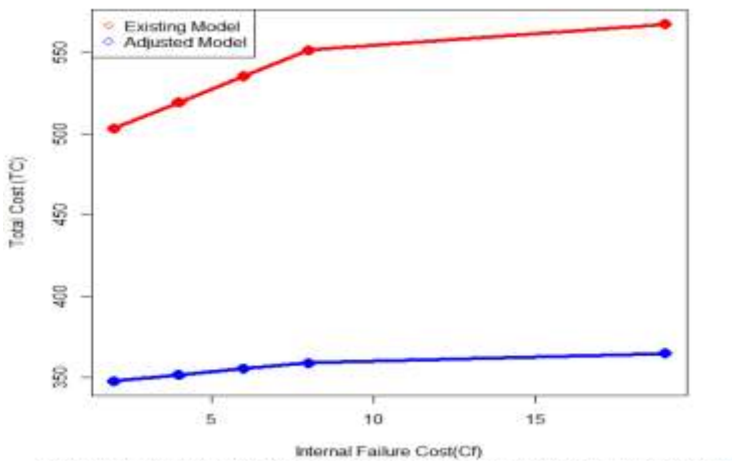

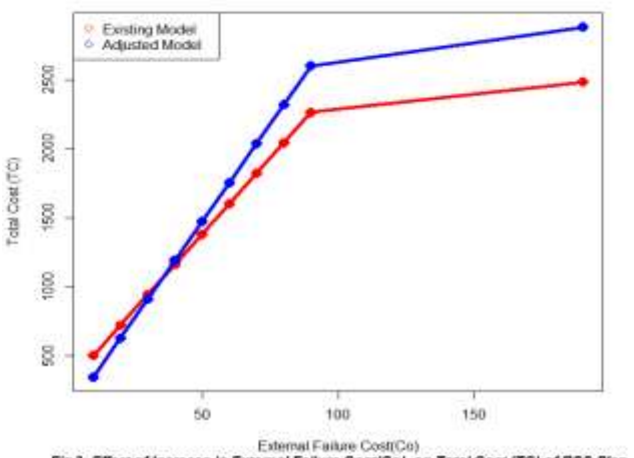

Fig.3: Effect of Increase in External Failure Cost(Co) on Total Cost (TC) of RSS Plan

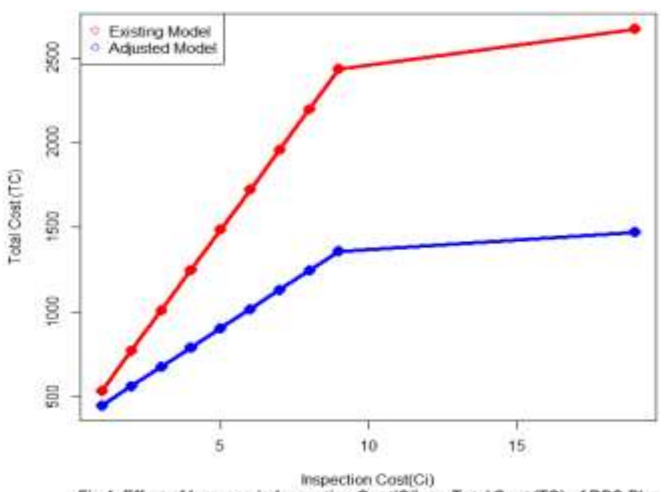

Fig.4: Effect of Increase in Inspection Cost(Ci) on Total Cost (TC) of RDS Plan

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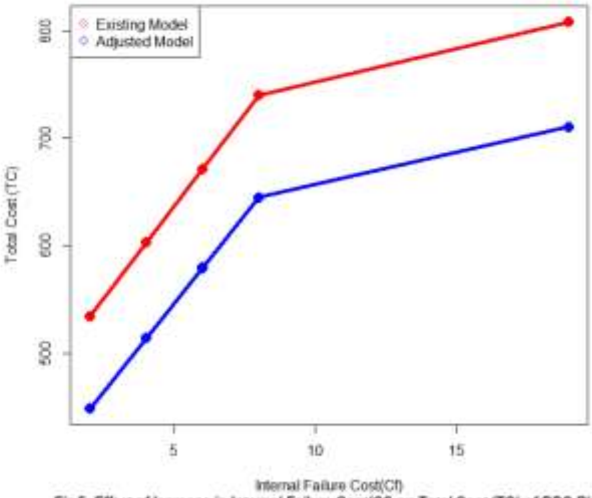

Fig.5: Effect of Increase in Internal Failure Cost(Cf) on Total Cost (TC) of RDS Plan

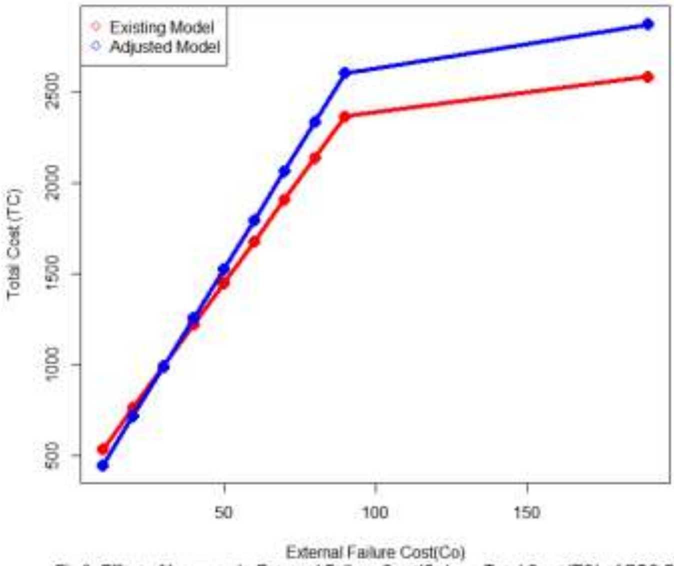

Fig.6: Effect of Increase in External Failure Cost(Co) on Total Cost (TC) of RDS Plan

Tables 5 and 6 and figures 1 to 6 above show the effects of increasing the keeping constant the values of inspection **cost (**C_i), Internal failure cost (C_f) and External failure cost on the optimal total cost of RSS and RDS using the adjusted model and the existing model. It is seen that the total cost in all the sampling plans in the existing model and the adjusted increased as the values of the cost parameters also increased. However, the Total Cost (TC) in the adjusted model is minimal as compared to that of the existing model. It is also noted in figure 3 and 6 that as the external failure cost increased above the value of 35 , the total cost (TC) in the existing model increased above that of the existing model.

IV. CONCLUSION

The existing cost model as developed by kumar (2018) is adjusted in this work to incorporate inspection errors and additional objective functions. The model is tested on Rectifying Single sampling (RSS) and Rectifying Doable Sampling (RDS) plans to achieve optimal sampling and to also minimize total cost of inspection and failure cost while protecting both the producer and the consumer against losses. The performance of the adjusted model is compared with the existing model. It is found that the adjusted model showed smaller sample size and minimal total cost in RSS and RDS plans than in the existing model. Sensitivity analysis also revealed minimal total cost for RSS and RDS plans in the adjusted model than in the existing model when the effect of changes in the inspection cost, Internal failure cost and External failure cost on the total coat of the two sampling plans was investigated.

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