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A Double Acceptance Sampling Plan for Truncated Life Test Having Exponentiated Transmuted Weibull Distribution

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ABSTRACT

This paper proposes DASP and SASP based on Lifetime life test when a product's life follows an exponential Weibull distribution using a two-point approach (consumer risk and product risk). Suggested dual sampling and individual sampling plans were submitted, assuming a two-point approach design assumes that the product life follows ETW distribution. It was found that the dual sampling plan may be more economical than the individual sampling plan which gives a lower quality level. As the savings in the sample size increase with the double sampling plan with the decrease in consumer risks.

Keywords: Double sampling plan; Single sampling plan; Producer's risk; Consumer's risk; exponentiated transmuted Weibull distribution; Time truncated experiment.

INTRODUCTION

Quality control plays an increasingly important role in the processing of decision making. It has become one of the most important tools to differentiate between the competitive enterprises in a global business market. One of the important tools for ensuring quality is the acceptance sampling plans technique. Acceptance sampling plans are concerned with inspection and decision making regarding the lot through sample has been taken from the lot. There are many reasons that motivate us to use the acceptance sampling plans technique such as, it is usually less expensive applicable to destructive testing. Therefore, it is desirable to design an acceptance sampling plans to achieve the greatest possible accuracy. The single acceptance sampling plan (SASP) is determined with two parameters. The first parameter is the number of random chosen units n from the observed lot, and the second is the number of failure or defective units which can be tolerated c. If the lot inspection finds more failure or defective units in the lot than is allowed, the lot will be rejected. This type of sampling plans based on the truncated life test for various statistical distributions, Gupta and Groll (1961) for

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gamma distribution, Goode and Kao (1961) for Weibull distribution, Rosaiah and Kantam (2005) for the inverse Rayleigh distribution, Tsai and Wu (2006) for generalized Rayleigh distribution, Lio *et al.,* (2010) for the Burr type XII distribution. On the other hand, the single acceptance sampling plan calls for a decision on acceptance or rejection of a lot on the basis of the evidence of one sample from that entire lot, the double acceptance sampling plan (DASP) involves the possibility of putting off the decision on the lot until the second has been taken. In a double acceptance sampling plan, management specifies two sample size (n_1, n_2) and two acceptance numbers (c_1, c_2). A lot of authors introduced the literatures relative to the double acceptance sampling plan (DASP), such as, Aslam (2007) for "Rayleigh Distribution", Aslam and Jun (2010) for Generalized Log-logistic Distribution, Aslam *et al.,* (2011) for Birnbaum-Saunders Distribution, Srirmachandran and Palanivel (2013) for Burr Type XII Distribution.

The aim of this paper is to propose a DASP and SASP based on truncated life test when the lifetime of a product follows an exponentiated transmuted Weibull distribution by using two-point approach (consumer's risk and producer's risk). The rest of his paper is organized as follows: We will introduce the glance about the exponentiated transmuted Weibull (ETW) distribution in section 2. Propose DASP with the operating characteristics (OC) curve in section 3. Propose SASP with the operating characteristics (OC) curve in section 4. The both results of DASP and SASP are compared in section 5. Finally, we conclude with some remarks in section 6.

Exponentiated transmuted Weibull distribution

The exponentiated transmuted Weibull (ETW) distribution was originally proposed by Ebraheim [4] to generalize the weibull probability distribution. The cumulative distribution function (CDF) of the ETW distribution is given by:

$$F(t,\delta,\sigma,\lambda,v) = \left[1 + (\lambda - 1)e^{-\left(\frac{t}{\sigma}\right)^{\delta}} - \lambda e^{-2\left(\frac{t}{\sigma}\right)^{\delta}}\right]^{v} , \qquad (1)$$

where $\sigma, v > 0$, $\delta > 0$ and $|\lambda| \leq 1$ are the scale, shape and transmuted parameters, respectively.

The ETW distribution has many applications in different areas, such as the life modeling in reliability analysis and life testing problems. It is clear that ETW distributions is very flexible, this is so since several other distributions follow as special cases from ETW distribution by selecting the appropriate values of parameters. For example, when $v = 1$ and $\lambda = 0$ the ETW distribution goes to the Weibull distribution.

The median life of ETW distribution is given by Ebraheim (2014):

$$\text{median} = \sigma \left\{ -\ln\left[\frac{1}{\lambda}\left(1 - (0.5)^{\frac{1}{v}}\right) + \frac{1}{4}\left(\frac{1-\lambda}{\lambda}\right)^{2}\right]^{\frac{1}{2}} - \frac{1}{2}\left[\frac{1-\lambda}{\lambda}\right] \right\}^{\frac{1}{\delta}} . \qquad (2)$$

Design of DASP for exponentiated transmuted Weibull distribution

Let μ represent the true value of the median of lifetime distribution of a product and μ_0 denote the specified median, under the assumption that lifetime of an item follows an exponential transmuted Weibull distribution. We interested in designing a sampling plan in order to assure that the median of life of items in a lot (μ) is greater than the specified life (μ_0). We will accept the lot if there is enough evidence that $\mu \geq \mu_0$ at certain levels of consumer's and producer's risks. Otherwise, we have to reject the lot. Let us propose the following double acceptance sampling plan based on the truncated life test, Aslam (2007):

Step 1. Draw the first sample of size n_1 from a lot and put them on test for t_0 units of time.

Step 2. Accept the lot if there c_1 or smaller number of failures. Reject the lot and terminate the test as soon as $(c_1 + 1)$ or more failures are observed. If the number of failures is between c_1 and c_2, then draw the second sample of size n_2 from the lot and put them on test for another t_0 units of time.

Step 3. Accept the lot if the total number of failures from the first and the second samples is no greater than c_2. Otherwise, terminate the test and reject the lot.

We are interested in determining the four parameters of the double sampling plan $(n_1, n_2, c_1, c_2\ )$ which satisfies both risks at the same time, whereas the termination time t_0 is assumed to be specified.

When the lifetime of an item follows the ETW distribution with CDF given in Equation (1), the failure probability is given by:

$$p = F(t_0) = \left[1 + (\lambda - 1)e^{-\left(\frac{t_0}{\sigma}\right)^{\delta}} - \lambda e^{-2\left(\left(\frac{t_0}{\sigma}\right)\right)^{\delta}}\right]^{\nu} \tag{3}$$

It would be convenient to specify the termination time t_0 as a multiple of the specified life $t_0 = a\,\mu_0$. Also from Equation (2), the scale parameter σ can be expressed by the median lifetime μ. Then the failure probability given in Equation (3) can be rewritten as:

$$p = \left[1 + (\lambda - 1)e^{-\left(\frac{a.m}{\mu/\mu_0}\right)^{\delta}} - \lambda e^{-2\left(\frac{a.m}{\mu/\mu_0}\right)^{\delta}}\right]^{\nu} \tag{4}$$

where $m = \left\{-\ln\left[\frac{1}{\lambda}\left(1 - (0.5)^{\frac{1}{\nu}}\right) + \frac{1}{4}\left(\frac{1-\lambda}{\lambda}\right)^2\right]^{\frac{1}{2}} - \frac{1}{2}\left[\frac{1-\lambda}{\lambda}\right]\right\}^{\frac{1}{\delta}}$ and $\mu = \sigma\,.m$ from Equation (2).

As pointed out by (Grant and Leavenworth (1988) and Montgomery (2009)), binomial distribution can be used to calculate the probability acceptance of a sampling plan, when the lot size is large enough and the experimenter focuses only on two options either to accept or reject the lot.

The probability of the lot acceptance for the proposed double sampling plan is given by Aslam *et al.,* [3]:

$$P_a(p) = \sum_{d_1=0}^{c_1} \binom{n_1}{d_1} p^{d_1}\,(1-p)^{n_1-d_1} + \sum_{D=c_1+1}^{c_2} \binom{n_1}{D} p^{D}\,(1-p)^{n_1-D}\left[\sum_{d_2=0}^{c_2-D} \binom{n_2}{d_2} p^{d_2}\,(1-p)^{n_2-d_2}\right] \tag{5}$$

where p is the failure probability in Equation (4). It would be convenient to specify the termination time t_0 as a multiple of the specified life. That is, we will consider $t_0 = a\,\mu_0$ for a constant a (termination ratio). The first term and the second term in Equation (5) represent the probability of acceptance from the first sample and from the second sample, respectively.

For the known values of the parameters δ, λ *and* ν, p can be evaluated when the multiplier a and the ratio $\frac{\mu}{\mu_0}$ are specified. We can express the quality level of a product in terms of ratio of its median lifetime to the specified life $\frac{\mu}{\mu_0}$. The usual approach to designing the plan parameters is two-point method, which utilizes the two points on the OC curve. As in Aslam *et al.,* (2011), the probability of acceptance should be greater than $1-\alpha$ (α is called producer's risk) at the acceptance reliability level (ARL), which is called p_2, and the probability of acceptance should be smaller than $1-p^*$ ($p^*$is called consumer's confidence level or β (this is called consumer's risk) at the lot tolerance reliability level (LTRL), which is called p_1. When the quality level is expressed by the ratio mentioned earlier, the proposed two-point approach of finding the design parameters is to determine the number of groups and the acceptance number that satisfy the following two inequalities simultaneously:

$$P_a\left(p_1 \middle| \frac{\mu}{\mu_0}=r_1\right) \le \beta \quad , \tag{6}$$

$$P_a\left(p_2 \middle| \frac{\mu}{\mu_0}=r_2\right) \ge 1-\alpha \quad . \tag{7}$$

where r_1 is median ratio at the consumer's risk (or median ratio corresponding LTRL), and r_2 is median ratio at the producer's risk (or median ratio corresponding ARL). Let p_1 be the failure probability corresponding to the median ratio of r_1 (at consumer's risk) and p_2 the failure probability corresponding to the median ratio of r_2 (at producer's risk). Then, the above two inequalities become:

$$P_a(p_1) = \sum_{d_1=0}^{c_1} \binom{n_1}{d_1} p_1^{d_1} (1-p_1)^{n_1-d_1} + \sum_{D=c_1+1}^{c_2} \binom{n_1}{D} p_1^{D} (1-p_1)^{n_1-D} \left[\sum_{d_2=0}^{c_2-D} \binom{n_2}{d_2} p_1^{d_2} (1-p_1)^{n_2-d_2}\right] \tag{8}$$

$$P_a(p_2) = \sum_{d_1=0}^{c_1} \binom{n_1}{d_1} p_2^{d_1} (1-p_2)^{n_1-d_1} + \sum_{D=c_1+1}^{c_2} \binom{n_1}{D} p_2^{D} (1-p_2)^{n_1-D} \left[\sum_{d_2=0}^{c_2-D} \binom{n_2}{d_2} p_2^{d_2} (1-p_2)^{n_2-d_2}\right] \tag{9}$$

There are many multiple solutions of plan parameters satisfying the above two inequalities. Therefore, we would like to select the one to minimize the average sample number (ASN). The ASN for proposed double sampling plan is calculated by:

$$ASN = n_1 P_I + (n_1 + n_2)(1 - P_I) \tag{10}$$

where P_I is the probability that the decision was made by the first sample and it is given by:

$$P_I = 1 - \sum_{D=c_1+1}^{c_2} \binom{n_1}{D} p^D (1-p)^{n_1-D} \tag{11}$$

We suggest ASN evaluation at p_1 because the ASN at p_1 is larger than at p_2 and minimizing the large value is more reasonable. In fact, the criterion of minimizing the ASN been adopted by many authors including (Aslam *et al.,* (2011) and Sriramachandran and Palanivel (2013)).
Therefore, the parameters for our double sampling plan will be determined by solving the following optimization problem:

$$Minimize\ ASN\ (p_1) \quad (12)$$

$$Subject\ to\ \ P_a\ (p_1) \leq\ \beta \quad (13)$$

$$P_a\ (p_2)\ \geq 1 -\ \alpha \quad (14)$$

$$1\ \leq\ n_2\ \leq\ n_1 \quad (15)$$

$$n_1\ , n_2\ \ ;\ \ integer \quad (16)$$

The constraint (15) is specified because it may not be desirable if the sample size in the second stage is greater than that in the first stage.
This optimization problem can be simply solved by a search method that can be implemented by MATLAB program.
Tables 1-2 show the design parameters of the double sampling plans with the lifetime of the product follows the ETW distribution with shape parameter $(\delta = 2, 2.5)$ and with fixed other parameters $(\lambda = -0.4)$ and $(\nu = 1)$. Four levels of consumer's risk $(\beta = 0.25, 0.10, 0.05, 0.01)$ were considered. Whereas, the producer's risk α was set to 0.05. The median ratio at the consumer's risk (r_1) was set to 1, while five values of the median ratio at producer's risk (r_2) $\left(r_2 = \frac{\mu}{\mu_0} = 2, 4, 6, 8, 10\right)$ were considered. Two levels of the test time were specified as $(a = 0.7, 1.0)$. The ASN and the lot acceptance probability $P_a(p_2)$ at the median ratio of r_2 were also shown in these Tables.
Example (1): Suppose that a bulb manufacturer is interested in adopting the double sampling plan to decide about the acceptance or rejection of the submitted lots. Assume that the lifetime of a product follows the ETW distribution with shape parameter $(\delta = 2.5)$ and with other parameters $(\lambda = -0.4)$ and $(\nu = 1)$, and that the specified median lifetime to this product is 1000h. We want to run the experiment up to 500h. It is know that the consumer's risk β is 10% when the true median lifetime is 1000h, whereas the producer's risk α is 5% when the true median lifetime is 4000. In this case, $a = 0.5$, $\beta = 0.10$ and $\frac{\mu}{\mu_0} = r_2 = 4$, so $(c_1\ , c_2\ ) =\ (0\ , 1)$ and $(n_1\ , n_2\ \ ) =\ (15\ , 14)$ from Table 2.

Design of SASP for exponentiated transmuted Weibull distribution
If we interest in adopting the single sampling plan to decide about the acceptance or rejection of the submitted lots. Let us propose the following single acceptance sampling plan based on the truncated life test:
Step 1. From a lot of size N, select a random sample of size n.
Step 2. Select the acceptance number c and the experiment time t_0.
Step 3. Perform the experiment for n simultaneously and record the number of failures in the sample n.
Step 4. Accept the lot if the number of failure or defective d is less than or equal the number of acceptance c.
Step 5. Truncate the experiment if more than d failures occur in the sample and reject the lot.

The proposed single sampling plan is characterized by two parameters n and c. The acceptance probability of a lot for the single sampling is given as Tsai and Wu (2006):

$$P_a\,(p) = \sum_{d=0}^{c} \binom{n}{d}\, p^d\, (1-p)^{n-d} \tag{17}$$

Where p is the failure probability of an item given in Equations (3) and (4). For this plan, the parameters can be determined by the two-point approach. Therefore, the values of n and c can be determined using the following:

$$P_a\,(p_1) = \sum_{d=0}^{c} \binom{n}{d}\, {p_1}^d \left(1-{p_1}^d\right)^{n-d} \le \beta \tag{18}$$

$$P_a\,(p_2) = \sum_{d=0}^{c} \binom{n}{d}\, {p_1}^d \left(1-{p_1}^d\right)^{n-d} \ge 1-\alpha \tag{19}$$

Table 1: The design parameters of the DASP with ETW distribution when ($\delta = 2, \nu = 1, \lambda = -0.4$)

β	$\frac{\mu}{\mu_0} = r_2$	$a = 0.5$						$a = 0.7$					
		c_1	c_2	n_1	n_2	ASN	$P_a(p_2)$	c_1	c_2	n_1	n_2	ASN	$P_a(p_2)$
0.25	2	o	3	13	10	17.3072	0.8739	1	3	7	5	8.8739	0.1500
	4	0	1	7	7	8.2317	1.000	0	1	4	2	4.2435	0.9993
	6	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	1.000
	8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	10	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
0.10	2	↑	↑	↑	↑	↑	↑	1	4	10	8	12.8330	0.1500
	4	↑	↑	↑	↑	↑	↑	0	1	5	5	5.3597	0.9993
	6	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	1.000
	8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	10	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
0.05	2	0	5	26	19	31.5790	0.8739	1	5	13	10	16.2673	0.1500
	4	0	1	13	11	13.4365	1.000	1	0	6	6	6.2550	0.9993
	6	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	1.000
	8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	10	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
0.01	2	1	7	38	31	45.4291	0.8739	0	6	17	14	20.3467	0.1500
	4	0	2	20	20	20.9265	1.000	0	1	10	4	10.0207	0.9993
	6	0	1	19	16	19.1432	1.000	0	1	9	8	9.0701	1.000
	8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	10	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑

Note. The upward arrow (↑) indicates that the same value of parameter as in the upward cell applies to the corresponding cell

Table 2: The design parameters of the DASP with ETW distribution when ($\delta = 2.5, \nu = 1, \lambda = -0.4$)

β	$\frac{\mu}{\mu_0} = r_2$	$a = 0.5$						$a = 0.7$					
		c_1	c_2	n_1	n_2	ASN	$P_a(p_2)$	c_1	c_2	n_1	n_2	ASN	$P_a(p_2)$
0.25	2	0	2	14	11	17.6566	0.9992	0	2	6	5	7.5974	0.7615
	4	0	1	10	10	11.8254	1.000	0	1	4	4	4.7150	1.000
	6	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	10	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
0.10	2	0	3	21	21	28.1496	0.9992	0	3	9	9	12.0400	0.7615
	4	0	1	15	14	16.0919	1.000	0	1	6	6	6.4534	1.000
	6	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	10	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
0.05	2	0	3	25	24	30.4487	0.9992	0	3	11	9	12.8050	0.7615
	4	0	1	19	16	19.6320	1.000	0	1	8	5	8.1598	1.000
	6	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	10	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
0.01	2	0	4	36	36	41.9059	0.9992	0	4	15	15	17.5971	0.7615
	4	0	1	28	21	28.1795	1.000	0	1	11	9	11.0790	1.000
	6	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	8	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	10	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑

Note. The upward arrow (↑) indicates that the same value of parameter as in the upward cell applies to the corresponding cell

Table (3). The design parameters of the SASP with ETW distribution when ($\delta = 2.5, \nu = 1, \lambda = -0.4$)

β	$\frac{\mu}{\mu_0} = r_2$	$a = 0.5$			$a = 0.7$		
		n	c	$P_a(p_2)$	n	c	$P_a(p_2)$
0.25	2	25	2	0.9698	11	2	0.9707
	4	9	0	0.9574	4	0	0.9560
	6	↑	↑	0.9844	↑	↑	0.9839
	8	↑	↑	0.9924	↑	↑	0.9921
	10	↑	↑	0.9956	↑	↑	0.9955
0.10	2	41	3	0.9744	18	3	0.9752
	4	24	1	0.9940	10	1	0.9947
	6	14	0	0.9758	6	0	0.9759
	8	↑	↑	0.9881	↑	↑	0.9882
	10	↑	↑	0.9932	↑	↑	0.9932
0.05	2	48	3	0.9577	20	3	0.9645
	4	29	1	0.9913	12	1	0.9923
	6	18	0	0.9690	7	0	0.9720
	8	↑	↑	0.9848	↑	↑	0.9863
	10	↑	↑	0.9913	↑	↑	0.9921
0.01	2	71	4	0.9545	30	4	0.9601
	4	40	1	0.9839	16	1	0.9864
	6	28	0	0.9522	11	0	0.9563
	8	↑	↑	0.9764	↑	↑	0.9785
	10	↑	↑	0.9864	↑	↑	0.9876

Note. The upward arrow (↑) indicates that the same value of parameter as in the upward cell applies to the corresponding cell

The ASN for this case is n, which is independent of the lot quality. The design parameters in of integers can be found by using a search which can be implement by MATLAB program.

Table (3) shows the design parameters of the single sampling plans with the lifetime of the product follows the ETW distribution with shape parameter $(\delta = 2.5)$ and with other parameters $(\lambda = -0.4)$ and $(\nu = 1)$. Four levels of consumer's risk $(\beta = 0.25, 0.10, 0.05, 0.01)$ were considered. Whereas, the producer's risk α was set to 0.05. The median ratio at the consumer's risk (r_1) was set to 1, while five values of the median ratio at producer's risk (r_2) $\left(r_2 = \frac{\mu}{\mu_0} = 2, 4, 6, 8, 10\right)$ were considered. Two levels of the test time were specified as $(a = 0.7, 1.0)$. The lot acceptance probability $P_a(p_2)$ at the median ratio of r_2 were also shown in this table.

Comparison with Existing Plans for ETW Distribution

In this section, we compare the results of the existing sampling plans for the ETW distribution. We can say that the results which have been got from the double sampling plan technique gives the best results compare to the single sampling plan technique. The ASN for the double sampling plan is always smaller than the sample size (n) for the single sampling plan for quality levels from 2 to 4, and when the quality level is greater than 4 the sample size (n) for the single sampling plan is always smaller than the ASN for the double sampling plan.

Example 2: Suppose a bulb manufacturer would like to implement whether a double or single sampling plans in order to make a decision on the submitted lots. The lifetime of bulbs follow the ETW distribution with known parameters $(\delta = 2.5,\ \lambda = -0.4,\ \nu = 1)$, consumer's risk $(\beta = 0.10)$ and at the quality levels $\left(r_2 = \frac{\mu}{\mu_0} = 2, 4, 6, 8, 10\right)$. The results of the ASN for the double sampling plan and the sample size (n) for the single sampling plan at $a = 0.5$ can be illustrated in the Table (4) and Figure (1).

Table (4): The comparison between DASP and SASP

β	$\frac{\mu}{\mu_0} = r_2$	Double Sampling Plans	Single Sampling plan
		ASN	n
0.10	2	28.1496	41
	4	16.0919	24
	6	16.0919	14
	8	16.0919	14
	10	16.0919	14

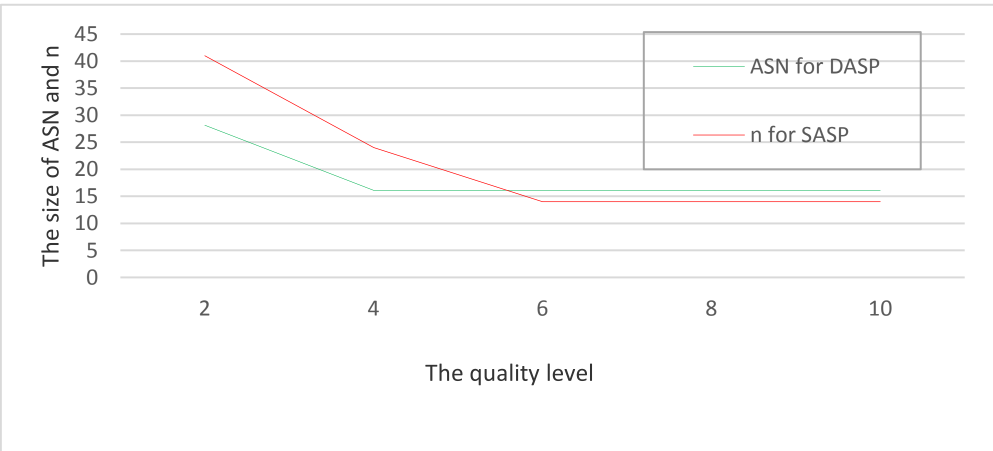

Figure 1: The comparison between DASP and SASP

CONCLUSION

The double sampling and single sampling plans are proposed and a two-point approach design is assumed that the product life follows ETW distribution. It has been observed that the double sampling plan may be more economical than the single sampling plan for a lower quality level. Savings in sample size with a dual sampling plan become greater with lower consumer risks.

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