JIRSS (2026)
Vol. 25, No. 1, pp 91-103
DOI: 10.22034/jirss.2026.2082914.1176

Sampling Scheme of Group Acceptance for Life Testing with the Half Logistic Distribution

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Received: 2026-01-05, Accepted: 2026-07-08, Published online: 2026-07-15

Abstract. In the present article, a sampling scheme of group acceptance is proposed with truncated life testing under the assumption that item lifetimes follow half logistic distribution. To a specified size of group, the least required count of groups and the corresponding acceptance count are calculated for given consumer's risk and test completion time. Operating characteristic numbers are computed for different quality levels, and the least ratios of true mean life to stated life corresponding to a given producer's risk are calculated. The findings are demonstrated through illustrative examples.

Keywords. half logistic distribution, group acceptance sampling plans, consumer's risk, operating characteristic (OC)function, producer's risk, truncated life test.

MSC: 62N05, 62P30.

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1 Introduction

Normal Distribution is the most commonly cited example of a probability model for any data to apply a statistical technique. The reason is perhaps the most powerful result of central limit theorem. However, there may be some exceptions where we may have to go to some probability models other than normal distribution. With this backdrop, one of the first modifications for normal distribution that is suggested is its folded version at its median. Such a distribution is named as half normal distribution. The advantage of this folding mechanism is that the resulting distribution eliminates negative values of the random variable from the population leading to a more practical model. In a similar manner the well known logistic distribution can also be folded at its median giving rise to half logistic distribution (HLD). In view of a number of similarities between normal and logistic distributions one can expect the same trend between half normal and half logistic distributions. Therefore, half logistic distribution can be an alternative to half normal distribution. Balakrishnan (1985) seems to be the person to have thought of half logistic distribution. Balakrishnan has introduced half logistic distribution by folding the well known logistic distribution at its median. His main contribution to the distribution is tabulation of means, variances and covariances of order statistics drawn from half logistic distribution. Other studies related to half logistic distribution are Balakrishnan and Puthenpura (1986), Balakrishnan and Wong (1991) and Balakrishnan and Chan (1992).

The probability density function (pdf) of a half logistic distribution is given by

$$f(x) = \frac{2e^{-x}}{(1+e^{-x})^2}, \quad x \geq 0 \tag{1.1}$$

Its cumulative distribution function (cdf) is

$$F(x) = \frac{(1-e^{-x})}{(1+e^{-x})}, \quad x \geq 0 \tag{1.2}$$

Reliability plays a crucial role in quality control analysis. Based on these studies, an investigator can reduce both cost and time by efficiently deciding whether to reject or accept the provided lot. Sampling scheme of acceptance deals with the inspection of product lots and the action taken to reject or accept them and it is one of the earliest schemes applied in quality control. When product lifetime is taken as the worth characteristic of concern, sampling scheme of acceptance can be described as: A firm accepts a lot of products from a supplier, often consisting of components or raw materials used in its manufacturing process. A specimen is drawn from the lot and the pertinent worth characteristics of sampled units are examined. Based on the sample knowledge, a conclusion is built concerning the disposition of the lot. Conventionally, if life testing shows that the average lifetime of the products goes beyond a stated value, the lot is approved; else, the lot is not accepted. Approved lots proceed to manufacturing, while rejected lots may be sent back to the supplier or underwent to alternative disposition actions. To reduce testing time and cost, truncated life tests are often employed. In such tests, the investigation is ceased at a predetermined time instant t_0, and the lot is accepted if the count of observed failures fall under a specified acceptance count c. A sampling scheme of acceptance specifies the minimum sample size required for testing, which is particularly important when product quality is defined in terms of lifetime. While sampling schemes are often designed presuming that only one item is tested at a time, practical considerations frequently necessitate the use of testers that can evaluate multiple items simultaneously. These objects are treated as a group, with the number of objects tested together referred to as the group size. Under this testing arrangement, determining the size of sample is identical to determining the required count of groups. Such testers are commonly employed in sudden-death testing. A sampling scheme of acceptance that is depending on testing items in groups is known as a group acceptance sampling plan (GASP). When a GASP is applied together with truncated life tests, it is referred to as a GASP depending on truncated life testing, under the assumption that the product lifetime obeys a specified probability distribution. Acceptance sampling plans for truncated life tests based on various distributions were studied (Balakrishnan et al., 2007; Srinivasa Rao et al., 2009; Lio et al., 2010; Srinivasa Rao and Kantam, 2010; Tripathi et al., 2022). Group acceptance sampling plans can be found in: Srinivasa Rao (2009), Aslam et al. (2011), Ramaswamy and Anburajan (2012), Srinivasa Rao and Lakshmi (2021), Abdullah et al. (2021), Ali (2022), Aisha and Khusnoor (2022), Al-Omari and Ismail (2024), Tripathi and Aslam (2024), Naghizedah et al. (2025), and Naghizedah and Aslam (2025). Other studies related to the extension of group acceptance sampling plans can be seen in: Srinivasa Rao (2011), Srinivasa Rao et al. (2021), Naghizedah et al. (2026).

Inspired by the above research papers, in this article, we present the methodology for a sampling scheme of group acceptance depending on truncated life tests, assuming that the product lifetime follows a half logistic distribution. The OC(operating characteristic) function is discussed and manufacturer's risk is addressed. Illustrative examples are provided and the article ends with a discussion. The C-programs used to generate various tables are included at the appendix. These C-programs can be used for further research based on GASP for other distributions if the cdf is changed.

2 Methodology for Sampling Scheme of Group Acceptance

Half logistic distribution pertains to the class of IFR (increasing failure rate) models and is therefore widely used in reliability studies. Owing to this IFR property, the half logistic distribution is considered in present work. Let the lifetime of a commodity follow a half logistic distribution having a scale parameter σ. The cdf $F(t)$ is then expressed as

$$F(t) = \frac{1 - e^{-\frac{t}{\sigma}}}{1 + e^{-\frac{t}{\sigma}}}, \quad t \geq 0, \sigma > 0 \tag{2.1}$$

Given $0 < q < 1$, the quantile is stated by

$$t_q = \sigma log(\frac{1+q}{1-q}) \tag{2.2}$$

Substituting σ from Equation (2.2) into Equation (2.1), the scaled form of the cumulative distribution function becomes

$$F(t) = \frac{1 - e^{-(\frac{t}{t_q})log(\frac{1+q}{1-q})}}{1 + e^{-(\frac{t}{t_q})log(\frac{1+q}{1-q})}},$$

$$F(t) = \frac{1 - e^{-\delta log(\frac{1+q}{1-q})}}{1 + e^{-\delta log(\frac{1+q}{1-q})}},$$

where $\delta = \frac{t}{t_q}$. In particular, when q =0.50, the median is obtained. For the skewed population considered in this study, the median provides a more appropriate measure of central tendency for decision-making on product lifetime than the population mean. Hence, median-based sampling schemes for half logistic distribution are extra economical, with respect to required size of sample, than schemes depending on the mean of the population. Suppose μ denote the true median lifetime of a commodity and μ_0 represent the mentioned median, assuming that the lifetime is distributed as half logistic distribution. Depending on the observed failure details, the hypotheses to be tested are $H_0 : \mu \geq \mu_0$ against $H_1 : \mu < \mu_0$. A lot is regarded as favorable if $\mu \geq \mu_0$ and as unfavorable if $\mu < \mu_0$. This hypothesis is tested using the group acceptance sampling scheme as:

1. Select the count of groups g and assign a fixed number of r objects to every group, such that the total size of lot is $n = g.r$.

2. Select the acceptance number c for a group and the experiment time t_0.

3. Conduct life test simultaneously on all g groups and note the count of failures in every group..

4. Accept lot if the count of failures in every group does not exceed c.

5. Terminate the test and refuse the lot if greater than c failures exist in any of the groups.

We aim to determine the required count of groups g for the half logistic distribution for different values of the acceptance count c, assuming that the size of the group r and the test termination time instant t_0 are predetermined. For convenience, the termination time instant is taken as product of the mentioned median μ_0; thus, we set $t_0 = \delta\mu_0$, where δ is a fixed termination ratio. The probability (α) of rejecting a good lot is called the producer's risk, whereas the probability (β) of accepting a bad lot is known as the consumer's risk. The parameter value g of the proposed sampling plan is determined

Table 1: Minimum number of groups(g) for the proposed plan in the case of HLD

β	r	c	δ					
			0.7	0.8	1.0	1.2	1.5	2.0
0.25	2	0	2	2	1	1	1	1
0.25	3	1	4	3	2	2	1	1
0.25	4	2	9	7	4	3	2	1
0.25	5	3	22	14	7	4	3	2
0.25	6	4	50	29	12	7	3	2
0.25	7	5	119	61	22	10	5	2
0.10	4	0	2	2	1	1	1	1
0.10	5	1	3	2	2	2	1	1
0.10	6	2	5	4	3	2	1	1
0.10	7	3	9	7	4	3	2	1
0.10	8	4	18	11	6	3	2	1
0.10	9	5	34	19	8	5	3	1
0.05	5	0	2	2	1	1	1	1
0.05	6	1	3	2	2	2	1	1
0.05	7	2	5	4	3	2	1	1
0.05	8	3	8	6	3	2	2	1
0.05	9	4	14	9	5	3	2	1
0.05	10	5	25	15	7	4	2	1
0.01	7	0	2	2	1	1	1	1
0.01	8	1	3	2	2	2	1	1
0.01	9	2	4	3	2	2	1	1
0.01	10	3	7	5	3	2	2	1
0.01	11	4	10	7	4	3	2	1
0.01	12	5	16	10	5	3	2	1

for ensuring the consumer's risk β. Often, the consumer's risk β is expressed by the consumer's confidence level. If the confidence level is p^*, then the consumer's risk will be $\beta = 1 - p^*$. We will determine the number of groups g in the proposed sampling plan so that the consumer's risk does not exceed a given value β.

When the lot size is sufficiently huge, binomial distribution might be utilized to establish the GASP. Under this plan, a lot is approved only if no more than c failures are noted in every group. Therefore, the probability of approving a lot is stated by

$$\left(\sum_{\mathrm{i}=0}^{\mathrm{c}} \binom{\mathrm{r}}{\mathrm{i}} \mathrm{p}_0^{\mathrm{i}} (1-\mathrm{p}_0)^{\mathrm{r}-\mathrm{i}}\right)^{\mathrm{g}} \leq \beta$$

here $p_0 = F_t(\delta_0)$ denotes the probability that an object is inadequate prior to termination time $t = \delta t_q^0$. For brevity, only selected results corresponding to small sample sizes are presented for β= 0.25, 0.10, 0.05, 0.01; group sizes $r = 2, ..., 7$; acceptance numbers $c = 0, ..., 5$; and termination ratios δ= 0.7, 0.8, 1.0, 1.2, 1.5, 2.0 in Table 1.

3 OC (Operating Characteristic) of the Sampling scheme

The probability of accepting a lot might be expressed as a function of the deviation between the stated median valueμ_0 and the true median μ. This function is known as the OC (operating characteristic) function of the sampling scheme. After determining the least required count g groups, it is often of interest to evaluate the probability of accepting a lot if the quality is taken as satisfactory, that is, when $\mu \geq \mu_0$ or $\frac{\mu}{\mu_0}$. The OC function is stated by

$$L(p) = \left(\sum_{i=0}^{c} \binom{r}{i} p^{i}(1-p)^{r-i}\right)^{g}$$

Using above equation, the OC values can be obtained for any sampling plan. To save space we present the OC values for sampling plans with $\frac{\mu}{\mu_0}$= 2, 4, 6, 8, 10, 12; β=0.25, 010, 0.05, 0.01; δ=0.7, 0.8, 1.0, 1.2, 1.5, 2.0; r=4, 6, 7, 9; are given in Table 2.

Table 2: OC numbers to the group sampling scheme for half logistic distribution

β	r	g	δ	$\frac{\mu}{\mu_0}$					
				2	4	6	8	10	12
0.25	4	9	0.7	0.9907	0.9996	0.9999	0.9999	1.0000	1.0000
0.25	4	7	0.8	0.9639	0.9962	0.9994	0.9999	0.9999	0.9999
0.25	4	4	1.0	0.8095	0.9316	0.9744	0.9893	0.9950	0.9975
0.25	4	3	1.2	0.6814	0.8262	0.9085	0.9491	0.9700	0.9813
0.25	4	2	1.5	0.5142	0.6292	0.7385	0.8129	0.8627	0.8967
0.25	4	1	2.0	0.3125	0.3394	0.4169	0.4887	0.5495	0.6003
0.10	6	5	0.7	0.9260	0.9879	0.9974	0.9993	0.9997	0.9999
0.10	6	4	0.8	0.8502	0.9588	0.9868	0.9950	0.9978	0.9990
0.10	6	3	1.0	0.7117	0.8663	0.9361	0.9668	0.9812	0.9889
0.10	6	2	1.2	0.5335	0.6886	0.7970	0.8627	0.9034	0.9297
0.10	6	1	1.5	0.3030	0.3910	0.4887	0.5675	0.6294	0.6786
0.10	6	1	2.0	0.3125	0.3394	0.4169	0.4887	0.5495	0.6003
0.05	7	5	0.7	0.9260	0.9879	0.9974	0.9993	0.9997	0.9999
0.05	7	4	0.8	0.8502	0.9588	0.9868	0.9950	0.9978	0.9990
0.05	7	3	1.0	0.7117	0.8663	0.9361	0.9668	0.9812	0.9889
0.05	7	2	1.2	0.5335	0.6886	0.7970	0.8627	0.9034	0.9297
0.05	7	1	1.5	0.3030	0.3910	0.4887	0.5675	0.6294	0.6786
0.05	7	1	2.0	0.3125	0.3394	0.4169	0.4887	0.5495	0.6003
0.01	9	4	0.7	0.8754	0.9708	0.9915	0.9970	0.9987	0.9994
0.01	9	3	0.8	0.7593	0.9086	0.9612	0.9813	0.9901	0.9944
0.01	9	2	1.0	0.5636	0.7385	0.8402	0.8967	0.9297	0.9502
0.01	9	2	1.2	0.5335	0.6886	0.7970	0.8627	0.9034	0.9297
0.01	9	1	1.5	0.3030	0.3910	0.4887	0.5675	0.6294	0.6786
0.01	9	1	2.0	0.3125	0.3394	0.4169	0.4887	0.5495	0.6003

4 Producer's Risk

The manufacturer is often curious in improving the quality level of the object such that the probability of lot acceptance exceeds a stated degree. For a stated manufacturer's risk γ, the least acceptable ratio might be determined by fulfilling the mentioned below inequality:

$$\left(\sum_{i=0}^{c}\binom{r}{i}p^{i}(1-p)^{r-i}\right)^{g} \geq 1-\gamma$$

To conserve space, only the least value of the ratio $\frac{\mu}{\mu_0}$=2, assuming a half-logistic distribution, is reported. These values are obtained using the sampling schemes listed in Table 1 and correspond to a manufacturer's risk level of $\gamma = 0.05$. The results are submitted in Table 3.

Table 3: Least ratio of the numbers of true median and stated median for the manufacturer's risk of $\gamma = 0.05$ with respect to HLD

β	r	c	δ					
			0.7	0.8	1.0	1.2	1.5	2.0
0.25	2	0	30.1766	34.4876	21.6895	26.0275	32.5343	43.3780
0.25	3	1	5.7590	5.6822	5.7696	6.9234	6.0504	8.0671
0.25	4	2	3.3035	3.4600	3.5563	3.8555	4.1715	4.3266
0.25	5	3	2.5146	2.5509	2.6497	2.7311	3.1535	3.7543
0.25	6	4	2.0854	2.1220	2.1908	2.3335	2.4059	2.9172
0.25	7	5	1.8471	1.8731	1.9439	2.0121	2.2001	2.4391
0.10	4	0	60.1629	68.7575	43.1095	51.7315	64.6642	86.2189
0.10	5	1	8.9363	8.2679	7.1722	12.4018	10.7582	14.3442
0.10	6	2	4.4942	4.7414	5.3420	5.5284	5.3375	7.1166
0.10	7	3	3.1396	3.3487	3.5821	3.9627	4.4093	4.7922
0.10	8	4	2.5459	2.6067	2.8389	2.8977	3.2864	3.6900
0.10	9	5	2.1685	2.2215	2.3506	2.5700	2.8962	3.0544
0.05	5	0	75.1555	85.8921	53.8191	64.5828	80.7285	107.8380
0.05	6	1	10.9045	10.0806	12.6008	15.1209	13.0928	17.4570
0.05	7	2	5.3819	6.9579	6.3897	6.6057	6.3640	8.4852
0.05	8	3	3.5858	3.7832	3.8870	4.1479	5.1849	5.6239
0.05	9	4	2.8058	2.9012	3.1663	3.3672	3.8156	4.2769
0.05	10	5	2.3623	2.4489	2.6371	2.8272	3.0586	3.5055
0.01	7	0	105.1480	120.1620	75.2377	90.8520	112.8565	150.4753
0.01	8	1	14.8320	13.6974	17.1217	20.5400	17.7492	23.6655
0.01	9	2	6.5908	6.7785	7.2894	8.7473	8.4027	11.2036
0.01	10	3	4.4968	4.6735	5.0450	5.3756	6.7196	7.2675
0.01	11	4	3.3269	3.5007	3.8341	4.2929	4.8576	5.4309
0.01	12	5	2.7369	2.8520	3.1007	3.3466	3.8368	4.3874

5 Tables and Examples

The model parameters of the sampling scheme of group acceptance for several numbers of the consumer's risk and test termination time multiplier are presented in Table 1. It should be acknowledged that the least required size of sample might be acquired as n = $r \times g$, here r is the size of the group and g is number of groups. Table 1 shows that, for a stipulated size of the group, an increase in the test termination time multiplier δ generally causes a decrease in required count of groups g. That is, fewer groups are needed as the termination time increases. For example, when β=0.01, r = 6, c = 2, increasing δ from 0.70 to 0.80 reduces the desired count of groups from g = 5 to g = 4. Yet, this pattern is not strictly monotonic, as it also influenced by the acceptance number c. The probability of lot acceptance at the median ratio related to the manufacturer's risk is reported in Table 2. Table 3 shows the least ratios of the true median to the stated median required for lot acceptance at a manufacturer's risk level of γ= 0.05, for various combinations of the design parameters. To illustrate the procedure, take an object whose lifetime obeys a half logistic distribution. If the objective is to develop a GASP to examine whether the median lifetime exceeds 1,000 hours, depending on a test duration of 700 hours, making use of testers that accommodate 6 objects each. Assume that the acceptance count is 2 and the consumer's risk is 0.10. This corresponds to a test termination time multiplier of 0.700. In Table 1, the least required count of groups is found to be g = 5. Consequently, a random sample consisting 30 objects is selected and allocated equally, with 6 objects assigned to every group of the 5 groups, for testing over 700 hours. The lot is accepted if at most two failures occur in every group before 700 hours and the experiment is terminated as early as the third failure happens prior to the completion of the test duration. For this sampling scheme, the probability of acceptance is 0.9879 if the true median lifetime is 4,000 hours. It implies that when the actual median is four times the specified value 1,000 hours, the corresponding manufacturer's risk is 0.0121. If a manufacturer's risk of 0.05 is desired, the required median ratio can be obtained from Table 3. For instance, if r = 6, g = 5, β = 0.01, c = 2, and δ = 0.700, the minimum needed ratio is 4.4942.

6 Discussion

In this article, a sampling scheme of group acceptance based on a truncated life test is developed for objects whose lifetimes follow a half-logistic distribution. The required acceptance number and count of groups are calculated for stated values of the consumer's risk β and other parameters. The results indicate that the least count of groups needed reduces as the test termination time multiplier rises. In addition, the OC function rises quickly as product quality enhances, demonstrating a disproportionate increase in the probability of lot acceptance with higher quality stages. The proposed GASP is particularly suitable for situations in which multiple items can be tested simultaneously. The use of such group testers offers clear advantages in terms of reduced testing time and lower testing costs, making the proposed plan practical and efficient for industrial applications.

Acknowledgments

The authors thank the editorial office and the reviewers for their helpful suggestions, comments and encouragement, which helped in improving the final version of the paper.

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Appendix

```
/* C-program to generate minimum number of groups */
#include<stdio.h> #include<math.h> #include<conio.h>
main()
{
int i=0,g=0,n,c=0;
longdouble nft,ift,nift,nci;
longdouble fact(longint l);
float p,q=0.50,temp,sum,value,d=0.7;
while(c<=5)
{
n=c+2;
clrscr();
temp=exp(-d*log((1+q)/(1-q)));
p=(1-temp)/(1+temp);
printf("\np=%f",p);
do
{ i=0;
sum=0;
while(i<=c)
{
nft=fact(n);
ift=fact(i);
nift=fact(n-i); nci=nft/(ift*nift);
value=nci*pow(p,i)*pow((1-p),n-i);
sum+=value;
i++;
}
if(pow(sum,g)>0.25) printf("\ng=%d",g);
g++;
}
while(pow(sum,g)>0.25);
printf("\ng=%d",g);
c++;
getch();
}
}
```

```
longdouble fact(longint l)
{
int k=1;
longdoublelfact=1;
for(;k<=l;k++)
lfact*=k; return(lfact);
}
```

```
/* C-program to generate OC values */
#include<stdio.h> #include<math.h> #include<conio.h>
main()
{
int i,c=2,n=4,g;
longdouble nft,ift,nift,nci;
longdouble fact(longint l);
float k,p,q=0.5,incr=2,d,temp,sum,value,dvalue;
printf("\nenterthevalueofganddvalue:");
scanf("%d%f",&g,&dvalue);
while(incr<=12)
{
sum=0; i=0;
d=dvalue/incr;
while(i<=c)
{
temp=exp(-d*log((1+q)/(1-q)));
p=pow((1-temp)/(1+temp),d); printf("\np=%f",p); nft=fact(n);
ift=fact(i); nift=fact(n-i); nci=nft/(ift*nift);
value=nci*pow(p,i)*pow((1-p),n-i);
sum+=value;
printf("\sum=%f",sum); i++;
}
sum=pow(sum,g);
printf("\n d=%f,p=%f, sum=%f",d,p,1-sum); incr=incr+2;
}
}
longdoublefact(longintl)
{
int k=1;
longdoublelfact=1;
for(;k<=l;k++)
lfact*=k; return(lfact);
}
```

```
/* C-program to generate minimum ratios for manufacturer's risk */
#include<stdio.h> #include<math.h> #include<conio.h>
main()
{
inti,n=12,c=5,g;
longdouble nft,ift,nift,nci;
longdouble fact(longint l);
float dvalue,p,q=0.50,incr=1,d,temp,sum,value;
printf("\n enter the values of g,dvalue:");
scanf("%d %f",&g,&dvalue);
do
{
sum=0; i=0;
d=dvalue/incr; while(i<=c)
{
temp=exp(-d*log((1+q)/(1-q)));
p=(1-temp)/(1+temp);
ift=fact(i);
nift=fact(n-i);
nci=nft/(ift*nift);
value=nci*pow(p,i)*pow((1-p),n-i);
sum+=value;
i++;
}
incr=incr+0.0001;
}
while(pow(sum,g)<=0.95);
printf("\nincr=%f",incr);
}
longdouble fact(longint l)
{
intk=1;
longdoublelfact=1;
for(;k<=l;k++)
lfact*=k; return(lfact);
}
```