A Study on Designing Acceptance Sampling Plans based on truncated life tests under Log-Logistic distribution using Minimum Angle Method

Thesis submitted in

Partial Fulfillment of the

Degree of Master of Philosophy (M.Phil)

By

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July 2019

DECLARATION

I declare that the dissertation entitled **A Study on Designing Acceptance Sampling Plans based on truncated life tests under Log-Logistic distribution using Minimum Angle Method** submitted by me for the degree of Master of Philosophy (M.phil.) is the record of work carried out by me during the period from August 2018 to July 2019 under the guidance of **Dr. (Tmt) A. R. Sudamani Ramaswamy** Professor, Department of Mathematics, Avinashilingam Institute for Home Science and Higher Education for women, Coimbatore, and has not formed the basis for the award of any Degree, Diploma, Associateship, Fellowship, Titles in this University or any other University or other similar institution of Higher Learning.

Signature of the Candidate

CERTIFICATE

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P. Jeyalakshmi 31.7.19

Signature of the

Head of the Department

31/7/19

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ACKNOWLEDGEMENT

Every work on its backdrop has the blessing of **LORD ALMIGHTY**. Therefore I submit my reverential gratitude at the feet of Lord Almighty

I am grateful to **Dr. P. R. KRISHNAKUMAR,** Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for providing all facilities necessary for the study.

My special debt of gratitude to **Dr. PREMAVATHY VIJAYAN,** Vice Chancellor, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for providing the opportunity and exposure to the world of knowledge.

My special thanks to **Dr. S. KOWSALYA,** Registrar, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for administrative support and for providing adequate help required to carry out the work.

I express my deep sense of gratitude to **Dr. G. P. JEYANTHI,** Director (Research and Consultancy), Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her commendable advice and guidance in each and every process involved in doing the research work in a successful manner.

My sincere thanks to **Dr. K. UDAYA CHANDRIKA,** Professor, Department of Mathematics, Dean, School of Physical Sciences and Computational Sciences, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for her guidance and affectionate support, expert suggestions throughout the project.

I express my heartfelt thanks to **Dr. P. JEYALAKSHMI,** Professor and Head, Department of Mathematics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her support and guidance during the course of the investigation.

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I express my heart-felt thanks and sincere gratitude to my guide **Dr. (Tmt.) A. R. SUDAMANI RAMASWAMY,** Professor, Department of Mathematics, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for her guidance, lively discussion, her patience, and sacrifice for the successful completion of my thesis, enthusiastic support given throughout my research period. I render my indebtedness and great deal of heartfelt appreciation to my beloved guide for her keen interest, benevolent concern and untiring efforts without which this work would not have been shaped up and completed at all.

I am thankful to all the staff members of the Department of Mathematics who rendered their help whenever required.

I owe my special thanks to my **BELOVED PARENTS, LOVING HUSBAND, BROTHER, FRIENDS** and **WELL-WISHERS,** who helped me by providing full strength, support and encouragement to complete my project successfully.

CONTENT

ABSTRACT

This dissertation is devoted to the study of truncated life test through acceptance sampling procedures using minimum angle method.

The first chapter describes the basic concepts of quality control, acceptance sampling, reliability, life testing, notations and symbols and review of literature.

In chapter-2 Single Sampling plans for truncated life test is considered. A new approach of designing single sampling plans for truncated life test using minimum angle method, is proposed when the life time distribution follows Log-Logistic distribution. The test termination time and mean ratio time are specified. The acceptance number is also specified. The design parameter is obtained such that it satisfies both producer's risk and consumer's risk simultaneously. The table of design parameter are provided for easy selection of the plan parameter. The results are analyzed with the help of table and examples.

In chapter-3 Special purpose Double sampling plan of type DSP (0, 1) Sampling plans for truncated life test is considered. A new approach of designing special purpose double sampling plan of type DSP (0, 1) sampling plans for truncated life test using minimum angle method, is proposed when the life time distribution follows Log-Logistic distribution. The test termination time and mean ratio time are specified. The acceptance numbers are specified as $c = 0$ and $c = 1$. The design parameter is obtained such that it satisfies both producer's risk and consumer's risk simultaneously. The table of design parameter are provided for easy selection of the plan parameter. The results are analyzed with the help of table and examples.

In chapter-4 Chain Sampling plans for truncated life test is considered. A new approach of designing chain sampling plans for truncated life test using minimum angle method, is proposed when the life time distribution follows Log-Logistic distribution. The test termination time, mean ratio time and number of preceding sample i are specified. The design parameter is obtained such that it satisfies both producer's risk and consumer's risk simultaneously. The table of design parameter are provided for

easy selection of the plan parameter. The results are analyzed with the help of table and examples.

In chapter-5 Group Sampling plans for truncated life test is considered. A new approach of designing group acceptance sampling plan for a truncated life test is proposed when the life time distribution follows Log-Logistic distribution. Minimum angle method is applied to determine the design parameter group size g by satisfying both the risks at the specified quality levels simultaneously. Table of design parameters are provided the results are explained with example.

CHAPTER - 1

INTRODUCTION

Reliability study plays a vital role in the quality control analysis. On the basis of this study, an experimenter can save his time and cost to reach result which is to accept the submitted lot or to reject it. If the genuine products are rejected on the basis of sample information, this error is called Type-I error and it is denoted by α. On the other hand, if the genuine products are not accepted by the consumer, this error is Type-II error and it is denoted by β. If a decision to accept or reject the lot are subjected to the risks associated with the two types of errors, this procedure is termed as reliability test plan or acceptance sampling plan based on life test. Acceptance sampling is concerned with inspection and decision making regarding lots of product and constitutes one of the oldest techniques in quality assurance. In the 1930s and 1940s acceptance sampling was one of the major components in the field of statistical quality control and was used primarily for incoming or receiving inspection.

The probability that a device will function over a specified time period or amount of usage at a stated condition is termed as reliability. A typical application of reliability acceptance sampling is as follows :

A company receives a shipment of products from a vendor. This product is often a component or raw material used in the company's manufacturing process. A sample is taken from the lot, and some quality characteristic of the units in the sample is inspected for a specified period of time. On the basis of the information in this sample, a decision is made regarding the lot's disposition. Usually, this decision is either to accept or to reject the lot. Accepted lots are put into production, rejected lots may be returned to the vendor or may be subjected to some other lot disposition action.

This chapter comprises of sections that consist of basic concepts and review of sampling plans which are relevant to this thesis and enumerated as:

1.1 Basic concepts of quality control

1.2 Basic concepts of acceptance sampling

1.3 Basic concepts of reliability

1.4 Life time distribution

1.5 Notations and symbols

1.6 Review of literature

1.7 Methodology

SECTION 1.1

BASIC CONCEPTS OF QUALITY CONTROL

1.1.1 Introduction

Quality control is a process by which entities review the quality of all factors involved in production. The reputation of companies depends upon the high reliability of their products. These companies compete with each other on the basis of quality and reliability. Thus quality control has become one of the most important tools to differentiate between competitive enterprises in a global business market. In order to control the quality of the purchased goods, two major alternatives are open to a buyer. One is the complete inspection, in which every single item in the lot is inspected and tested. This is often impractical, uneconomical or impossible. Secondly, the partial inspection in which a sample of the item is taken for inspection and testing and the whole lot is accepted or rejected depending on whether a few or many defective items are found in the sample.

Quality Control is the use of techniques and activities to achieve, sustain, and improve the quality of a product or service. It involves integrating the following related techniques and activities such as specifications of what is needed, design of the product or service to meet the specifications, production or installation to meet the full intent of the specifications, inspection to determine conformance to specifications and review of usage to provide information for the revision of specifications, if needed.

Quality control and management is not very complex at this time, but the craftsman's design of the product to meet the best of his customer's need is very important. The importance of Quality control lies in the following benefits likely to be realized by an effective quality assurance program.

- Improving the quality of product and services
- Increasing productivity
- Reducing tangible and intangible costs
- Reducing production and delivery lead times
- Improving the marketability of products and services
- Reducing the prices of products and services to customers
- Detecting the assignable causes and elevating its effects

1.1.2 Quality Control

Quality Control may generally be defined as a system that is used to maintain a desired level of quality in a product or service. This task may be achieved through different measures such as planning, design, use of proper equipment and procedures, inspection, and taking corrective action in case a deviation is observed between the products, service or process output and a specified standard. This general process may be divided into the three main sub processes namely, off-line quality control, statistical process control and acceptance sampling plans.

- An off-line quality control procedure deals with measures to select and choose controllable product and process parameters in such a way that the deviation between the products or process output and the standard will be minimized.
- Statistical Process Control involves comparing the output of a product or service with a standard and taking remedial actions in case of a discrepancy between the two. It also involves determining whether a process can produce a product that meets the desired specifications or requirements.
- Acceptance sampling deals with the inspection of the product or service. When 100 percent inspection of all items is not feasible, a decision has to be made on how many items should be sampled or whether the batch should be sampled at all. The information obtained from the sample is used to decide whether to accept or reject the entire batch, A plan that determines the number of items to be sampled and the acceptance

criteria of the lot, based on meeting certain stipulated conditions is known as an acceptance sampling plan.

1.1.3 Quality Improvement

Quality improvement is defined as the reduction of variability in process and product where variations are measured by statistical methods. An efficient quality improvement program can be instrumental in increasing productivity at a reduced cost. As a result of increasing customer quality requirements and development of new product technology, many existing quality assurance practices and techniques need modifications. The need for statistical and analytical techniques in quality assurance is rapidly increasing owing to stiff competition in the industry. To improve the quality of products and services, it is customary to modernize the quality practices and simultaneously reduce the cost of quality. The three important factors that affect the quality of a product are

- Quality of design
- Quality of conformance
- Quality of performance

Quality of Design

The quality of design of a product is concerned with the tightness of the specifications for manufacturing the product. A good quality of design must ensure consistent performance over its stipulated life span stated in terms of rated output, efficiency, and overload capacity, continued or intermittent operation for specified application or service. It should also consider the possible modes of failure due to stress, wear, distortion, corrosion, shocks, vibrations, high or low temperature, altitude or pressure, environmental conditions etc. However product design and development is a continuous process which results in the evaluation of a product, based on assessed user needs, their feedback after use and development in technology at a given point of time, in a given environment.

Factors controlling quality of design

- The most important factor that controls the quality of design is the type of customers in the market. This can be analyzed in detail with the help of a market survey. A market survey is the study of three main factors; the first and particularly important one is the consuming habits of people. Secondly it is the prices they are willing to pay for various products and services. Third is the choice of design of the product which means the needs of the customers. Thus the quality of the design depends upon the type of customers to provide the intended function with the greatest overall economy.
- In case of capital goods, the decision is usually governed by such considerations as environmental conditions, reliability, importance of continuity of service, maintainability etc.
- Profit is an important factor for the producers. Thus considering profit as a factor is very essential for a company to succeed monetarily. It is very difficult for a company to give 100 percent quality products and in quality control 100 percent quality from a company is also not essential. Instead a market segment to which the management desires to cater should be considered. Profit can be maximized by producing products in different grades to suit different types of customers.
- Environmental conditions also play an important role in deciding the quality of a design. A high end car model that can perform extremely well in a normal temperature and normal conditions cannot give the same performance in different temperatures and conditions.
- Another factor is the special importance of the product. Greater the requirements for strength, fatigue resistance, life interchange ability of the manufacture of an item, closer should be the tolerances to give better quality goods.

Quality of Conformance

The quality of conformance means comparing the manufactured product with the quality design to see how well the manufactured product conforms to the quality of design. It is responsible for production, planning and manufacturing to obtain a high level of quality of conformity when a design is established.

Factors controlling quality of conformance

For good quality of conformance with the design, an organization should ensure the following :

- Incoming raw materials are adequate.
- Machines / tools for the job and the measuring instruments are adequate.
- Proper selection of the process and process control
- Operators should be well trained, experienced and motivated.
- Proper storage for finished goods.
- Proper inspection program
- Obtaining feedback from both the internal inspection and the customers for taking corrective action.
- Quality control techniques should be used to control variability in manufacturing process.
- Higher quality of design usually costs more, higher quality of conformance usually costs less, by reducing the number of defective products produced.

1.1.4 Objectives of quality control

- A proper quality control aims to improve the income of the producers by making the product more acceptable in the market. It tries to fulfill the consumer's needs by providing the product a long life, greater usefulness, aesthetic aspects, maintainability etc.
- It tries to reduce the company's purchasing cost by reducing the losses due to defects.
- The aim of quality control is to achieve interchange ability of manufacture in large scale production.
- It helps to produce optimum quality at minimum price.
- It ensures satisfaction of customers with products or services of high quality level, to build customer's goodwill, confidence and reputation of manufacturer.
- It ensures quality control at proper stages by proper inspection to make sure that non – defective products are produced.
- It judges the conformity of the process to the established standards and takes suitable action when there are deviations.
- It improves quality and productivity by process control, experimentation and customer's feedback.
- It develops procedure for good vendor – vendee relations.
- It develops quality consciousness in the organization.

1.1.5 Costs of Quality

Every company has to satisfy the quality needs of their customers. The cost that a company spends for carrying out the quality functions is known as costs of quality. This includes

- Market survey cost to discover the quality needs of the customers.
- Product research and development costs.
- Design costs of translating the product concept into information which permits planning for manufacture.

- Cost of manufacturing planning in order to meet required quality specifications.
- Cost of inspection and test.
- Cost of defect prevention.
- Cost of scrap, quality failures.
- Cost of quality assurance.
- Cost for field service and such other factors attributed to the quality improvement.

According to the American Society for Quality Control(1987), the quality costs is defined in four categories

- **Cost of Prevention** : It consists of the cost associated with personnel engaged in designing, implementing, and maintaining the quality system. This includes the cost associated with creating overall quality planning, cost of preparation of manuals and procedures needed to communicate these plans, cost associated with implementing quality plans, cost for preparing training programs on quality performance, cost associated with preventing recurring defects, cost of the investigation, analysis and correction of causes of defects by quality control department and engineering department and finally the cost of cost consciousness programs.
- **Cost of Appraisal** : The costs associated with the measuring, evaluating or auditing of products, components and purchased materials to assure conformance with quality standards and performance requirements are called cost of appraisal. This includes the cost of receiving or incoming, laboratory acceptance testing, checking labour, set up for inspection and test materials, maintenance and calibration of test and inspection equipments, quality audits, review of test and inspection data and evaluation of field stock and spare parts.
- **Cost of Internal Failures** : The cost associated with defective products, components, and materials that fail to meet quality requirements and result in manufacturing losses are called as costs of internal failures. This includes the cost associated with scrap, cost of rework and repair, cost of re-inspection and retest after the defective parts are repaired, cost

associated with material review activity, cost to ensure whether non – conforming products are usable for some other work and the costs of process yield lower than the yield that might be attainable by improving controls.

- **Costs of External Failures** : It consists of the costs which are generated because of defective products being shipped to the customers. This includes the cost of processing complaints from the customers, cost of service to the customers who receive defective items, cost of inspecting and repairing the defective items returned by the customers, cost of replacing the defective materials or products, cost of concession made to the customers due to substandard products being accepted by them.

1.1.6 Statistical Quality control

Whenever a statistical technique is employed to control, improve and maintain quality or to solve quality problem it is termed as Statistical Quality Control. The new era of quality control development began during World War II when statistical quality control was much needed due to mass production. It is used throughout the quality system at various stages of production such as

- Incoming inspection
- Product moving from one stage to other
- In -process
- Machine start-up
- Process monitoring
- Process adjustment
- Final product
- Field surveillance

Statistical quality control is systematic as compared to the guess-work of haphazard process inspection, and also the mathematical and statistical approach neutralizes personal bias and uncovers poor judgment. Statistical quality control consists of three general activities

- Systematic collection and graphic recording of accurate data.
- Analyzing the data.

- Practical engineering / management or management action, if the information obtained indicates significant deviations from the specified limits.

Statistical quality control plays an important role in total quality control. The following are the statistical tools used generally for the purpose of exercising control, improvement of quality, enhancement of productivity, creation of consumer confidence and development of the industrial economy of the country.

- **Frequency distribution** : It is a tabulation or tally of the number of times a given quality characteristic occurs within the samples. Graphic representation of frequency distribution will show the average quality, spread of quality, comparison with specific requirements and process capability.
- **Control Chart** : It is a graphical representation of quality characteristics, which indicates whether the process is under control or not.
- **Acceptance sampling** : It is a popular quality control technique that is applied to discrete lots or batches of product. The term lot refers to a collection of physical units; the term batch is usually applied to chemical materials. The lot or batch should be presented to the inspection department by either a supplier or a production department. The inspection department then inspects a sample from the lot or batch and, based on the results of the inspection, determines the acceptability of the lot or batch.
- **Analysis of the data** : This includes techniques such as analysis of tolerances, correlation, analysis of variances, analysis for engineering design to eliminate cause of troubles.

1.1.7 Advantages of Statistical Quality Control

- Statistical quality control ensures rapid and efficient inspection at a minimum cost

- It finds out the cause of excessive variability in manufactured products by forecasting trouble before rejections occur and reducing the amount of spoiled work.
- It exerts more effective pressure for quality improvement than that of a 100 percent inspection.
- It easily detects faults. For example using control charts one can easily examine the deterioration in quality by examining whether the points fall above the upper control limits or below the lower control limits.
- So long as the statistical control continues, specifications can be accurately predicted for the future, by which it is possible to assess whether the production processes are capable of producing the products with the given set of specifications.
- Increases output and reduces wasted machines and materials resulting in higher productivity.
- Better customer relations through general improvement in product and higher share of the market.
- It provides a common language that may be used by designers, production personnel and inspectors.
- Elimination of bottlenecks in the process of manufacturing.
- It says when and where 100 percent inspection is required.
- Creates quality awareness in employees.

SECTION 1.2

BASIC CONCEPTS OF ACCEPTANCE SAMPLING

1.2.1 Introduction

Acceptance sampling procedure is an essential tool in statistical quality control. It is a methodology that deals with quality contracting on product order between the producers and consumers thus allowing the producers to take the decision to accept or reject the manufactured products based on the inspection of samples. Acceptance sampling is necessary to limit the cost of inspection and is the only available method to appraise the quality in destructive testing. Acceptance sampling itself does not improve quality, but whenever the lot is rejected it indicates the instability of the production process. Acceptance sampling is cost efficient and the only admissible method of efficient tests with quick results.

1.2.2 Importance of Acceptance Sampling

Acceptance sampling is one of the latest aspects of quality assurance and used primarily for the incoming and outgoing lot by lot quality assurance. The most effective use of acceptance sampling is not to “inspect quality into the product,” but rather as an audit tool to ensure that the output of a process conforms to requirements.

According to Ducan (1986), an acceptance sampling plan is likely to be implemented

- When the cost of inspection is high and the loss arising from the passing of a non conforming unit is not great; it is also possible in some cases that no inspection at all will be the cheapest plan.
- When 100 percent inspection is fatiguing, a carefully worked out sampling plan will produce good or better results. The 100 percent may

not mean 100 percent perfect quality, and the percentage of non conforming items passed may be higher than under a scientifically designed sampling plan.

- When inspection is destructive i.e., a situation where inspection is not possible without destroying the article chemically or physically.
- When there are great quantities or areas to be inspected.
- When it is desired to stimulate the maker and/or the buyer.

1.2.3 Major Areas of Acceptance Sampling

According to Dodge (1959), the major areas of acceptance sampling are

- Lot-by-Lot sampling by the method of attributes, in which each unit in a sample is inspected on a go-not-go basis for one or more characteristics.
- Lot-by-Lot sampling by the method of variables, in which each unit in a sample is measured for a single characteristic such as weight or strength.
- Continuous sampling of a flow of units by the method of attributes, and
- Special purpose plans including chain sampling, skip-lot sampling, small sample plans, repetitive group sampling plans etc.

1.2.4 Basic Terminologies and Notations

Sampling Plan

According to the American National Standards Institute / American Society for Quality Control (ANSI / ASQC) Standard A2 (1987), an acceptance sampling plan is a specific plan that states the sampling rules to be used with the associated acceptance and non acceptance criteria.

Sampling Scheme

According to the American National Standards Institute / American Society for Quality Control (ANSI / ASQC) Standard A2 (1987), a sampling scheme is a specific set of procedures which usually consists of acceptance sampling plans in which lot sizes, sample sizes and acceptance criteria, or the amount of 100 percent inspection and sampling are related. Hill (1962), has also described the difference between sampling plans and the sampling scheme.

According to him, a sampling scheme is a whole set of sampling plans and operations included in the standard over-all strategy specifying the way in which sampling plans are to be used.

Sampling System

A sampling system can be described as an assigned grouping of two or more sampling plans with the rules for using these plans for sentencing lots to achieve a blend of the advantageous features of each of the sampling plans. Tightened – Normal – Tightened scheme is an example for sampling scheme.

ANSY ASQ Z1.4 – 1993

The International organization adopts a single sampling plan and acceptance level for Standardization and designed International Standard IS01 DIS-2859 and MIL-STD-105E**.** While MIL-STD-105E was developed for government procurement, it has become the standard for attribute inspection for the industry. It is the most widely used acceptance-sampling plan in the world. The American Society made modifications to MIL-STD-l05E (1989), for Quality (ASQ) under the designations ANSY ASQ Z1.4.

The standard is applicable, but not limited, to attribute inspection of the following

- End items
- Components and raw materials
- Operations
- Materials in process
- Supplies in storage
- Maintenance operations
- Data or records
- Administrative procedures

Sampling plans of this standard are intended to be used for a continuing series of lots.

Cumulative and Non – Cumulative Sampling Plans

The non - cumulative sampling plan is defined as one which uses the current sample information from the process or current product entity in making decisions about the process or product quality. Single and Double sampling plans are examples of non-cumulative sampling. Cumulative results sampling inspection is one which uses the current and past information from the process in making a decision about the process. The Chain sampling plan of Dodge (1955), is an example for cumulative sampling plan.

Inspection

ANSI / ASQC Standard A2 (1987), defines the term inspection as ‘activities’, such as measuring, examining, testing, gauging one or more characteristics of a product and/or service and comparing these with specified requirements to determine conformity. A sampling scheme or sampling system may contain three types of inspections namely normal, tightened and reduced inspection.

- **Normal Inspection**: Inspection that is used in accordance with an acceptance scheme when a process is considered to be operating at its acceptance quality level or slightly better than its acceptance quality level is termed as normal inspection.
- **Tightened Inspection**: A feature of a sampling scheme using stricter acceptance criteria than those used in normal inspection is known as tightened inspection.
- **Reduced Inspection**: A feature of a sampling scheme permitting smaller sample sizes than used in normal inspection is known as reduced inspection.

Acceptance Quality Level (AQL)

The AQL is a percent defective that is the base line requirement for the quality of the producer's product. The producer would like to design a sampling plan such that there is a high probability of accepting a lot that has a defect level less than or equal to the AQL.

Lot Tolerance Percent Defective (LTPD)

The LTPD is a designated high defect level that would be unacceptable by the consumer. The consumer would like the sampling plan to have a low probability of accepting a lot with a defect level as high as the LTPD.

OC Curve

Every sampling plan is associated with an operating characteristic curve, familiarly known as OC curve of the plan. This curve when referred to two axes,, the axis of p-proportion nonconforming of the material offered for inspection and the axis of Pa(p) – probability of acceptance of a lot or process, is the locus of (p, Pa(p)). The OC curve gives the practical performance of a sampling plan.

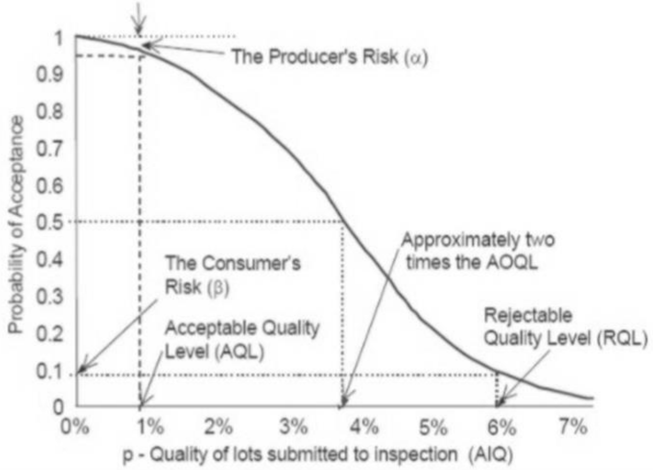

Figure 1.1 OC Curve

OC curves are generally classified as Type A and Type B OC curves. ANSI/ASSQC Standard A2 (1987), defines the two terms as follows :

- Type A OC curve for isolated or unique lots or a lot from an isolated sequence. For a given sampling plan, a type A curve shows the probability of accepting a lot as a function of the lot quality.
- Type B OC curve for a continuous stream of lots. For a given sampling plan, a type B curve shows the probability of accepting a lot as a function of the process average.

For continuous sampling plans the OC curve is a curve showing the long run percentage of the product accepted during the sampling phase(s) as a function of the quality level of the process. For special purpose plans the OC curve is a curve showing, for a specified sampling plan, the probability of continuing to permit the process to continue without adjustment as a function of the process quality.

In sampling schemes or systems, one will have a composite OC curve which gives the steady state probability of acceptance under the switching rules of the scheme or system as a function of process quality.

Under Type A situations (when sampling an attribute characteristic from a finite lot without replacement) hyper geometric distribution is exact to calculate $P_a(p)$. Under Type B situations (when sampling from the conceptually infinite output of units that the process would turn out under the same essential conditions) binomial model will be exact for the case of non conforming units to calculate $P_a(p)$. Binomial model is also exact in the case of sampling from a finite lot with replacement. Poisson model is exact in calculating $P_a(p)$ which specifies a given number of non conformities per unit (or per hundred units). Variable sampling plans use normal distribution for calculating $P_a(p)$ .Binomial, Poisson, Hyper geometric and Normal distributions are the most frequently used distributions in acceptance sampling.

Average Outgoing Quality (AOQ) and Average Outgoing Quality Level (AOQL)

ANSI/ASQC Standard A2 (1987), defines AOQ as the expected quality of outgoing product following the use of an acceptance sampling plan for a given value of incoming product quality.

AOQL is defined as the maximum AOQ over all possible levels of incoming quality.

Average Sample Number (ASN)

ANSI/ASQC Standard A2 (1987), defines ASN as the average number of sample units per lot used for making decisions (acceptance or non- acceptance). A plot of ASN against *p* is called the ASN curve.

Type I Error (Producer's Risk)

The producer's risk is the probability of rejecting a good lot which otherwise would have been accepted. The symbol α is commonly used for Type I error.

Type II Error (Consumer's Risk)

The consumer's risk is the probability of defective lots being accepted which otherwise would have been rejected. The symbol β is commonly used for Type II error.

Single sampling plan

Sampling inspection in which the decision to accept or not to accept a lot is based on the inspection of a single sample of size 'n'.

Double sampling plan

Sampling inspection in which the inspection of the first sample of size n_1 leads to a decision to accept a lot, not to accept it or to take a second sample of size n_2 and the inspection of the second sample then leads to a decision to accept or not to accept the lot.

Chain sampling plan

Sampling inspection in which the criteria for acceptance and non-acceptance of the lot depends in part on the results of the inspection of the immediately preceding lots.

Group sampling plan

Sampling inspection in which the items in a group are tested independently, identically and simultaneously on the different testers for a pre-assigned time.

1.2.4 Designing sampling plans

In designing a sampling plan, one has to accomplish a number of different purposes. According to Hamaker (1960), the important ones are :

- To strike a proper balance between the consumer's requirements, the producer's capabilities, inspector's capacity.
- To separate bad lots from good.
- Simplicity of procedures and administration.
- Economy in number of observations.
- To reduce the risk of wrong decisions with increasing lot size.
- To use accumulated sample data as a valuable source of information.
- To exert pressure on the procedure or supplier when the quality of the lots received is unreliable or not up to the standard.
- To reduce sampling when the quality is reliable and satisfactory.

He further noted that these aims are partly conflicting and all of them cannot be simultaneously realized.

The design methodologies of acceptance sampling may be categorized as follows :

	Risk Based	Economical Based
Non – Bayesian	1	2
Bayesian	3	4

Risk based sampling plans are traditional in nature, drawing upon procedure and consumer type of risks as depicted by the OC curve. Economically based sampling plans explicitly consider such factors as costs of inspections, accepting a non conforming unit and rejecting a conforming unit in an attempt to design a cost-effective plan. Bayesian plan design takes into account the past history of similar lots submitted previously for inspection purposes. Non - Bayesian plan design is not explicitly based upon the past lot history.

According to Peach (1947), the following are some of the major types of designing the plans, which are classified according to the types of protection.

- The plan is specified by requiring the OC curve to pass through (or nearly through) two fixed points. In some cases it may be possible to impose certain additional conditions. The two points generally selected are (P_1, $1-\alpha$) and (P_2, β) where
- P_1 or $P_{1-\alpha}$ – the quality level that is considered to be good so that the procedure expects lots of P_1 quality to be accepted most of the time.
- P_2 or P_β – the quality level that is considered to be poor so that theconsumer expects lots of P_2 quality to be rejected most of the time.
- α – the producer's risk of rejecting P_1 quality.
- β – the consumer's risk of accepting P_2 quality.

The tables provided by Cameron (1952), are an example for this type of designing. Schilling (1980), considered the term P_1 as the Producer's Quality Level (PQL) and P_2 as the Consumer's Quality Level (CQL). Earlier literature calls P_1 as the Acceptance Quality Level (AQL) and P_2 as the Limiting Quality Level (LQL) or Rejectable Quality Level (RQL) or Lot Tolerance Proportion Defective (LTPD). Peach (1947), have defined the ratio P_2/P_1 associated with specified values of α and β as the 'Operating Ratio'. Traditionally the values of α and β are assumed to take 0.05 and 0.10 respectively.

- The plan is specified by fixing one point only, through which the OC curve is required to pass and setting up one or more conditions, not explicitly in terms of the OC curve. Dodge and Romig (1959), LTPD tables is an example for this type of design.
- The plan is specified by imposing upon the OC curve two or more independent conditions none of which explicitly involves the OC curve. Dodge and Romig (1959), AOQL tables is an example of this type of design.

SECTION 1.3

BASIC CONCEPTS OF RELIABILITY

1.3.1 Introduction

The concept of reliability has been known for a number of years, but it has assumed greater significance and importance during the past decade, particularly due to the impact of automation, development in complex missile and space programmes. The manufacture of highly complex equipment has served to focus greater attention on reliability. However, reliability is only one of the tools of management which must be supplemented by other tools like quality control and design of experiments for the solution of problems of quality and cost. Reliability is the probability of a device performing its purpose adequately for the period of time intended under the operating conditions encountered. Reliability of a product is the measure of the ability of a product to function successfully, when required, for the period required, in the specified environment.

The study of reliability is important because it is related to the quality of a product. Reliability of a product is more important because it is common for a person to think that, what is the use of buying a product that does not satisfy the customer needs and fails within a short period. Thus the effectiveness of a system is understood to mean the suitability of the system for the fulfillment of the intended tasks and the efficiency of utilizing the means put into it. The suitability of performing definite tasks is primarily determined by the quality of the system.

1.3.2 Historical Background of Reliability

The growth and development of reliability has strong links with quality control and its developments in the first quarter of the 1900s. In the 1920s a team of workers at Bell Telephone Laboratories, developed statistical methods to solve some of their quality control problems. They provided the basis for the further developments in the area of statistical quality control (SQC). Subsequently, the American Society for Testing and Mechanical Engineers joined Bell Laboratories in popularizing the quality control techniques. However, the rate of adoption of these techniques among the enterprises was very slow till World War II broke out in 1939. The importance of reliability and quality control was born out of the demands of modern technology used in the World War II. Complexity and automation of equipments used in the war resulted in severe problems of maintenance and repair. Failures of equipments and components, particularly, electronic tubes, were more than expected. During the war the army and navy in the USA set up a joint committee known as the Vacuum Tube Development Committee in 1943 to study the failure of vacuum tubes which was considered to be one of the focal points of trouble. Quantitative techniques for reliability measurement were evolved and introduced.

During the decade following the war many research laboratories and universities initiated studies on failures of equipments and components. Bell Laboratories and Aeronautical Radio, Inc were the two leading organizations among those who contributed heavily in this area. Practicing engineers and mathematicians took interest in the study of life testing and reliability problems. The first major committee on reliability was set up by the US Department of Defence in 1950. This was later called the Advisory Group on Reliability of Electronic Equipment (AGREE). The AGREE published its first report in 1957 which included some reliability specifications such as minimum acceptability limits, reliability test equipments, etc. Since then many new organizations were formed to promote the concepts of reliability and quality among both manufacturers and users.

During the 1950s other countries such as Britain and Japan began to take keen interest in the application of reliability principles to their products. In Britain, The British Productivity Council and the Institute of Production Engineers were independently engaged in promoting quality control concepts. In 1961, the National Council for Quality and Reliability was formed with the main objective of creating an awareness of importance of achieving quality and reliability in the design, manufacture and use of products. The last two decades have seen remarkable progress in the application of reliability principles in industries and government departments in almost all developed and developing countries. Today reliability has become a catchword in many firms and is a very common term in most countries.

1.3.3 Definition of Reliability

Reliability of a unit is the probability that the unit performs its intended function adequately for a given period of time under the stated operating conditions or environment. By a unit we mean an element, a system or a part of a system.

If T is the time till the failure of the unit, then the probability that it will not fail in a given environment before time t is

$$R(t)= P(T > t)$$

Thus, reliability is always a function of time. It also depends on environmental conditions which may or may not vary with time. Since it is a probability, its numerical value is always between one and zero, i.e,

$$R(0) = 1,\ R(\infty)= 0$$

and R(t) is a non- increasing function between these limits.

1.3.4 Basic Elements of Reliability

`The reliability definition stresses five elements mainly

- Numerical value of probability.
- Statement defining successful product performance.
- Statement defining the environment in which the equipment must operate.
- Statement of the required operating time.
- The type of distribution likely to be encountered in reliability measurement.

1.3.5 Design for Reliability

Reliability design is an iterative process that begins with the specification of reliability goals consistent with cost and objectives. This requires consideration of the life-cycle costs of the system and the effect that reliability has on overall costs and system effectiveness. Once there liability goals have been established, these goals must be translate into individual component, subcomponent, and part specifications. This is not necessarily an easy task, and it generally requires a reliability block analysis.

After individual component and part requirements have been determined, various design methods can be applied in order to meet the goals. These methods include the proper selection of parts and material, stress-strength analysis, derating, simplification, identification of technologies, and use of redundancy.

Following the completion of a preliminary detailed design along with initial development and prototyping, a failure analysis may be performed to determine whether the specifications are being met and also provide a systematic approach for identifying, ranking, and eliminating failure models. This requires the use of reliability testing, including, perhaps a formalized reliability growth testing program. Once reliability goals have been achieved, verification that safety margins are also being met must be made. If either the reliability or safety goals are not met, the design process must continue, This may require reallocating reliability goals among the components if it is not possible to achieve a desired component reliability. The effect of design changes should then be verified through continued use of failure analysis and reliability testing.

Although we are considering reliability as an inherent system or component attribute that can largely be determined during design, one cannot ignore the fact that reliability is influenced throughout a product life cycle by factors external to the product itself.

1.3.6 Achievement of Reliability

There are five effective areas for the achievement of reliability of the product.

They are :

- Design
- Production
- Measurement and testing
- Maintenance
- Field operation

Design is very important than the other four areas and a greater percentage of causes of unreliability can be traced out in this area.

1.3.7 Failure Pattern

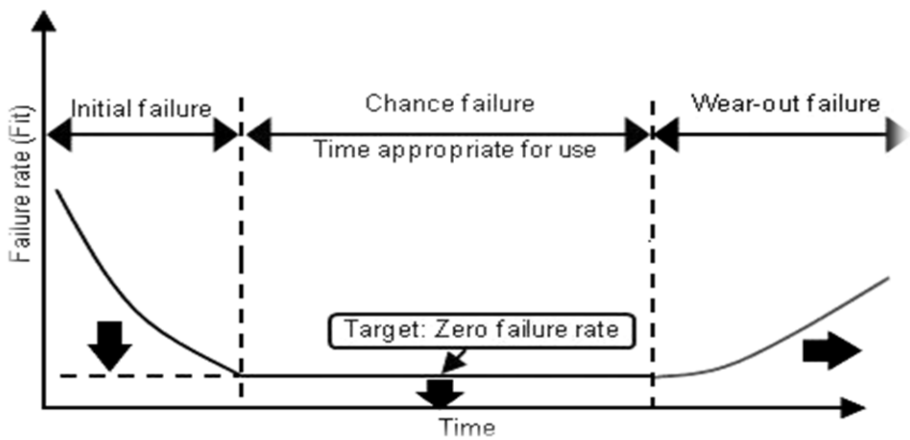

Figure 1.2 Failure Pattern

The products often follow a familiar failure pattern of failure. When the failure rate (number of failures per unit time) is plotted against a continuous time scale , the resulting chart is known as "bath tub curve". This curve exhibits three distinct zones. These zones differ from each other in frequency of failure and in the cause of failure pattern. These are as follows

- **Infant Morality Period**(Or Burn In Or The Debugging Period): This is characterized by high failure rates. It begins at the first point during manufacture that total equipment operation is possible and continues for such a period of time as permits (through maintenance and repairs), the elimination of marginal parts initially defective though not inoperative and unrecognizable as such until premature failure. Commonly, these are early failures resulting from defect in manufacturing, or other deficiencies which can be detected by debugging, running on or extended testing.

- **The constant failure rate period**: Upon replacement of all prematurely failing items, the failure rate will have reached a lower value. From this point the failure rate remains fairly constant. These are chance failures which may result from the limitations inherent in the design plus accidents caused by usage or poor maintenance or hidden defects which escape inspection. This period is the normal operating period in which the average failure rate remains fairly constant.
- **The wear out period**: These are failures due to abrasion fatigue, corrosion, vibration etc. Example, the metal becomes embrittled, the insulation dries out. A reduction in failure rate requires preventive replacement of these dying components before they result in catastrophic failure.

Many failure-causing mechanisms give rise to measured distributions of times-to-failure which approximate quite closely to a definite mathematical form, known as probability density functions. These functions provide mathematical models of failure patterns, which can be used in performance forecasting calculations.

1.3.8 Methods for improving design reliability

Improving the reliability of a product by changing the design is done by designer himself. The following are some of the approaches used by the designers working jointly with reliability engineers to improve the design.

- Review the index selected to define product reliability to make sure that it reflects customer needs.

- Question the function of the unreliable parts with a view of eliminating them entirely if the function is found to be unnecessary.
- Review the selection of any parts which are relatively new.
- Conduct a research and development program to increase the reliability of the parts which are contributing most to the unreliability of the equipments.
- Specify corrective replacement times for unreliable parts and replace the parts before they fail.
- Select the parts which will be subjected to stress which are lower than the parts can normally withstand.
- Control the operating environment so that a part will be operating under conditions which yield a lower failure rate.
- Use redundancy so that if one unit fails a redundant unit will be available to do the job.
- Consider possible trade-offs of reliability with functional performance weight or other parameters.

1.3.9 Life testing

Reliability testing refers to the tests conducted to verify that a product will work satisfactorily for a given time period. Reliability testing therefore consists of functional test, environmental test and life testing.

A functional testing involves a test to determine if the product will function at time zone. An environmental test consists of determining the expected environmental levels and then carrying the functional test under the environments under which the product has to operate.

The life of the component is the time period during which it retains its quality characteristic. Life tests are carried out to access the working life of a product, its capabilities and hence to form an idea of its quality level. The life test aims to measure the time or period during which the product will retain its desired quality characteristics. This may apply to either shelf life or life during use or both.

Life tests are carried out in different manners under different conditions as follows

- Tests under actual working conditions
- Tests under intensive conditions
- Tests under accelerated conditions

Tests under actual working conditions

This kind of test is a life test of the component under actual working conditions for full durations. This is impractical and do not lend any help in controlling a manufacturing process.

Tests under intensive conditions

Suppose if a product works one hour daily and if it is tested under actual working condition it would be operated only one hour daily and it is just a waste of days. This is impractical and time consuming. Therefore it is worked continuously at rated specifications and thus the life can be estimated in a much shorter duration of time.

Tests under accelerated conditions

These tests are conducted under severe operating conditions to quicken the product failure or break down.

1.3.10 Accelerated life tests

One obtains information on the failure time (actual failure time or an interval containing the failure time) for units that fail and lower bounds for the failure time (also known as the running time or run out time) for units that do not fail.

Accelerated life test models

Most popular accelerated life test models have the following two components

- A parametric distribution for the life of a population of units at a particular level(s) of an experimental variable or variables. It might be possible to avoid this parametric models (e.g., Weibull and lognormal) to provide important practical advantages for most applications.
- A relationship between one (or more) of the distribution parameters and the acceleration will effect that the variables like temperature, voltage, humidity and specimen or unit size will have on the failure-time distribution. This part of the accelerated life model should be based on a physical model such as one relating the accelerating variable to degradation, on a well established empirical relationship, or some combinations.

1.3.11 Acceptance sampling plans based on life tests

The sampling techniques and control charts are very important tools which analyses the data of life (destructive) tests. It is not necessary to subject all the sample pieces to destructive testing, the results in such case can be concluded from the time of first and middle failure. However, the potential capability of the product can be determined only through destructive testing.

In recent times many authors have developed tables which show, for a life test, the relationship between the sample size, probability and percent of units which will fail before their shortest life for different parametric models.

SECTION 1.4

LIFE TIME DISTRIBUTION

1.4.1 Introduction

The use of parametric distributions complements non-parametric techniques and provides the following advance s:

- Parametric models can be described concisely with just few parameters, instead of having to report an entire curve.
- It is possible to use a parametric model to extrapolate (in time) to the lower or upper tail of a distribution.
- Parametric models provide smooth estimates of failure- time distributions.

1.4.2 Log – Logistic Distribution

The Log -Logistic distribution has been studied by Shah and Dav (1963) and Tadikamalla and Johnson (1982).The cumulative distribution function of the Log -Logistic distribution is given by

$$F(t,\sigma)=\frac{\left(\frac{t}{\sigma}\right)^{\lambda}}{1+\left(\frac{t}{\sigma}\right)^{\lambda}}$$

Let us assume that the shape parameter $\lambda = 2$. If another parameters are involved, then they are assumed to be known. In quality control analysis, the scale parameter is commonly referred to as the quality parameter or characteristics parameter. Therefore it is assumed that the distribution function depends on time only through the ratio t/σ**.**

Log-Logistic distribution has been studied so many times by different authors and areas. O'Quigely and Struthers (1982) studied the Log-Logistic distribution in the case of survival analysis. Ragab and Green(1984) and Ali and Khan(1987) used the Log-Logistic distribution for the order statistics area. Balakrishnan and Malik (1987) for the linear unbiased estimation of its parameters. Kantam et al. (2006) studied An economic reliability test plan: log-logistic distribution.

SECTION 1.5

NOTATIONS AND SYMBOLS

n - Sample size

d - Number of defectives

λ - Shape parameter

c - Acceptance number

σ - Scale parameter, Mean life

t - Termination time

α - Producer's risk

β - Consumer's risk

P - Failure probability

$L(p)$ - Probability of acceptance

θ - Minimum angle

σ_0 - Specified life

t/σ_0 - Time termination ratio

σ/σ_0 - Mean ratio

g - Number of groups

r -Number of items in a group

a -Test termination time multiplier

SECTION 1.6

REVIEW OF LITERATURE

The objective of reliability acceptance sampling plans is to obtain information concerning failures in order to quantify reliability and to improve product reliability. As required by the principles of statistical inference it is necessary to specify the probability distribution of the variable quality characteristic under consideration. In the absence of such specifications, it is taken as the well known normal distribution. However, if the normal distribution is not a good fit to the data under consideration, the decision process constructed on this basis would be misleading. At the same time, an appeal to central limit theorem as a justification to normality assumption is not always valid as the sample size in quality control data is not large enough to adopt normality. In this backdrop, acceptance sampling plans based on truncated life tests for a variety of distributions was discussed by many authors.

In (1952), Cameron constructed and computed tables for the operating characteristics of attributes Single sampling plans. Dodge and Romig presented sampling inspection tables for the Single and Double sampling plans in (1959), Evolution of acceptance sampling plans was discussed by Dodge in the year (1969). Schilling along with Johnson (1982), presented tables for the construction of matched Single, Double and Multiple sampling plans with application to MIL-STD-105E in the year (1989).

Hald (1981), has proposed Double sampling plan with acceptance number 0 and 1 and rejection number 2. Dodge and Romig (1959) have studied the use of DSP(0,1) plan to product characteristics involving costly and destructive testing. Vijayaragavan (1990) has presented tables for the selection of DSP(0,1) plan for attributes under Poisson and Binomial conditions of sampling.

Dodge (1995) developed chain sampling inspection plans. Dodge and Stephens (1966), studied the Chain sampling plans and in 1974, they gave comparison of chain sampling plans with single and double sampling sizes. Raju (1984) contributed to the study on selection of chain sampling plans.

Aslam and Jun (2009) proposed a group sampling plan based on time truncated test for gamma distributed items. Srinivasa Rao (2009) presented a group acceptance sampling plans for life times following a generalized exponential distribution. Aslam and Jun (2009) proposed group acceptance sampling plan for truncated life tests based on the inverse Rayleigh and log-logistic distribution. Group acceptance sampling plan for truncated life tests having weibull distribution was developed by Aslam and Jun (2009). Aslam, Jun and Ahmad (2011) presented a group acceptance sampling plan for generalized Rayleigh distribution. Radhakrishnan and Alagirisamy (2011) constructed Group acceptance sampling plan using weighted binomial distribution. Srinivasa Rao (2011) presented a group acceptance sampling plans based on truncated life tests for Marshall-Olkin Extended Lomax distribution. Sudden death testing is discussed by Pascual and Meeker (1998). They proposed the modified sudden death test planning life tests with a limited number of test positions. Vicek, Hendricks and Zaretsky (2003) proposed Monte Carlo simulation of sudden death bearing testing. Jun, Balamurali and Lee (2006) proposed variables sampling plans for weibull distributed lifetimes under sudden death testing.

The Log -Logistic distribution has been studied by Shah and Dav (1963) and Tadikamalla and Johnson (1982) have studied systems of frequency curves generated by the transformation of logistic variables. O'Quigely and Struthers (1982) have studied the Log-Logistic distribution in the case of survival analysis. Ragab and Green(1984) and Ali and Khan(1987) used the Log-Logistic distribution for the order statistics area. Balakrishnan and Malik (1987) for the linear unbiased estimation of its parameters. Kantam et al. (2006) studied An economic reliability test plan: log-logistic distribution.

Norman Bush, Leonard and Merchant (1953) have used completely different techniques involving comparison of some portion of the OC curve to it of the best curve.

Kantam and Rosaiah (1998) discussed half logistic distribution in acceptance sampling based on life tests. Srinivasa Rao and Kantam (2010) presented acceptance sampling plans from truncated life test based on the log-logistic distribution for percentiles. Sudamani Ramaswamy and Sutharani (2013) planned a technique for designing single acceptance sampling plan based on truncated life tests under various distribution. The various distributions are Rayleigh distribution, Generalized Exponential distribution, Weibull distribution and Gamma distribution.

Aslam (2007) proposed double acceptance sampling plan based on truncated life tests in Rayleigh distribution. Aslam, Jun and Ahmad (2009) designed double acceptance sampling plans based on the truncated life tests in the Weibull distribution. Aslam and Jun (2010) proposed a double acceptance sampling plan for Generalized Log-Logistic distribution with known shape parameters. Srinivasa Rao (2012) have designed a double acceptance sampling plans based on truncated life tests for the Marshall - Olkin Extended Exponential distribution. Sudamani Ramaswamy and Sutharani (2014) planned a technique for designing double acceptance sampling plan based on truncated life tests for various distribution using minimum angle method. Sudamani Ramaswamy and Sutharani (2014) planned a technique for designing DSP(0,1) acceptance sampling plan based on truncated life tests for various distribution using minimum angle method. The various distributions they considered are Rayleigh distribution, Generalized Exponential distribution, Weibull distribution and Gamma distribution. Sudamani Ramaswamy and Sowmya (2016) proposed a time truncated special purpose double sampling plan DSP(0,1) for compound Rayleigh distribution.

Kantam, Rosaiah and Srinivasa Rao (2001) proposed Acceptance sampling based on life tests for a Log-logistic models. Sudamani Ramaswamy and Priyah Anburajan (2012) developed group acceptance sampling plan using weighted binomial on truncated life tests for Inverse Rayleigh, Log-Logistic and Marshall-Olkin Extended distribution. Sudamani Ramaswamy and Sutharani (2012) have designed group acceptance sampling plan for various distribution using minimum angle method. The various distribution they are considered as Generalized Rayleigh distribution, Generalized Exponential distribution, Weibull and Gamma distribution. Sudamani Ramaswamy and Sowmya(2016) presented on group acceptance sampling plan for Compound Rayleigh distribution.

SECTION 1.7

METHODOLOGY

Acceptance sampling plans are statistical tools for rectifying quality assurance. The sampling plan provides the vendor and buyer the decision rules for product acceptance to meet the present quality requirements. Several types of decision rules have been proposed for the acceptance sampling problem but work on designing the parameters to control quality of the received lots based on Minimum Angle Method is scare. According to the author's knowledge in acceptance sampling plan based on truncated life test, no one has applied minimum angle method to design the parameter. In acceptance sampling plan based on truncated life test, the design parameters are usually determined for the specified experiment time and for the acceptance number which satisfies consumer's risk only. This method used the one-point approach on operating characteristic curve, so it may not always satisfy the producer's risk. In this thesis a new approach for designing parameter for acceptance sampling plans based on truncated life test is introduced. An attempt is made to design the parameter such that it satisfies both the conditions producer's risk as well as consumer's risk and at the same time it minimizes the sum of the risks. Using minimum angle method the design parameter is selected such that $L(p_1) \geq 1-\alpha$ and $L(p_2) \leq \beta$ and at the same time sum of risk is minimum.

1.7.1 Minimum Angle Method

The practical performance of a sampling plan is discovered by it operating characteristic curve. Norman Bush et. al. (1953), have used completely different techniques involving comparison of some portion of the OC curve to it of the best curve. In the minimum angle method, the tangent of the angle between the lines joining the points (AQL,1- α) and Limiting Quality Level (LQL, β) is considered. It is shown in Fig.1.3 wherever p_1= AQL, p_2 = LQL. By using this method one will get a improved discriminating plan with the minimum angle. Tangent of angle created by lines AB and AC is

$$\tan \theta = BC/AC$$

$$\tan \theta = (P_2 - P_1)/(P_a(P_1) - (P_a(P_2))$$

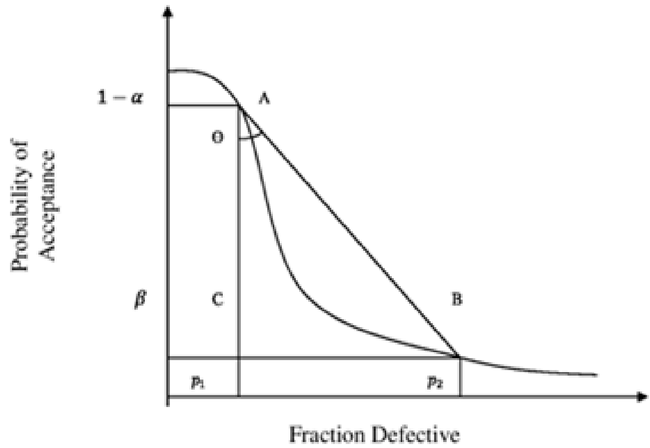

Figure 1.3 Minimum angle for given p_1 and p_2

The smaller the value of this tan θ, nearer that the angle θ approaching zero and also the chord AB approaching AC, the best condition through (AQL, 1-α). This criterion minimizes the consumer's and producer's risks simultaneously. So each producer and consumer favour the plans evolved by this criterion.

CHAPTER 2

DESIGNING SINGLE SAMPLING PLAN BASED ON TRUNCATED LIFE TEST FOR LOG-LOGISTIC DISTRIBUTION USING MINIMUM ANGLE METHOD

2.1 Introduction

Statistical quality control is systematic as compared to guess-work of haphazard process inspection. It plays a vital role in total quality control. Whenever a applied mathematics technique is used to control, improve and maintain the standard or to resolve quality problem it is termed as Statistical Quality Control. Reliability study plays a significant role in quality control analysis. In time truncated acceptance sampling plan, a random sample is chosen from a submitted lot of items and placed on the test wherever the number of failures is discovered till the pre-specified time. If the number of failures is higher than the specified acceptance number, then the submitted lots are going to be rejected. Acceptance sampling is an inspecting procedure applied in statistical quality control. Sample may be a part of operations management and repair quality maintenance. Life test sampling plan may be a technique, which consist of decision making based on sampling inspection of batch of products by experiments for examining the continual utility of the product for the specified function. During a truncated life test, the units are randomly selected from a lot of products and are subjected to a set of test procedures, wherever the number of failures is recorded until the pre-specified time. If the number of discovered failures at the tip of mounted time is not bigger than the specified acceptance number, then the lots are going to be accepted. The probability of rejecting the good lot is Type-I error (Producers risk) and it is denoted by α. The probability of accepting the bad lot is Type-II error (Consumers risk) and it is denoted by β.

In this chapter Single sampling plan is considered. The Single sampling plan is basic to all or any sampling situations. The Single sampling plan for life test has become the benchmark against that different sampling plans are judged. Single sampling plan based on truncated life tests have been proposed for a variety of life distribution by many authors. Cameron (1952), constructed and computed tables for the operating characteristics of attributes Single sampling plans. Evolution of acceptance sampling plans was discussed by Dodge in the year (1969). Schilling along with Johnson (1982), presented tables for the construction of matched Single, Double and Multiple sampling plans with Application to MIL-STD-105D. Kantam et.al. (1998), discussed the half Logistic distribution in acceptance sampling based on life tests. SrinivasaRao and Kantam (2010), presented acceptance sampling plans for the log-logistic distribution percentiles when the life test is truncated at a pre-specified time. Sudamani Ramaswamy and Sutharani (2012) planned a technique for designing single sampling plan based on truncated life tests for various distribution using minimum angle method. The various distributions they considered are Rayleigh distribution, Generalized Exponential distribution, Weibull distribution and Gamma distribution. In this chapter, designing single sampling plan for Log-Logistic distribution using minimum angle method is presented.

2.2 Operating procedure for single sampling plan for life test

The Single sampling plan for life test is described as follows, it is completely specified by three numbers N, n and c where N is the lot size, n is the sample size, and c is the acceptance number.

1) Select a random sample of size n from a lot of size N, and put them on test for time t_0.
2) Inspect all the items included in the sample. Let d be the number of defectives in the sample.
3) (i) If $d \leq c$, accept the lot.
   (ii) If $d > c$, reject the lot.

The following flow chart enumerates the operating procedure for Single sampling plan for life test.

2.3 Flow chart

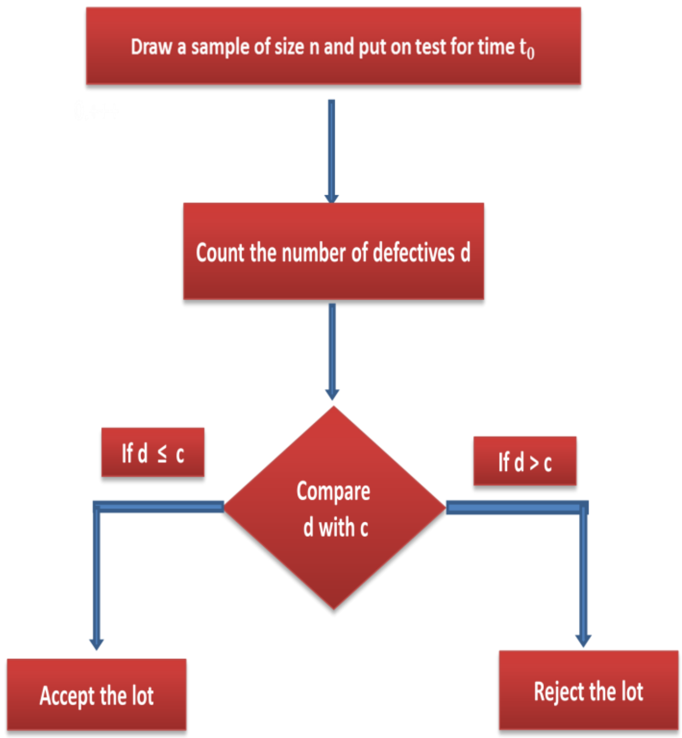

Figure 2.1 Operating procedure for Single sampling plan for life tests

2.4 Operating characteristic curve

The figure 2.2 shows the OC curve of single sampling plan when the life time of the items follows Log-Logistic distribution. From the figure 2.2 one can observe that the probability of acceptance increases as the mean ratio increases.

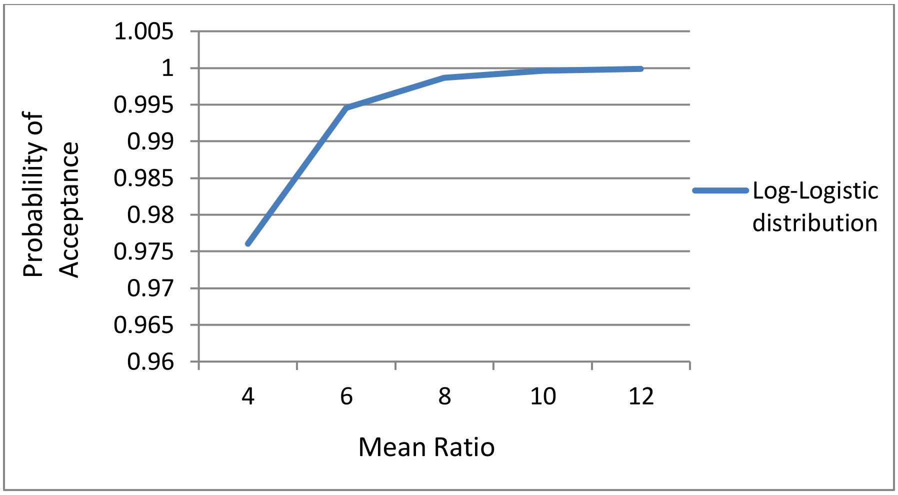

Figure 2.2 OC curve of Single sampling plan when the life time of the items follows Log-Logistic distributions with (t/σ_0=0.628)

2.5 Construction of table

It is assumed that the lot size is large enough to use the binomial distribution to seekout the probability of lot acceptance. The probability of acceptance L(p) for the Single sampling plan is calculated using the following equations,

$$L(p) = \sum_{x=0}^{c} \binom{n}{c} p^x q^{n-x}$$

where p is the failure probability. The time termination ratio t/σ_0 values are fixed as 0.628, 0.912, 1.257, 1.571, 2.356, 3.141, 3.927 and 4.712, and also the mean ratio σ/σ_0 values are fixed as 4, 6, 8, 10 and 12. The failure probability p is obtained such that it satisfies the following inequality at worst case $\sigma = \sigma_0$, $L(p) \leq \beta$ where β is taken as 0.10. The parameter value n is obtained using minimum angle method for specified values of acceptance numbers and satisfying the conditions $L(p_1) \geq 0.95$ and $L(p_2) \leq 0.10$ at the similar time, the sum of risks which is also minimum for Log-Logistic distribution and are presented in Table 2.1. The value of θ and tan θ are also provided in the Table. The sample size n is selected corresponding to the minimum value of θ.

TABLE – 2.1 The sample size and probability of acceptance for single sampling plan based on truncated life test for log-logistic distribution

t/σ_0	σ/σ_0	c	n	$L(p_1)$	$L(p_2)$	tan θ	θ
0.628	4	1	15	0.950626	0.047218	0.286450	15.984362
	4	**2**	**26**	**0.976049**	**0.010891**	**0.268123**	**15.009313**
	6	1	22	0.976506	0.006446	0.280396	15.663291
	6	2	33	0.994554	0.001653	0.273946	15.320079
	8	0	8	0.952041	0.069975	0.313710	17.417149
	8	1	25	0.989752	0.002668	0.280334	15.659978
	8	2	35	0.998701	0.000949	0.277336	15.500628
	10	0	13	0.950118	0.013275	0.297712	16.578880
	10	1	28	0.994550	0.001091	0.281311	15.681857
	10	2	35	0.999639	0.000949	0.279275	15.603723
	12	0	15	0.959805	0.006828	0.293927	16.379511
	12	1	30	0.996916	0.000598	0.281141	15.702871
	12	2	35	0.999875	0.000949	0.280407	15.663888
0.942	6	1	11	0.972449	0.009941	0.463482	24.866852
	6	2	17	0.992648	0.002518	0.450551	24.253995
	8	1	13	0.986803	0.003251	0.464119	24.896908
	8	2	20	0.997551	0.000512	0.457841	24.600238
	10	0	5	0.956789	0.041756	0.504206	26.757514
	10	1	14	0.993438	0.001844	0.465276	24.951444
	10	2	22	0.999075	0.000173	0.461872	24.790879
	12	0	7	0.957908	0.011722	0.490428	26.124622
	12	1	15	0.996265	0.001042	0.466263	24.997914
	12	2	23	0.999629	0.000100	0.464255	24.903303
1.257	6	1	7	0.967762	0.015848	0.599177	30.929080
	6	2	11	0.990490	0.004617	0.578538	30.051032

t/σ_0	σ/σ_0	c	n	$L(p_1)$	$L(p_2)$	tan θ	θ
	8	1	9	0.981329	0.003005	0.601352	31.020678
	8	2	13	0.996663	0.000963	0.590858	30.577048
	10	0	3	0.954058	0.058226	0.666259	33.673875
	10	1	9	0.991900	0.003005	0.603558	31.113405
	10	2	14	0.998795	0.000432	0.597834	30.872430
	12	0	4	0.957288	0.022568	0.643569	32.764083
	12	1	10	0.994997	0.001285	0.605364	31.189184
	12	2	15	0.999472	0.000192	0.601990	31.047525
1.571	8	1	6	0.981283	0.009086	0.693812	34.753365
	8	2	10	0.994953	0.001191	0.678756	34.166926
	10	0	2	0.952408	0.083144	0.790976	38.343142
	10	1	7	0.988761	0.003029	0.697519	34.896516
	10	2	11	0.998006	0.000416	0.689228	34.575695
	12	0	3	0.950296	0.023974	0.750066	36.872322
	12	1	8	0.992569	0.000991	0.700704	35.019080
	12	2	12	0.999061	0.000143	0.695555	34.820737
	12	2	7	0.999841	0.024229	0.712171	35.457363
2.356	12	1	5	0.987218	0.002384	0.822706	39.444331
	12	2	8	0.997512	0.000268	0.812468	39.092759

Example 2.1

Assume that an experimenter needs to ascertain that the life of the electrical devices created within the factory ensures that the true unknown mean life is at least 1000 hours when the ratio of the unknown average life is t/σ_0 = 0.628 and acceptance numbers c = 2. Suppose one wants to design single sampling under Log-Logistic distribution. The specified value are σ/σ_0 = 4, t/σ_0 = 0.628. One can observe that from the Table 2.1 minimum angle is θ = 15.009313°, for the c=2 and also α =0.023951, β = 0.010891 which correspond to n=26. It is very much less than the specified risk. Thus the required Single sampling plan has parameters (26,2).

Example 2.2

Suppose one wants to design single sampling under Log-Logistic distribution. The specified value are $\sigma/\sigma_0 = 10$, $t/\sigma_0 = 1.571$. One can observe that from the Table 2.1 minimum angle is $\theta = 38.343142°$, for the c=0 and also $\alpha = 0.047592$, $\beta = 0.083144$ which correspond to n=2. The sample size is 2 which is very much less. So it is clear that when the time of experiment increases, the sample size decreases. Thus the required Single sampling plan has parameters (2,0).

It can be seen that by applying minimum angle method one can obtain parameters which satisfy both the conditions on the producer's risk as well as consumer's risk. This minimum angle method plan provides better discrimination of accepting good lots.

CHAPTER 3

DESIGNING SPECIAL PURPOSE DOUBLE SAMPLING PLAN OF TYPE DSP (0,1) BASED ON TRUNCATED LIFE TEST FOR LOG-LOGISTIC DISTRIBUTION USING MINIMUM ANGLE METHOD

3.1 Introduction

An acceptance sampling plan involves quality contracting on product orders between the producers and the consumers. It is an essential tool in Statistical Quality Control. In most of the statistical quality control experiment, it is not possible to perform hundred percent inspection, due to various reasons. A plan in which management specifies two sample sizes and two acceptance numbers of the quality of the lots is very good or very bad, the consumer can make a decision, to accept or reject the lot on the basis of the first sample, which is smaller than the Single sampling plan.

Aslam(2007) introduced the double sampling plan for truncated life test for Rayleigh distribution. Aslam, Jun and Ahmad(2009) developed the plan for Weibull distribution and Aslam and Jun(2010) extended the plan for Generalized LogLogistic distribution. Srinivasa Rao(2012) have designed double acceptance sampling plan based on truncated life tests for the Marshall – Olkin extended exponential distribution. Sudamani Ramaswamy and Sowmya(2016) proposed A time truncated special purpose double sampling plan DSP(0,1) for compound Rayleigh distribution. Sudamani Ramaswamy and Sutharani (2014) planned a technique for designing double acceptance sampling plan based on truncated life tests for various distribution using minimum angle method. Sudamani Ramaswamy and Sutharani (2014) planned a technique for designing DSP(0,1) acceptance sampling plan based on truncated life tests for various distribution using minimum angle method. The various distributions they considered are Rayleigh distribution, Generalized Exponential distribution, Weibull distribution and Gamma distribution.

From Cameron table (1952), one can observe a jump between the operating ratios of c = 0 and c = 1 and slow reduction of operating ratios for other values of c. It may also be seen that, in between the OC curves of c = 0 and c = 1 plans, there is vast gap to be filled which leads one to access the possibility of designing plans having OC curves lying between the OC curves of c = 0, and c = 1 plans. To overcome such situation, Hald (1981), has proposed Double sampling plan with acceptance number 0 and 1 and rejection number 2.

In this chapter a new approach of designing Special purpose Double sampling plan of type DSP (0,1) for truncated life test using minimum angle method, is proposed when the life time distribution follows Log- Logistic distribution. The test termination time and mean ratio time are specified. The design parameter is obtained such that it satisfies both producer's risk and consumer's risk. The Operating characteristic values for various quality levels are obtained and the results are discussed with the help of table. The table of design parameter are provided for easy selection of the plan parameter. The results are analyzed with the help of table and examples.

3.2 Operating Procedure of Special Purpose Double Sampling plan of type DSP (0, 1)

According to Hald (1981), the operating procedure for DSP (0,1) is as follows :

1) From a lot, select a sample size n_1, and observe the number of defectives d_1.
2) If $d_1 = 0$, accept the lot.
   If $d_1 > 1$, reject the lot.
3) If $d_1 = 1$, select a second sample of size n_2 and observe d_2.
   If $d_2 = 0$, accept the lot. Otherwise reject the lot..

3.3 Operating Procedure of Special Purpose Double Sampling Plan of type DSP (0, 1) for life tests

1) From a lot, select a sample size $n_1$andobserve the number of defectives d_1, during the time t_0.

2) If $d_1 = 0$, accept the lot.

If $d_1 > 1$, reject the lot.

3) If $d_1 = 1$, select a second sample of size n_2 and observe d_2 during the time t_0.

If $d_2 = 0$, accept the lot. Otherwise reject the lot.

The following is the operating procedure for DSP (0,1) for life test in the form of a flow chart.

3.4 Flowchart

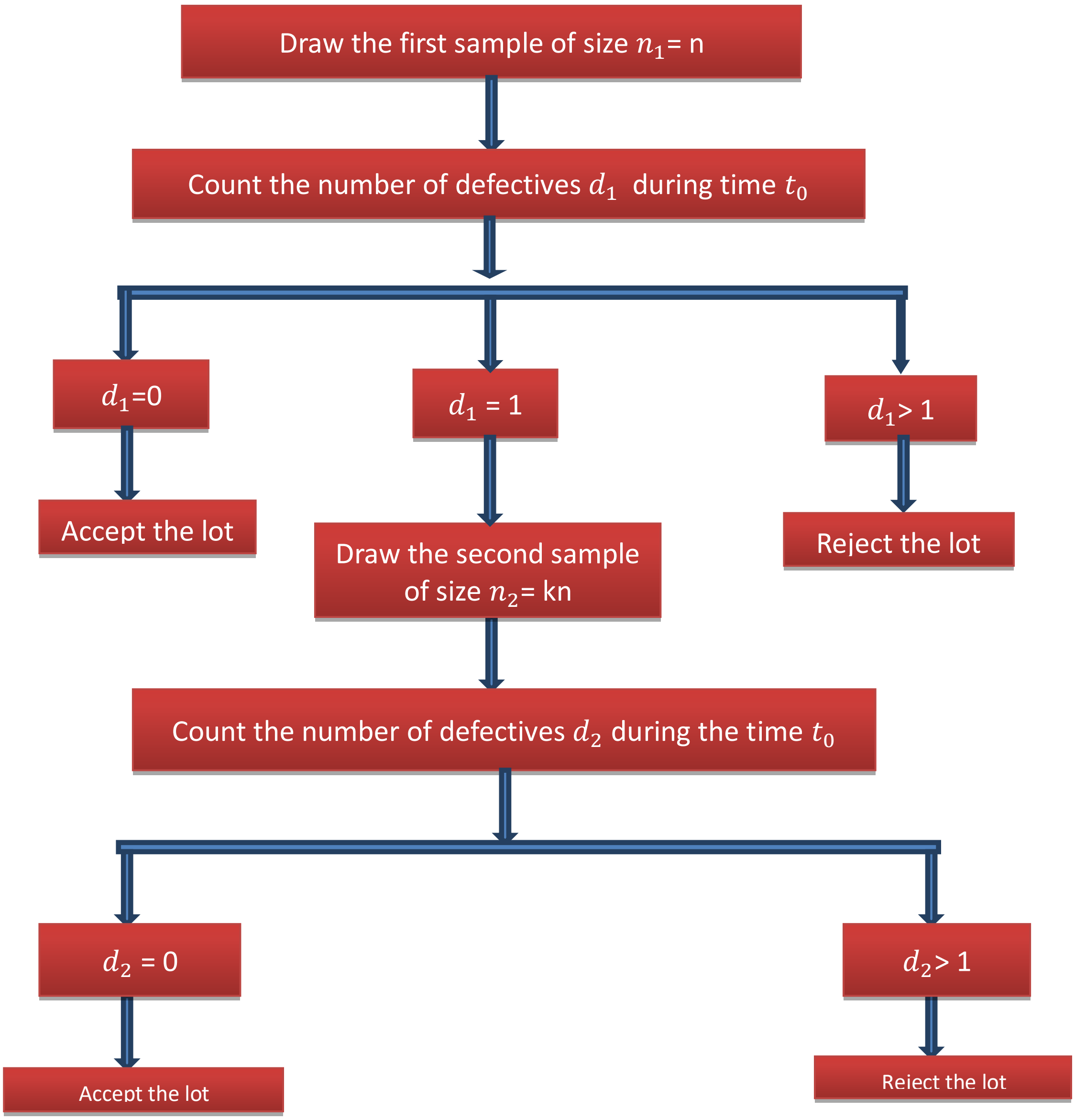

Figure 3.1 Operating procedure for special purpose double sampling plan of type DSP(0,1) for life test

3.5 Operating characteristic curve

The figure 3.2 shows the OC curve of special purpose double sampling plan of type DSP(0,1) when the life time of the items follows Log-Logistic distribution. From the figure 3.2 one can observe that the probability of acceptance increases as the mean ratio increases.

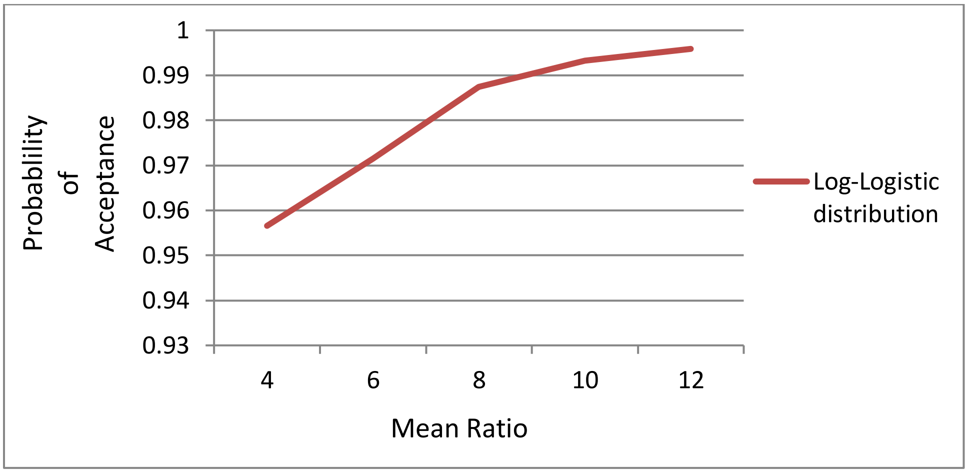

Figure 3.2 OC curve for special purpose double sampling plan of type DSP(0,1) when the life time of the items follows Log-Logistic distributions with (t/σ_0=0.628)

3.6 Construction of Table

The DSP(0,1) is composed of parameters n_1 and n_2 if t_0 is specified. Let σ be the unknown average life and σ_0 be the specified average life. A lot is considered to be good if the true unknown average life is more than the specified average life. In this chapter we have applied Log-logistic distribution to design DSP(0,1) plan for life test. We assume that the lot size is large enough to use the binomial distribution to find the probability of acceptance of the lot. Then the probability of acceptance for DSP(0,1) is given by P(A)= P(no failure occur in sample 1) + P(1 failure occur in sample 1 and 0 failure occur in sample 2). Under the conditions for application of binomial model for the OC function of DSP(0,1) or the probability of acceptance DSP(0,1) is given by,

$$L(P) = (1-P)^{n_1} + n_1 P\,(1-P)^{(n_1+n_2-1)}$$

The usual practice is to choose the second sample size equals to some constant (k) multiple of first sample size which facilitates sample administration of the DSP(0,1) sampling plan.

Taking n_1= n and n_2=kn we get

$$L(P) = (1-P)^{n} + n_1 P\,(1-P)^{(n(k+1)-1)}$$

The failure probability of an item by time t_0, given by

P = F(t_0, σ)

The Table 3.1 is constructed using OC function for Special purpose Double sampling plan of type DSP (0, 1) when the life time of items follows Log-Logistic distributions. The test termination ratio t/$\sigma_0$values are fixed as 0.628, 0.912, 1.257, 1.571, 2.356, 3.141, 3.927 and 4.712, and the mean ratio σ/σ_0values are fixed as 4,6,8,10,12. For various time ratios t/σ_0 and mean ratios σ/σ_0 the parameter values n_1= n and n_2 = kn are obtained and satisfying L(p_1) ≥ 0.95 and L(p_2) ≤ 0.10 for Log-Logistic distribution and are provided in Table 3.1. The values of θ and tan θ are also provided in the Table 3.1. The parameters can be selected such that the angle is minimum.

TABLE – 3.1 The sample size and probability of acceptance for special purpose double sampling plan of type DSP(0,1) using Minimum Angle method for specified value of k when the life time of the items follows log-logistic distribution

t/σ_0	σ/σ_0	k	n	$L(p_1)$	$L(p_2)$	tan θ	θ
0.628	4	1	8	0.956562	0.085423	0.297061	16.544638
	6	1	14	0.971572	0.010021	0.282877	15.795004
	6	2	13	0.961046	0.013287	0.286994	16.013147
	6	3	12	0.955364	0.018511	0.290335	16.189854
	8	1	16	0.987382	0.005048	0.281689	15.731947
	8	2	15	0.982077	0.006829	0.283736	15.840559
	8	3	14	0.978747	0.009520	0.285499	15.933977
	10	**1**	**18**	**0.993212**	**0.002563**	**0.281542**	**15.724131**
	10	2	17	0.990128	0.003512	0.282693	15.785212
	10	3	16	0.988014	0.004896	0.283698	15.838559
	12	1	8	0.999329	0.085423	0.306493	17.039953
	12	1	20	0.995868	0.001308	0.281638	15.729262
	12	2	18	0.994491	0.002518	0.282373	15.768244
	12	3	18	0.992448	0.002518	0.282956	15.799162
0.942	6	1	7	0.965985	0.012576	0.467905	25.075107
	6	2	6	0.959482	0.022182	0.475946	25.451941
	6	3	5	0.961099	0.041770	0.485250	25.884978
	8	1	8	0.984680	0.006485	0.466661	25.016609
	8	2	8	0.975398	0.006213	0.470999	25.220384
	8	3	7	0.974116	0.011722	0.474323	25.376049
	10	1	9	0.991690	0.003377	0.466821	25.024154
	10	2	9	0.986483	0.003291	0.469252	25.138419
	10	3	8	0.985271	0.006211	0.471232	25.231330
	12	1	10	0.994913	0.001771	0.467240	25.043860
	12	2	10	0.991666	0.001744	0.468760	25.115301
	12	3	9	0.990667	0.003291	0.469969	25.172061
1.257	6	1	3	0.980850	0.074296	0.629158	32.176368

t/σ_0	σ/σ_0	k	n	$L(p_1)$	$L(p_2)$	tan θ	θ
	6	2	3	0.968547	0.059162	0.627199	32.095880
	6	3	3	0.957732	0.058280	0.634126	32.379840
	8	1	5	0.981925	0.009351	0.604907	31.170045
	8	2	5	0.970821	0.008752	0.611512	31.446299
	8	3	5	0.960992	0.008747	0.617821	31.708651
	10	1	6	0.988772	0.003499	0.605777	31.206525
	10	2	6	0.981721	0.003391	0.610076	31.386368
	10	3	5	0.982348	0.008747	0.613039	31.509940
	12	1	7	0.992381	0.001333	0.606991	31.257370
	12	2	6	0.990715	0.003391	0.609280	31.353116
	12	3	6	0.987287	0.003390	0.611403	31.441735
1.571	8	1	4	0.973509	0.007385	0.698173	34.921694
	8	2	3	0.974991	0.024076	0.709340	35.349598
	8	3	3	0.966159	0.023977	0.715914	35.599400
	10	1	4	0.988309	0.007385	0.700938	35.028056
	10	2	4	0.980762	0.006916	0.706033	35.223345
	10	3	4	0.973915	0.006913	0.711029	35.413932
	12	1	5	0.990843	0.002042	0.702672	35.094634
	12	2	4	0.990193	0.006916	0.706620	35.245780
	12	3	4	0.986518	0.006913	0.709268	35.346845
2.356	12	1	3	0.984896	0.003768	0.825814	39.550386
	12	2	3	0.975010	0.003558	0.834040	39.829451
	12	3	3	0.966184	0.003557	0.841686	40.086841

Example 3.1

Suppose one wants to design DSP(0,1) under Log-Logistic distribution, for specified values t/σ_0=0.628, σ/σ_0 = 10, k=1.One can observe that from the Table 3.1, among the various values of θ the minimum angle is θ=15.724131° and also α = 0.006788 and β= 0.002563 which corresponds to n= 18. It is very much less than the specified risk. Thus the required DSP(0,1) plan has parameters (18,18) which satisfies both the producer's risk and consumer's risk.

Example 3.2

Suppose one wants to design DSP(0,1) under Log-Logistic distribution, for specified values t/σ_0=0.628, σ/σ_0 = 12, k=1. One can observe that from the Table 3.1, among the various values of θ the minimum angle is θ=17.039953° and also α = 0.000671 and β= 0.085423 which corresponds to n= 8. There is a slight change in the sample size but there is increase in the probability of acceptance. The probability of acceptance as 0.9993 which is almost equal to 1 and the consumer's risk is 0.085423 which shows that there is a reduction in consumer's risk.

It can be seen that by applying minimum angle method one can obtain parameters which satisfy both the conditions on the producer's risk as well as consumer's risk. This minimum angle method plan provides better discrimination of accepting good lots.

CHAPTER 4

DESIGNING CHAIN SAMPLING PLAN BASED ON TRUNCATED LIFE TEST FOR LOG-LOGISTIC DISTRIBUTION USING MINIMUM ANGLE METHOD

4.1 Introduction

The concept of Chain sampling inspection plans was proposed by Dodge (1955), The ChSP – 1 plans are applicable for both smaller and larger samples. The Chain Sampling Plan (ChSP-1) was proposed by Dodge (1955), making use of cumulative results of several sampling helps to overcome the shortcoming of the Single sampling plan. It avoids rejection of a lot on the basis of a single nonconforming unit and improves the poor discrimination between good and bad quality that occurs with the c = 0 plan. Chain sampling method is applied to cases where there is continuous production under the same essential conditions, and where the lots or batches of product to be sampled are offered for acceptance substantially in order of their production.

When large sampling is not practicable, and the use of c=0 plan is warranted, for example, when an extremely high quality is essential, the use of chain sampling plan is often recommended. Kantam et. al. (2001) studies Log-logistic models. Sudamani Ramaswamy and Jayasri proposed Time Truncated Chain Sampling Plans for various distribution. The various distributions they considered are Generalized Exponential distribution (2012), Marshall – Olkin Extened Exponential distribution (2013), Log – Logistic distribution (2013), Inverse Rayleigh distribution (2014), Generalized Rayleigh distribution (2014), Weibull distribution distribution (2015). Sudamani Ramaswamy and Jayasri (2015), Time Truncated Modified Chain Sampling Plan for Selected Distributions. Sudamani Ramaswamy and Sutharani (2013) planned a technique for designing chain sampling plan based on truncated life tests for various distribution using minimum angle method. The various distributions they considered are Rayleigh distribution, Generalized Exponential distribution, Weibull distribution and Gamma distribution.

In this chapter a new approach of designing Chain sampling plans for truncated life test using minimum angle method, is proposed when the life time of the item follows Log-Logistic distribution. The test termination time, mean ratio time and number of preceding sample i = 2 are specified. The design parameter is obtained such that it satisfies both the producer's risk and consumer's risk simultaneously. The table of the design parameter are provided for easy selection of the plan parameter. The results are analysed with the help of table and examples.

4.2 Condition for Application of Chsp – 1

The cost of destructiveness of testing is such that a relatively small sample size is necessary, although other factors make a large sample desirable.

1) The product to be inspected comprises a series of successive lots produced by a continuing process.
2) Normally lots are expected to be of essentially the same quality.
3) The consumer has faith in the integrity of the producer.

4.3 Operating Procedure of Chain Sampling Plan for Life Tests

The plan is implemented in the following way :

1) For each lot, select a sample of n units and test each unit for conformance to the specified requirements during the time t_0
2) Accept the lot if d (the observed number of defectives) is zero in the sample of n unit, and reject if d >1.
3) Accept the lot if d is equal to 1 and if no defectives are found in the immediately preceding i samples of size n.

Thus a lot is accepted if no defects are found in its sample of n units. A lot is rejected if two or more defects are found in this sample. But if one defect is found the lot is still be accepted if the last defect found was far enough back in history as determined by the choice of i.

Dodge (1955), has given the operating characteristic function of ChSP-1 as $P_a(p) = P_0 + P_1(P_0)^i$,

where P_a= the probability of acceptance,

P_0 = probability of finding no defects in a sample of n units from product of quality p.

P_1= probability of finding one defect in such a sample.

i = Number of preceding samples.

The Chain sampling plan is characterized by the parameters n and i. We are interested in designing the chain sampling plans based on truncated life tests under Log-logistic distribution using minimum angle method. If the confidence level is p^* then the consumers risk will be $\beta = 1 - p^*$. The sample size is determined so that the consumers risk does not exceed a given value β. The following is the operating procedure for Chain sampling plan for life test in the form of a flow chart.

4.4 Flow Chart

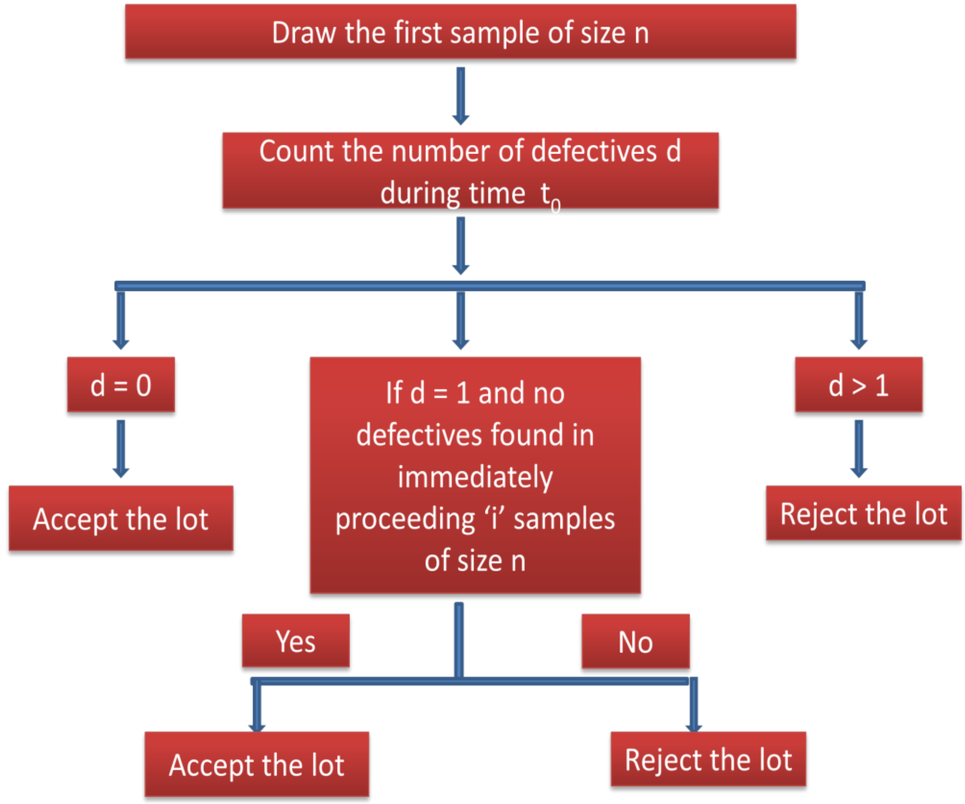

Figure 4.1 Operating procedure for Chain sampling plan for life tests

4.5 Operating characteristic curve

The figure 4.2 shows the OC curve of chain sampling plan when the life time of the items follows Log-Logistic distribution. From the figure 4.2 one can observe that the probability of acceptance increases as the mean ratio increases.

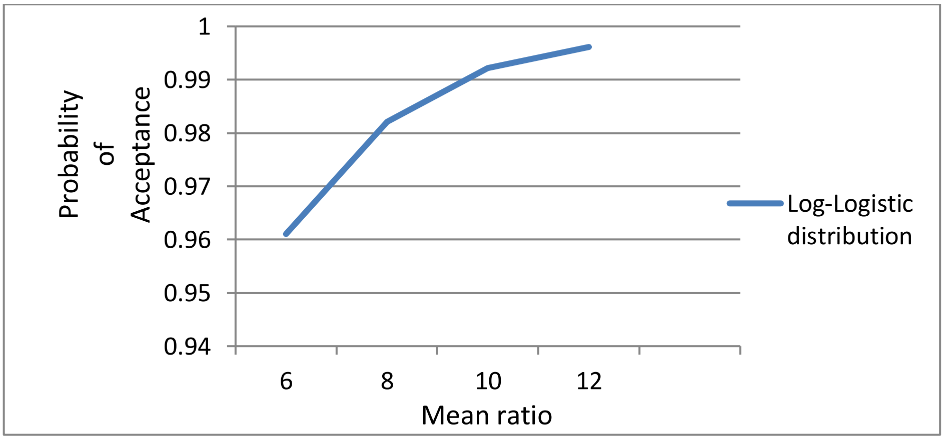

Figure 4.2 OC curve of chain sampling plan when the life time of the items follows Log-Logistic distributions with (t/σ_0=0.628)

4.6 Construction of Table

It is assumed that the lot size is large enough to use the binomial distribution to find the probability of lot acceptance. According to Dodge (1955), the probability of acceptance $P_a(p)$for the Chain sampling plan is calculated using the following equation

$$P_a(p) = (1-p)^n + np(1-p)^{n-1}(1-p)^{ni}$$

Where p is the failure probability.

The Tables are constructed using OC function for Chain sampling plans under various distributions. The test termination ratio t/σ_0 values are fixed as 0.628, 0.912, 1.257, 1.571, 2.356, 3.141, 3.927 and 4.712, and the mean ratio σ/σ_0 values are fixed as 4,6,8,10,12. For various time ratios t/σ_0 and mean ratios σ/σ_0, the parameter values n satisfying $L(p_1) \geq 0.95$ and $L(p_2) \leq 0.10$ are determined for Log-Logistic distribution and are provided in Table 4.1. The values of θ and tan θ are also provided in Table 4.1. The parameters can be selected corresponding to the minimum value of θ.

TABLE – 4.1 The sample size and probability of acceptance for Chain sampling plan when the life time of the items follows log-logistic distribution (i=2)

t/σ_0	σ/σ_0	n	$L(p_1)$	$L(p_2)$	tan θ	θ
0.628	6	12	0.966248	0.018540	0.287009	16.013978
	6	13	0.961046	0.013287	0.286994	16.013147
	6	14	0.955579	0.009525	0.287511	16.040531
	8	13	0.986284	0.013287	0.284392	15.875339
	8	14	0.984240	0.009525	0.283891	15.848779
	8	15	0.982077	0.006829	0.283736	15.840559
	10	13	0.994092	0.013287	0.284367	15.874029
	10	14	0.993186	0.009525	0.283542	15.830250
	10	**15**	**0.992223**	**0.006829**	**0.283043**	**15.803815**
	12	14	0.996615	0.009525	0.283770	15.842326
	12	15	0.996129	0.006829	0.283136	15.808719
0.942	6	4	0.980806	0.080547	0.495529	26.359736
	6	5	0.970904	0.042079	0.480289	25.654473
	6	6	0.959482	0.022182	0.475946	25.451941
	8	7	0.980795	0.011732	0.471059	25.223179
	8	8	0.975398	0.006213	0.470999	25.220384
	8	9	0.969483	0.003291	0.472458	25.288763
	10	7	0.991629	0.011732	0.470830	25.212463
	10	8	0.989190	0.006213	0.469355	25.143230
	10	9	0.986483	0.003291	0.469252	25.138419
	12	9	0.993194	0.003291	0.468769	25.115733
	12	10	0.991666	0.001744	0.468760	25.115301
	12	11	0.990002	0.000924	0.469160	25.134092
1.257	6	3	0.968547	0.059162	0.627199	32.095880
	8	3	0.988916	0.059162	0.632766	32.324253
	8	4	0.980751	0.022640	0.614039	31.551549
	8	5	0.970821	0.008752	0.611512	31.446299
	10	5	0.987056	0.008752	0.610093	31.387055

t/σ_0	σ/σ_0	n	$L(p_1)$	$L(p_2)$	tan θ	θ
	10	6	0.981721	0.003391	0.610076	31.386368
	10	7	0.975646	0.001314	0.612579	31.490780
	12	5	0.993477	0.008752	0.610889	31.420288
	12	6	0.990715	0.003391	0.609280	31.353116
	12	7	0.987532	0.001314	0.609963	31.381658
1.571	8	2	0.988578	0.085981	0.747312	36.771209
	8	3	0.974991	0.024076	0.709340	35.349598
	8	4	0.957502	0.006916	0.709585	35.358945
	10	4	0.980762	0.006916	0.706033	35.223345
	12	4	0.990193	0.006916	0.706620	35.245780
2.356	12	3	0.975010	0.003558	0.834040	39.829451
	12	2	0.988587	0.023444	0.839491	40.013172

Example 4.1

Suppose one wants to design chain sampling plan under Log-Logistic distribution. The specified values are t/σ_0 = 0.628, σ/σ_0 = 10,i = 2. One can observe that from the Table 4.1, among the various values of θ the Minimum angle is θ = 15.803815 and also α = 0.007777, β = 0.0068 it corresponds to n=15. It is very much less than the specified risk. Thus, the desired sampling plan has parameters (15, 2).

Example 4.2

Suppose one wants to design chain sampling under Log-Logistic distribution. The specified value σ/σ_0 = 12, t/σ_0 = 2.356, i = 2. One can observe that from the Table 4.1 minimum angle is θ = 40.013172° and also α =0.011413, β = 0.023444 which correspond to n=2. The sample size is 2 which is very much less. So it is clear that when the time of experiment increases, the sample size decreases. Thus the required Single sampling plan has parameters (2,2).

It can be seen that by applying the minimum angle method one can get the parameters which minimize simultaneously the consumer's risk and producer's risk. This minimum angle method plan provides better discrimination of accepting good lots.

CHAPTER 5

DESIGNING GROUP SAMPLING PLAN BASED ON TRUNCATED LIFE TEST FOR LOG-LOGISTIC DISTRIBUTION USING MINIMUM ANGLE METHOD

5.1 Introduction

An acceptance sampling plan is concerned with accepting or rejecting a submitted lot of products on the basis of the quality of the products inspected in a sample taken from the lot. An acceptance sampling plan is that establishes the minimum sample size to be used for testing. This becomes particularly important if the quality of product is defined by its lifetime. Often, assumed that the when designing a sampling plan that only a single item is put in a tester. That is, more than one item can be tested in the experiment simultaneously. In this situation experimenters/ practitioner cannot use the ordinary acceptance sampling plan to test the items. The items in a tester can be regarded as a group and the number of items in a group is called the group size. An acceptance sampling plan based on such groups of items is called a group acceptance sampling plan (GASP). Moreover, the group acceptance sampling scheme can be used for the strict inspection of items than the ordinary acceptance sampling before it will be realized for consumers' use.

Sudden death testing is an example using this type of testers. Some applications of sudden death testing is discussed by Pascual and Meeker (1982), Vlcek et. al. (1982) and Recently, Jun et. al. (2016) proposed the sudden death test under the assumption that the lifetime of items follows the Weibull distribution with known shape parameter. In acceptance sampling plan, Aslam and Jun (2009) was proposed group acceptance sampling plan under the Inverse Rayleigh and Log-Logistic distributions, respectively. Aslam and Jun (2009) was proposed a group sampling plan based on time truncated test for gamma distributed items. Group acceptance sampling plan for truncated life tests having Weibull distribution is present by Aslam and Jun (2009) .Srinivasa Rao applied the Marshall-Olkin Extended Lomax distribution (2009) and Generalized exponential distribution (2014) for a group acceptance sampling plan based on truncated life tests. Radhakrishnan and Alagirisamy (1984) constructed attribute group acceptance sampling plan using weighted binomial distribution. Aslam, Jun and Ahmad (2011) presented a group acceptance sampling plan for generalized Rayleigh distribution. Kantam et. al.(2001) studies Log-logistic models. Rosaiah et. al. (2011) studied the reliability plans using the exponentiated log-logistic distribution. Kantam and Rosaiah (1998) have studied Half logistic distribution in acceptance sampling based on life tests. Sudamani Ramaswamy and Jayasri (2014)presented time truncated group sampling plan using weighted Binomial for Various distributions. Sudamani Ramaswamy and Priyah Anburajan developed group acceptance sampling plan using weighted binomial on truncated life tests for Inverse Rayleigh, Log-Logistic (2012) and Marshall-Olkin Extended distribution (2012). Sudamani Ramaswamy and Sowmya (2016) presented on group acceptance sampling plan for Compound Rayleigh distribution. Sudamani Ramaswamy and Sutharani (2012) have designed group acceptance sampling plan for various distribution using minimum angle method. The various distribution they are considered as Generalized Rayleigh distribution, Generalized Exponential distribution, Weibull and Gamma distribution.

In this chapter a new approach of designing Group sampling plans for truncated life tests using minimum angle method, is proposed when the life time follows Log-Logistic distribution. The test termination time multiplier and mean ratio time are specified. The number of groups of the sampling plan are determined for the specified values of acceptance numbers c, group size r, time termination multiplier a and the mean ratio σ / σ_0 using minimum angle method so that the both the consumer's risk and producer's risk are minimized. The results are analyzed with the help of table and examples.

5.2 Design of the group sampling plan

The following GASP is proposed based on the truncated life test:

1) Select the number of groups g and allocate predefined r items to each group so that the sample size for a lot will be n = g. r.
2) Select the acceptance number c for a group and the experiment time t_0 .
3) Perform the experiment for the g groups simultaneously and record the number of failures for each group.
4) Accept the lot if atmost c failures occur in each of all groups.
5) Terminate the experiment if more than c failures occur in any group and reject the lot.

Often, the consumer's risk is expressed by the consumer's confidence level. If the confidence level is P*, then the consumer's risk will be β =1-P*. The number of groups in the proposed sampling plan is determined so that the consumer's risk does not exceed β . The lot of products is accepted only if there were at most c failures occurred in each of g groups. So, the lot acceptance probability will be

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

where p is the probability that an item in a group fails before the termination time.

5.3 Flow Chart

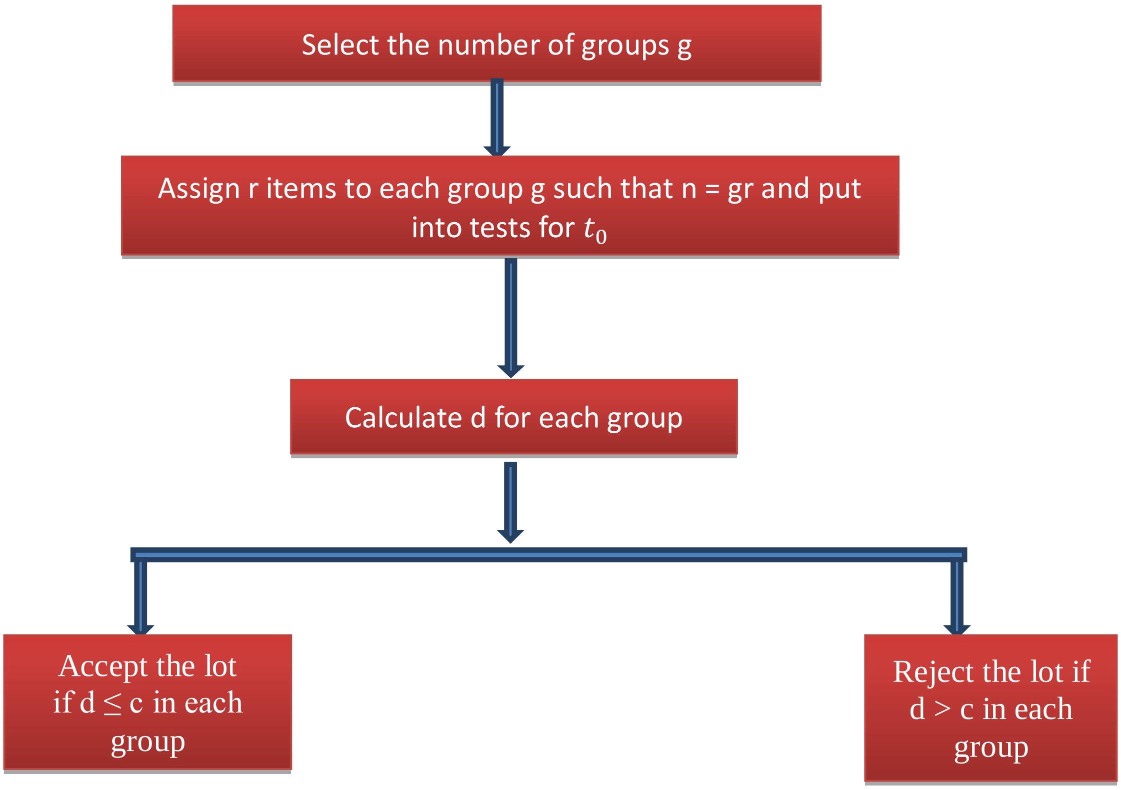

Figure 5.1 Operating procedure for group sampling plan for life tests

5.4 Operating characteristic curve

The figure 5.2 shows the OC curve of chain sampling plan when the life time of the items follows Log-Logistic distribution. From the figure 5.2 one can observe that the probability of acceptance increases as the mean ratio increases.

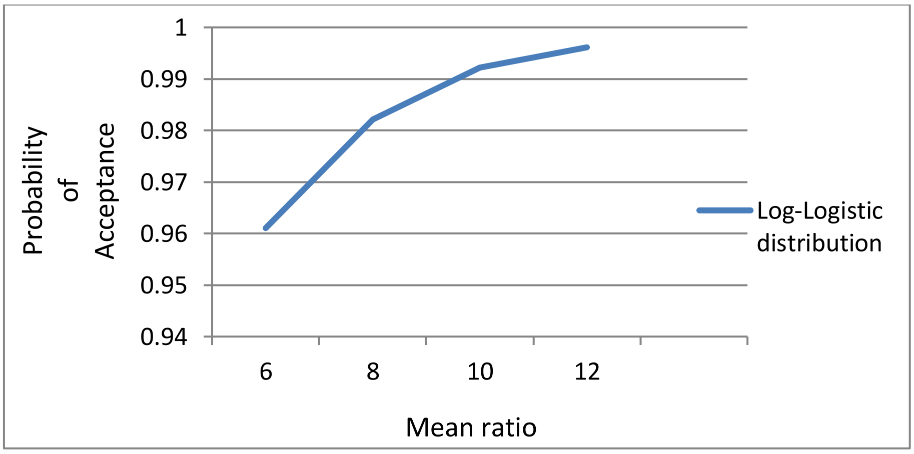

Figure 5.2 OC curve of group sampling plan when the life time of the items follows Log-Logistic distributions with (t/σ_0=0.628)

5.5 Construction of table

The probability of acceptance of the Group acceptance sampling plan is given by

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

where p is the probability that an item in a group fails before the termination time t_0.

The time termination ratio t/σ_0 values are fixed as 0.7, 0.8, 1.0, 1.2, 1.5 and 1.8, and the mean ratio σ/σ_0 values are fixed as 4, 6, 8, 10 and 12. The failure probability p is obtained such that it satisfies the following inequality at worst case $\sigma=\sigma_0$,

$$L(p_2) = \left(\sum_{i=0}^{c} \binom{r}{i} p^{i} (1-p)^{r-i}\right)^{g} \leq \beta$$

where β is less than 0.10.

The number of groups is determined using minimum angle method for predetermined values of acceptance numbers c, group size r, time termination multiplier a and the mean ratios σ/σ_0 and also satisfying the conditions

L(p_1) ≥ 0.95 and L(p_2) ≤ 0.10. The minimum number of groups is determined using minimum angle method, when the items follows Log-Logistic distribution. The results are presented in Table 5.1. The value of θ and tan θ are also provided in table. The number of groups is selected corresponding to the minimum value of θ.

TABLE – 5.1 The number of groups and probability of acceptance for Group sampling plan based on truncated life for Log-Logistic distribution (r=6, c=2)

a	σ/σ_0	g	$L(p_1)$	$L(p_2)$	tan θ	θ
0.7	4	16	0.992181	0.002591	0.302291	16.819591
	4	17	0.991694	0.001786	0.302194	16.814483
	4	**18**	**0.991208**	**0.001231**	**0.302173**	**16.813384**
	6	16	0.999249	0.002591	0.316489	17.561981
	6	17	0.999202	0.001786	0.316248	17.549449
	6	18	0.999155	0.001231	0.316087	17.541063
	8	16	0.999862	0.002591	0.322140	17.855828
	8	17	0.999853	0.001786	0.321883	17.842480
	8	18	0.999845	0.001231	0.321707	17.833337
	10	16	0.999963	0.002591	0.324836	17.995687
	10	17	0.999961	0.001786	0.324575	17.982143
	10	18	0.999959	0.001231	0.324396	17.972832
	12	16	0.999988	0.002591	0.326317	18.072400
	12	17	0.999987	0.001786	0.326054	18.058781
	12	18	0.999986	0.001231	0.325873	18.049411
0.8	4	10	0.989624	0.003288	0.356656	19.629065
	4	11	0.988593	0.001856	0.356511	19.621710
	4	12	0.987562	0.001048	0.356591	19.625792
	6	16	0.998362	0.000106	0.373428	20.477045
	6	17	0.998260	0.000060	0.373449	20.478097
	6	18	0.998157	0.000034	0.373477	20.479529
	8	16	0.999696	0.000106	0.380499	20.831768
	8	17	0.999677	0.000060	0.380489	20.831247
	8	18	0.999658	0.000034	0.380486	20.831110
	10	16	0.999919	0.000106	0.383957	21.004623
	10	17	0.999914	0.000060	0.383941	21.003832
	10	18	0.999909	0.000034	0.383933	21.003427
	12	16	0.999973	0.000106	0.385871	21.100145
	12	17	0.999971	0.000060	0.385854	21.099286

a	σ/σ_0	g	$L(p_1)$	$L(p_2)$	tan θ	θ
	12	18	0.999969	0.000034	0.385844	21.098815
0.9	4	7	0.986054	0.003541	0.406435	22.118557
	4	8	0.984078	0.001581	0.406442	22.118896
	4	9	0.982106	0.000706	0.406897	22.141238
	6	9	0.998177	0.000706	0.426588	23.102506
	6	10	0.997974	0.000315	0.426507	23.098601
	6	11	0.997772	0.000141	0.426519	23.099178
	6	12	0.997570	0.000063	0.426572	23.101756
	8	12	0.999545	0.000063	0.435241	23.520665
	8	13	0.999507	0.000028	0.435243	23.520731
	8	14	0.999469	0.000013	0.435252	23.521201
	10	12	0.999878	0.000063	0.439560	23.728383
	10	13	0.999868	0.000028	0.439549	23.727863
	10	14	0.999857	0.000013	0.439547	23.727750
	12	12	0.999959	0.000063	0.441966	23.843818
	12	13	0.999955	0.000028	0.441953	23.843154
	12	14	0.999952	0.000013	0.441947	23.842898
1.2	6	4	0.995837	0.001390	0.554783	29.020770
	6	5	0.994799	0.000268	0.554737	29.018736
	6	6	0.993762	0.000052	0.555195	29.038801
	8	5	0.998987	0.000268	0.568888	29.635033
	8	6	0.998784	0.000052	0.568880	29.634689
	8	7	0.998582	0.000010	0.568972	29.638651
	10	4	0.999778	0.001390	0.576898	29.980556
	10	5	0.999723	0.000268	0.576283	29.954099
	10	6	0.999668	0.000052	0.576190	29.950104
1.5	8	2	0.998550	0.005890	0.663213	33.552862
	8	3	0.997826	0.000452	0.660079	33.427957
	8	4	0.997102	0.000035	0.660282	33.436049
	10	2	0.999595	0.005890	0.674549	34.001602
	10	3	0.999392	0.000452	0.671014	33.862170

a	σ/σ_0	g	$L(p_1)$	$L(p_2)$	tan θ	θ
	10	4	0.999189	0.000035	0.670870	33.856473
	12	2	0.999859	0.005890	0.681030	34.256036
	12	3	0.999789	0.000452	0.677372	34.112620
	12	4	0.999719	0.000035	0.677137	34.103385
1.8	8	1	0.997996	0.030619	0.740110	36.505517
	8	2	0.995996	0.000938	0.719521	35.735815
	8	3	0.993999	0.000029	0.720308	35.765520
	10	1	0.999424	0.030619	0.756362	37.102482
	10	2	0.998849	0.000938	0.734301	36.289886
	10	3	0.998274	0.000029	0.734056	36.280744
	12	1	0.999797	0.030619	0.765748	37.443004
	12	2	0.999595	0.000938	0.743144	36.617667
	12	3	0.999392	0.000029	0.742619	36.598279

Example 5.1

Suppose one wants to design group sampling plan under Log-Logistic distribution for specified values are a = 0.7, r = 6, c = 2 and σ/σ_0 = 4. One can observe that from the Table 1, among the various values of θ the Minimum angle is θ = 16.813384 and also α = 0.0087 and β = 0.001 which corresponds to g = 18. It is very much less than the specified risk. Thus, the desired sampling plan has parameters as (4, 6, 2, 18) as mean ratio, number of items, acceptance number, number of groups respectively.

It can be seen that the application of the minimum angle method minimizes simultaneously the consumer’s risk and producer’s risk. This minimum angle method plan provides better discrimination of accepting good lots.

SUMMARY AND CONCLUSION

This dissertation is devoted to the study of truncated life test through acceptance sampling procedures using minimum angle method.

The first chapter describes the basic concepts of quality control, acceptance sampling, reliability, life testing, notations and symbols and review of literature.

In chapter-2 Single sampling plan for truncated life test is considered. A new approach of designing Single sampling plans for truncated life test using minimum angle method, is proposed when the life time distribution follows Log-Logistic distribution. The test termination time and mean ratio time are specified. The acceptance number is also specified. The design parameter is obtained such that it satisfies both producer’s risk and consumer’s risk simultaneously. The table of design parameter are provided for easy selection of the plan parameter. The results are analysed with the help of table and examples. It can be seen that by applying minimum angle method one can obtain parameters which satisfy both the conditions on the producer’s risk as well as consumer’s risk. This minimum angle method plan provides better discrimination of accepting good lots.

In chapter-3 Special purpose Double sampling plan of type DSP (0, 1) based on truncated life test is considered. A new approach of designing special purpose Double sampling plan of type DSP (0, 1) for truncated life test using minimum angle method, is proposed when the life time distribution follows Log-Logistic distribution. The test termination time and mean ratio time are specified. The design parameter is obtained such that it satisfies both producer’s risk and consumer’s risk simultaneously. The tables of design parameter are provided for easy selection of the plan parameter. The results are analyzed with the help of table and examples. It can be seen that by applying minimum angle method one can obtain parameters which minimize simultaneously the consumer’s risk and producer’s risk. This minimum angle method plan provides better discrimination of accepting good lots.

In chapter-4 Chain sampling plan for truncated life test is considered. A new approach of designing chain sampling plans for truncated life test using minimum angle method, is proposed when the life time distribution follows Log-Logistic distribution. The test termination time, mean ratio time and number of preceding sample i are specified. The design parameter is obtained such that it satisfies both producer's risk and consumer's risk simultaneously. The tables of design parameter are provided for easy selection of the plan parameter. The results are analysed with the help of table and examples. It can be seen that by applying the minimum angle method one can get the parameters which minimize simultaneously the consumer's risk and producer's risk. This minimum angle method plan provides better discrimination of accepting good lots.

In chapter-5 Group sampling plan for truncated life test is considered. A new approach of Group sampling plan for a truncated life test using minimum angle method is proposed when the life time distribution follows Log-Logistic distribution. Minimum angle method is applied to determine the design parameter group size g by satisfying both the risks at the specified quality levels simultaneously. Tables of design parameters are provided. . The results are analysed with the help of table and examples. It can be seen that the application of the minimum angle method minimizes simultaneously the consumer's risk and producer's risk. This minimum angle method plan provides better discrimination of accepting good lots.

REFERENCES

1. **Ali M. M. and Khan A. H.,** (1987), "On Order Statistics from the Log-Logistic Distribution," J. Stat. Plan. Inference, vol. 17, pp. 103-108.
2. **American National Standards Institute / American Society for Quality Control(ANSI / ASQC) Standard A2,** (1987), "Terms, Symbols and Definitions for Acceptance Sampling", American Society of Quality Control, Milwaukee, Wisconsin, USA.
3. **Aslam A., Jun C.H. and Ahmad M.,** Group Acceptance Sampling Plan for Generalized Rayleigh Distribution, International Journal of Intelligent Technologies and Applied Statistics, 4(3)(2011), 355-365.
4. **Aslam M and Jun C.H.,** "A Double Acceptance Sampling Plan for Generalized Log-Logistic Distribution with known Shape Parameters," *J. Appl. Stat.*, vol. 37, no. 3, pp. 405-414, 2010.
5. **Aslam M,** "Double Acceptance Sampling based on Truncated Life Tests in Rayleigh Distribution," *Eur. J. Sci. Res.*, vol. 17, no. 4, pp. 605-606, 2007.
6. **Aslam M, Jun C.H and Ahmad M.,** "A Double Acceptance Sampling Plan based on Truncated Life Test in the Weibull Distribution," *J. Stat. Theory Appl.*, vol. 8, no. 2, pp. 191-206, 2009.
7. **Aslam M. and Jun C.H.,** A Group Acceptance Sampling Plan for Truncated Life tests having Weibull Distribution, Journal of Applied Statistics, 39(2009), 1021-1027.
8. **Aslam M. and Jun C.H.,** A Group Sampling Plan based on Truncated Life tests for Gamma Distributed Items, Pakistan Journal of Statistics, 25(2009), 333-340.
9. **Aslam, M., and Jun, C.-H.** (2009): A group acceptance sampling plans for truncated life tests based on the inverse Rayleigh and log-logistic distributions. Pakistan Journal of Statistics 25, 1-13.
10. **Balakrishnan, N. and Malik, H.J.,** (1987), Best linear unbiased estimation of location and scale parameter of log-logistic distribution, Communication Statist. Theory and Methods, 16, 3477-3495.

11. **Bush N., Leonard E.J. and Merchant M.O.M.Jr.,**(1953) A Method Single and Double Sampling OC curves Utilizing the Tangent of the Point of the Inflexion, No,PR-7, 1-77.
12. **Cameron J.M.,** (1952)Tables for Constructing and for Computing the Operating Characteristics of Single Sampling Plans, Industrial Quality Control , Vol. 9(1), 37-39.
13. **Dodge H. F.,** (1955), "Chain Sampling Inspection Plans, Industrial Quality Control", Vol. 11(4), 10-13.
14. **Dodge H.F.,**(1969) Notes on the Evolution of Acceptance Sampling Plans,Part – I, Journal of Quality Technology, Vol. 1(2), 77-78.
15. **Ducan A. J.** (1986), "Quality Control and Industrial Statistics", 5th Edition, Home Wood, Illinois.
16. **Hald, A (1981),** "Statistical Theory of Sampling by Attributes", Academic Press, New York Statistical Theory.
17. **Hamaker H. C.** (1960), "Attribute Sampling in Operation", Bulletin of the International Statistical Institute, Vol. 37(2), 265-281.
18. **Hill I. D.** (1962), "Sampling Inspection and Defense Specification DEF 131", Journal of the Royal Statistical Society, Series A, Vol. 125(1), 31-73.
19. **Jun, C.H., Balamurali, S. and Lee, S.-H.** (2006). Variables sampling plans for Weibull distributed lifetimes under sudden death testing. IEEE Transactions on Reliability, 55(1), 53-58.
20. **Kantam, R.R. L., Rosaiah, K.** (1998): Half logistic distribution in acceptance sampling based on life tests. IAPQR Transactions 23(2), 117-125.
21. **Kantam, R.R. L., Rosaiah, K. and Srinivasa Rao, G.** (2001): Acceptance sampling based on life tests: Log-logistic models. Journal of Applied Statistics 28, 121-128.
22. **Kantam, R.R.L. and Srinivasa Rao, G. and Sriram, G.** (2006). An economic reliability test plan: log-logistic distribution. J. App. Statist., 33(3), 291-296.
23. **Military Standard _MIL-STD-105E** (1989), "Sampling Procedures and Tables for Inspection by Attributes", U.S. Department of Defense,Washington, DC, USA.

24. **Norman Bush N. Leonard E.J., and Merchant M.Q.M.Jr.,** (1953), " A Method of Single and Double Sampling OC curves Utilizing the Tangent of the Point of the Inflexion".

25. **O'Quigley J. and Struthers L.,** (1982), "Survival Model based upon the Logistic and Log-Logistic Distribution," Computer Programs in Biomedicine, vol. 15, pp. 3-12.

26. **Pascual, F. G. and Meeker, W. Q.,**(1998) "The Modified Sudden Death Test: Planning Life Tests with a Limited Number of Test Positions," J. Test. Eval., Vol. 26, No. 5,pp. 434–443.

27. **Peach P.** (1947), "An Introduction to Industrial Statistics and Quality Control", 2nd Edition, Edwards and Broughton, Raleigh, North Carolina.

28. **Priyah Anburajan and Sudamani Ramaswamy A.R** (2012) : A Group Acceptance Sampling Plans Using Weighted Binomial on Truncated Life tests for Marshall – Olkin Extened distributions, Global Journal of Mathematical Sciences, 4(4).

29. **Priyah Anburajan and Sudamani Ramaswamy A.R** (2012) : A Group Acceptance Sampling Plans Using Weighted Binomial on Truncated Life tests for Inverse Rayleigh and Log – Logistic distribution, IOSR Journal of Mathematics, 2(3), pp 33-38.

30. **Radhakrishna R. and Alagirisamy K.,** (2011) Construction of Group Acceptance Sampling Plan using Weighted Binomial Distribution, International Journal of Recent Scientific Research, 2(7), 229-231.

31. **Ragab, A. and Green, J.** (1984). On order statistics from the log-logistic distribution and their properties, Commu. Statist. Theory and Methods, 13, 2713-2724.

32. **Rosaiah, K., Kantam, R.R.L. and Santosh Kumar, Ch.** (2007): Exponentiated loglogistic distribution - an economic reliability test plan. Pakistan Journal of Statistics 23, 147-156.

33. **Schilling E.G. and Johnson L.**(1982) ,Tables for the Construction of MatchedSingle, Double and Multiple Sampling Plans with Application to MIL-STD-105D", Journal of Quality Technology, Vol. 12(4), 220-229.

34. **Schilling, E.G.** (1980), "Acceptance Sampling in Quality Control". Marcel Dekker, New York.

35. **Shah, B.K. and Dave, P.H.,** (1963). A note on log-logistic distribution, J. Math. Sciences University Baroda (Science number) 12, 21-22.
36. **Srinivasa Rao G.** (2012), "Double Acceptance Sampling Plans Based on Truncated Life Tests for the Marshall – Olkin Extended Exponential Distribution", Austrian Journal of Statistics Vol. 40, No. 3, 169 – 176.
37. **Srinivasa Rao, G.** (2009): A Group Acceptance Sampling Plans for Lifetimes Following a Generalized Exponential Distribution . Economic Quality Control, Vol 24, No. 1, 75 – 85
38. **Srinivasa Rao, G.** (2009): A group acceptance sampling plans for truncated life tests for Marshall-Olkin extended Lomax distribution. Electronic Journal of Applied Statistical Sciences, 3(2011), 18-27.
39. **Sudamani Ramaswamy A.R & Sutharani S** (2013), "Designing Chain Sampling Plan Based on Truncated Life Tests under various Distribution using Minimum Angle Method", SOP Transactions on Applied Mathematics, volume1, Number 1 page 21-29.
40. **Sudamani Ramaswamy A.R and Sutharani R** (2012), "Designing GASP under Generalized Exponential Distribution using Minimum Angle Method", Serials Publications, IJAMAA volume 8, No 1 Jan – June 2013,pp 9-19, ISSN0973-3868.
41. **Sudamani Ramaswamy A.R and Sutharani R** (2012), "Designing Group Acceptance Sampling Plan under Generalized Rayleigh Distribution using Minimum Angle Method", IJMA, ISSN 2229 – 5046-3(11).
42. **Sudamani Ramaswamy A.R and Jayasri S** (2012), "Time Truncated Chain Sampling Plans for Generalized Exponential Distribution", International Journal of Computational Engineering Research,volume 2,issue 5,PP:1402-1407
43. **Sudamani Ramaswamy A.R and Jayasri S** (2013), " Time Truncated Chain Sampling Plans for Log - Logistic Distribution" International Journal of Engineering Research and Development ,Volume 7, Issue 4, PP. 09-13
44. **Sudamani Ramaswamy A.R and Jayasri S** (2013), "Time Truncated chain sampling plans for Marshal-Olkin extended exponential distributions", International organization of scientific research,volume 5, issue 1, PP:01-05.

45. **Sudamani Ramaswamy A.R and Jayasri S** (2014) , "Time Truncated Chain Sampling Plans for Generalized Rayleigh Distribution," International Refereed Journal of Engineering and Science, vol. 3, no. 2, pp. 49-53.
46. **Sudamani Ramaswamy A.R and Jayasri S** (2014), "Time Truncated Chain Sampling Plans for Inverse Rayleigh Distribution", International Journal of Engineering Inventions, Volume 3, Issue 6, PP: 41-45
47. **Sudamani Ramaswamy A.R and Jayasri S** (2015) , "Time Truncated Chain Sampling Plan for Weibull Distribution," Int. J. Eng. Res. Gen. Sci., vol. 3, no. 2, pp. 59-67.
48. **Sudamani Ramaswamy A.R and Jayasri S** (2015), "Time Truncated Modified Chain Sampling Plan for Selected Distributions", International Journal of Research in Engineering and Science (IJRES),Volume 3, Issue 3 , PP.01-18
49. **Sudamani Ramaswamy A.R and Sowmya N** (2016): A time truncated GSP for Compound Rayleigh Distribution. International Journal of Mathematics and its Applications, 4(2-A).
50. **Sudamani Ramaswamy A.R and Sowmya N**(2016),"A time truncated Special purpose Double Sampling Plan DSP(0,1) for Compound Rayleigh Distirbution", International Journal of Engineering Sciences & Management,3(5)
51. **Sudamani Ramaswamy A.R and Sutharani R** (2012) Designing Group Acceptance Sampling Plan under Weibull and Gamma Distribution using Minimum Angle Method". International Journal of Mathematics and Statistics Studies IJMSS-125, ISSN2053-2229 Volume 1, No 4, page 23-36, July – Dec 2013.
52. **Sudamani Ramaswamy A.R and Sutharani S** (2014), "Designing Double acceptance Sampling Plan Based on Truncated Life Tests under various Distribution using Minimum Angle Method", International Journal of Scientific and Engineering Research, Volume 5, Issue 1,PP: 626-640.
53. **Sudamani Ramaswamy A.R and Sutharani S** (2014), "Designing DSP(0,1) acceptance Sampling Plan Based on Truncated Life Tests under various Distribution using Minimum Angle Method", International Journal of Research in Engineering and Technology. ISSN (2321-7308) (IJRET) page 116-129, Volume 3, Issue 1, January 2014.

54. **Sudamani Ramaswamy A.R. and Jayasri S.,** (2014) Time Truncated Group Sampling plan using Weighted Binomial for various distributions, International Journal of Mathematics Research, 6(3), 227-244.
55. **Sudamaniramasamy A.R., Sutharani R.,** (2013)Designing single acceptance sampling plans based on truncated life tests under various distributions using minimum angle method,34-47.
56. **Tadikamalla, P. R. and Johnson, N.L.** (1982). Systems of frequency curves generated by the transformation of logistic variables. Biometrika, 69, 461-465.
57. **Vlcek, B. L., Hendricks, R. C., and Zaretsky, E. V.,** Monte Carlo Simulation of Sudden Death Bearing Testing, NASA, Hanover, MD, 2003.

LIST OF PUBLICATIONS

1. **Sudamani Ramasamy A.R., Tharani K.,** Designing single acceptance sampling plans based on truncated life tests under log-logistic distributions using minimum angle method, International Journal of Services Technology and Management (Accepted).
2. **Sudamani Ramasamy A.R., Tharani K.,** Designing special purpose double sampling plan of type DSP (0,1) based on truncated life test for log-logistic distribution, International Journal of Research and Analytical Reviews (Accepted).
3. **Sudamani Ramasamy A.R., Tharani K.,** Designing chain sampling plan based on truncated life test for log-logistic distribution using minimum angle method, International Journal of Mathematics Trends and Technology(Accepted).
4. **Sudamani Ramasamy A.R., Tharani K.,** Designing group sampling plan based on truncated life test for log-logistic distribution using minimum angle method, submitted.