CHAPTER I

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CHAPTER I

1.1 INTRODUCTION

In almost all production processes, the producer must rely on outside sources for both raw material and components. Suppose that the production manager of a personal computer manufacturing company purchases large lots of electronic components from an outside vendor, and then the components are assembled in the making of a computer. Each component can be classified as either good unit or defective according to some specifications. Every time a lot of components arrive from the vendor, the manager faces a problem. How can the manager be sure that the lot contains a small number of defectives, or no defectives at all. Inspecting every component, that is, 100% inspection is expensive. Moreover, the effort required is often so overwhelming that it is inevitable for the inspection personnel and will have inspection fatigue which may cause a defective component which is classified as a good one or vice versa. The 100% inspection approach is clearly not feasible if the inspection procedure is destructive. On the other hand, if no inspection is done, and if the incoming lot contains a large number of defective components, many defective parts are bound to be produced. It is expensive to trouble-shoot the problems and rework the defective parts at the later stages of the production process.

It is natural to consider a compromising situation. The production manager might select a random sample of units from the incoming lot, and then determine the number of defective components found in the sample. If the number of defective components found, does not exceed a pre-determined number called the acceptance number, the lot is accepted; otherwise the lot is rejected.

These procedures comprise an attribute acceptance sampling plan or simply an attribute sampling plan. Attribute sampling plans are widely used quality control tools which can be used in any kind of industry. In the context of manufacturing, attribute sampling plans are implemented to make sure that the quality of incoming parts satisfies certain requirements before they are assembled; that the quality of semi-finished
products is acceptable before they are passed to the next manufacturing stage; or that the quality of finished products satisfies the customer's specifications before they are shipped to the customer.

ANSI/ASQC Standard A2 (1987) defines acceptance sampling as the methodology that deals with procedures by which decision to accept the lot or not to accept the lot are based on the results of the inspection of samples. According to Dodge (1969) the general areas of acceptance sampling are

1. Lot-by-Lot acceptance 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.
2. 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.
3. Continuous sampling of a flow of units by the method of attributes and
4. Special purpose plans.

In designing a sampling plan one has to accomplish a number of different purposes. According to Hamaker, the important factors are

1. To strike a proper balance between the consumers requirements, the producer’s capabilities and inspections capacity.
2. To separate bad lots from good.
3. Simplicity of procedures and administration.
4. Economy in number of observations.
5. To reduce the risk of wrong decisions with increasing lot size.
6. To use accumulated sample data as a valuable source of information.
7. To exert pressure on the producer or supplier when the quality of the lots received is unreliable or not up to the standard and
8. To reduce sampling when the quality is reliable and satisfactory.

Hamaker (1960) also noted that these aims are partially conflicting and all of them cannot be simultaneously realized.
According to Case and Keats (1982), the sampling plan design methodologies are classified as i) risk-based non-Bayesian, ii) risk-based Bayesian, iii) economically based non-Bayesian, iv) economically based Bayesian approaches. The risk-based non-Bayesian approach is applied by the vast majority of quality control practitioners due to their wider availability of tables and ease of application.

Economically based sampling plans explicitly consider certain factors as cost of inspection, accepting a non-conforming unit and rejecting a conforming unit in an attempt to design a cost-effective plan. Bayesian plan design procedures take into account the past history of similar lots submitted previously for the inspection purposes. Non-Bayesian plan design methodology is not explicitly based upon the past history.

Sampling plans are used to make product disposition decisions for each lot of product. With attribute sampling plans, these accept/reject decisions are based on account of the number defects and defectives, while variable sampling plans require measurements and calculations, with decision based on the sample average and standard deviation. Acceptance sampling by attributes was originally developed for controlling the quality (fraction defective or number of defects) of lots or batches of mass-produced articles in industry, the most important aspect being the separation of a series of lots into lots of satisfactory and unsatisfactory quality.

Ideally, when a sampling plan is used, all bad lots will be rejected and all good lots will be accepted. However because accept/reject decision are based on a sample of the lot, there is always a chance of making an incorrect decisions. The behaviour of a sampling plan can be described by its operating characteristic (OC) curve, which is lots percent defective versus the corresponding probabilities of acceptance. According to Peach (1947), the following are some of the major topics of designing sampling plans based on the OC curves:

1. The plan is specified by requiring the OC curve to pass through (or nearly through) two fixed points. Tables of Cameron (1953) and Radhakrishnan and Sivakumaran (2008) were based on this type of designing.
2. The plan is specified by fixing one point through which the OC curve is required to pass, and setting up one or more conditions not explicitly in terms of the OC curves. Stephens (1981) and Govindaraju (1989) followed this type of designing.

3. The plan is specified by imposing upon the two or more independent conditions more of which explicitly involves the OC curves. Dodge and Romig (1959) AOQL table is an example for this type of designing.

This thesis presents Reliability based mixed sampling plans (RMSPs) by considering variable sampling in the first stage and attribute sampling in the second stage. These plans are developed by assuming two-parameter exponential family in the first stage and Poisson distribution in the second stage. The operating characteristic function and its associated measures of the plans are also provided for computing Probability of acceptance, Average Outgoing Quality, Average Sample Number etc.

In this thesis, the Reliability based mixed sampling plans by variables and attributes together to determine the acceptability of a process or lot. The first stage variable sampling is dealt with progressively censored data on its life testing and the second stage is with type-1 censoring having number of conformities, which follows exponential and Poisson family respectively.

An attribute life test is one in which each unit in a sample are tested, to find out whether each unit survives or fails a specified life test. The main advantage of an attribute life test over a variable life test is that, it is more economical with respect to less test equipments, test monitoring, etc.,

1.2 STATEMENT OF THE PROBLEM

The construction of sampling plans is an important aspect in acceptance sampling which is used in product control. It has two types

1. Acceptance sampling by Variables
2. Acceptance sampling by Attributes

Latha (1988) and Devabharathi (1990) studied mixed acceptance sampling plans. Oliver and Springer (1972) and Latha (2002) studied Bayesian attribute acceptance plans. The concept of Reliability is more important in life testing procedure and is very much applied in all major industries of developing and developed countries. A sampling plan involving Reliability concepts is much more essential. In this thesis, an attempt is made to construct the sampling plans based on all the above aspects to get Reliability based mixed sampling plans indexed through various parameters suggested by different authors.

1.3 OBJECTIVES OF THE STUDY

The following are the important objectives of the study

1. To construct and select the Reliability based mixed sampling plans indexed through AQL, LQL, IQL, MAPD and MAAOQ.
2. To compare the plans constructed through MAPD and MAAOQ.
3. To construct Reliability based mixed sampling plans indexed through COAOQ.
4. To highlight the advantage of considering the MAPD as incoming quality and MAAOQ as an outgoing quality.
5. The Reliability based mixed sampling plans are constructed for the basic plans such as:
   - Single Sampling Plan
   - Double Sampling Plan
   - Double Sampling Plan of the type DSP- (0,1)
   - Conditional Double Sampling Plan
   - Chain Sampling Plan of the type ChSP- 1
• Chain Sampling Plan of the type ChSP- 2
• Chain Sampling Plan of the type ChSP- (0.1)
• Tightened- Normal- Tightened Plan of the type TNT- (n₁, n₂; 0)
• Tightened- Normal- Tightened Plan of the type TNT- (n; c₁, c₂)
• Repetitive Group Sampling Plan
• Conditional Repetitive Group Sampling Plan
• Link Sampling Plan

1.4 LIMITATIONS OF THE STUDY

The study has the following limitations.

1. The baseline distribution assumed in the construction of sampling plan is Poisson.

2. The life testing procedure till a specified time under given environmental conditions may not be feasible and practicable in some companies or products.

3. Assessing the probability of acceptance in the first stage is possible but cumbersome.

1.5 SCOPE OF THE STUDY

The Reliability based Mixed sampling plans has been developed to reduce the sample size, test duration, etc. These mixed plans will be very useful to practitioners because they provide Economic sample size, which in turn minimizes inspection cost, data recordings, inspector error and so on. Reliability based mixed sampling plans differs from the ordinary double sampling procedure in the sense that only acceptance can take place as a result of the application of the variables plan to the first sample. If acceptance is not indicated, a second sample is drawn; acceptance or rejection is then being determined on an attributes basis. The Reliability based mixed sampling plans achieves reduction in sample size associated with a variables plan. In rejecting lots, it is also often decided as psychological or legal advantage to show actual defectives to the producer, a feature which can be had only by rejecting on an attributes basis. Truncated and non-normal distributions cannot be rejected for poor variables results alone, but only on the basis of defective or nonconforming units found in the attributes sample. Furthermore, with regard to acceptance-rejection decisions, the effect of changes in
shape of distribution can be minimized by accepting only evidence so good as to be practically beyond question for most distributions which might reasonably be presented to the plans. Thus, Reliability based mixed sampling plans provide a worthwhile alternative to variables plans used.

The principal advantage of a variables-attributes plan over attributes alone is a reduction in sample size with same protection. The variables aspect of the mixed plan also allows for a far more careful analysis of the distribution of product presented to the plan that would be possible with attributes inspection alone. Variables control charts kept on this data can provide information on the variability and stability of product from lot to lot. Control charts should normally be used in conjunction with acceptance sampling procedures involving variables inspection.

With small first samples, the Reliability based mixed plan provides an excellent form of surveillance inspection on product which is generally expected to be of good quality but which may, at times, show degradation. A small variables first sample can be employed to accept at relatively low values of proportion nonconforming and the second attributes sample is then used to provide a definitive criterion for disposition of the lot if it is not accepted on the first sample.

In application, it is also conceivable that reliability based mixed plan might be more difficult to administer than either variable plans or attribute plans alone. As with all plans using variables criteria, a separate Reliability based mixed plan must be developed for each characteristic to which it is applied. Any increase in complexity would, however be compensated by the advantages of the mixed procedure.

1.6 METHODOLOGY AND MATERIALS

The Reliability based mixed sampling plan is a two stage sampling procedure, in the first stage sampling plan by variables is constructed and in the second stage sampling plans by attribute is constructed. In the construction of these plans the base line distribution assumed to be Poisson. The other characteristics such as probability of acceptance are also calculated using a suitable Visual Basic computer Program.
In designing the plans with various indexing parameters, Visual Basic Program was used to construct the sampling plans for various combinations of incoming/outgoing qualities. This procedure helped the Researcher in constructing tables for the ready-made usage for the engineers working in the floor of the assembly.

1.7 TERMINOLOGIES

The important terms and phrases used in the area of acceptance sampling and in this thesis are given below:

Acceptance quality level (AQL)

In sampling inspection, AQL is the maximum percent defective or the maximum number of defects per hundred units, which can be considered as a satisfactory process average. This is the lot quality or process quality considered good that one does not wish to reject more than a specified small probability.

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 no-acceptance). A plot of ASN against p is called the ASN curve.

Conditional sampling plans

The sampling plan in which the acceptance or rejection of the current lot is based not only on the sample information from current lot, but also on the sample results from the neighbouring lot.

Conforming unit

A conforming unit is one which meets the acceptance criteria established for the characteristic being considered.

Consumer's risk

ANSI/ASQC standard A2 (1987) defines consumer's risk as follows: "For a given sampling plan, the probability of accepting product quality of which has a designated numerical value representing a level which it is seldom desired to accept
Continuous sampling inspection

Continuous sampling inspection is the examination or testing of units of product as they move fast an inspection station. Only those units of product found by the inspector to the non-conforming units are corrected or replaced with conforming units. The rest of the production, un-inspected unit as well as units found to be conforming, is allowed to continue down the production line as conforming material.

Defect

A defect is any non-conformance of the unit of product with specified requirements.

Defective

A defective is any unit of product, which contains one or more defects. The terms ‘defective’, ‘non-conforming unit’ and ‘non-conformity’ are interchangeably used in this thesis.

100% inspection

100% inspection means the inspection of every unit of product for the defects concerned listed for an inspection station. The two terms ‘screening’ and ‘100% inspection’ are interchangeably used in this thesis.

Inspection

Inspection is the process of measuring, examining, testing or otherwise comparing the unit of product with the requirement.

Inspection by attributes

Inspection by attributes is inspection whereby certain characteristics of units of products are inspected and classified simply as conforming or non-conforming to the specified requirements.

Indifference quality level (IQL)

Fixing \( p_0 \), the indifference quality level (IQL), gives adequate protection not only to the consumer but also to the producer. IQL is defined as the quality level in the region
containing quality levels between AQL and LQL. It would represent a process containing a proportion of non-conforming units not low enough that it should be limited to having only a small risk of being called not acceptable on sampling basis, nor high enough that it should be limited to having only a small risk of being accepted on sampling basis.

**Limiting quality level (LQL)**

The percentage or proportion of variant units in a batch or lot for which, for the purpose of acceptance sampling plan, the consumer wishes the probability of acceptance to be restricted to a specified low value (usually 0.10).

**Life testing**

An attribute life test is one in which each units in a sample are tested whether each unit survives or fails a specified life test.

**Maximum allowable percent defective (MAPD)**

The proportion defective corresponding to the inflection point of the operating characteristic curve (OC) is interpreted as the maximum allowable proportion defective (MAPD). The desirability of developing a set of sampling plans indexed with $p^*$ (MAPD) has been explained by Soundararajan (1975). One of the desirable properties of an OC curve is that the decrease of the probability of acceptance should be slower for lesser values of $p$ (good quality level) and steeper for larger values of $p$ (bad quality level), which provides a better overall discrimination. If $p^*$ is considered as a standard quality measure then the above property of a desirable OC curve is exactly followed since $p^*$ corresponds to the inflection point of the OC curve. Hence, MAPD is found from

$$\frac{d^2 Pa(p)}{dp^2} = 0 \text{ for } p = p^*$$

$$\frac{d^2 Pa(p)}{dp^2} > 0 \text{ for } p > p^*$$

and $$\frac{d^2 Pa(p)}{dp^2} < 0 \text{ for } p < p^*$$

The SSP that would discriminate perfectly between good and bad lots would have an ideal OC curve. This would run horizontally at a probability of acceptance of 1.0 until $p^*$, at which point it would drop vertically and then for higher values $p$ would run again horizontally at the probability of acceptance of 0. Thus, in the ideal OC curve $p^*$ is the
quality standard and therefore several authors state that the engineer’s requirements on a quality standard is more or less fulfilled by p*, compared to any other parameter.

**Maximum allowable average outgoing quality (MAAOQ)**

Use of the maximum allowable average outgoing quality (MAAOQ) for deriving sampling plans has been justified by Suresh and Ramkumar (1996). The MAAOQ of single sampling is defined by the average outgoing quality (AOQ) at MAPD, which is a favourable index for the engineers. Since MAAOQ = AOQ at p = p*, it is written as MAAOQ = p* P_a (p*). (MAPD, MAAOQ) indexed plans have a more discriminating OC curve than the plans indexed through (MAPD, AOQL). Considering the simplicity, practicability and more consumer protection offered, the MAAOQ is used as the indexing parameter for the selection of the plan. Radhakrishnan (2004) constructed sampling plan of type CSP-T using MAPD and MAAOQ.

**Non-conforming unit**

A non-conforming unit is one, which does not meet the acceptance criteria established for the characteristic being considered.

**Operating Characteristic (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 the two axes, the axis of p-proportion non-conformities and the axis of Pa (p)-Probability of acceptance of a lot or process, is the locus {p, Pa(p)}. The OC curve gives the practical performance (discriminating power) of the sampling plan. The OC curves are generally classified under type A and type B.

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

For special purpose plans, OC curve is a curve showing, for a specified plan the
probability of continuing to permit the process to continue without adjustment as a function of the process quality.

**Process average**

The process average is defined as the percent defective of product submitted by the supplier for original inspection. Original inspection is the first inspection of a particular quantity of product as distinguished from the inspection of product, which has been resubmitted. The phrases 'Process average', 'lot quality', 'Proportion defective' and 'Percent defective' are used interchangeably.

**Process quality**

ANSI/ASQC standard A2 (1987) defines process quality as a statistical measure for the quality of a product from a given process. The most commonly used measure of process quality is the percentage or proportion of non-conforming units in the process.

**Producer's risk**

ANSI/ASQC standard A2 (1987) defines producer’s risk as follows: “For a given sampling plan, the probability of not accepting product quality of which has a designated numerical value representing a level which it is generally desired to accept on sampling basis”.

**Reliability**

Reliability is the probability of a device performing its purpose adequately for the period intended under the given operating conditions.

**Sampling inspection**

Sampling inspection means inspection of the defects concerned where the inspection units are selected through sampling procedure.

**Sampling plan**

ANSI/ASQC standard A2 (1987) defines an acceptance sampling plan as a specific plan that states the sampling rules to be used, the associated acceptance and non-acceptance criteria and an acceptance sampling scheme in 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% inspection and sampling are related.

**Sampling Scheme**

Sampling scheme is whole set of sampling plans and operations included in the standard ‘The overall strategy specifying the way in which sampling plans are to be used’. The well known sampling schemes are MIL- STD-105D (1963) and Tightened-Normal-Tightened scheme of Calvin (1977).

**Sampling System**

Stephens and Larson (1967) have described a sampling system as assigned group of two or more sampling plans and the rules for using these plans for sentencing lots to achieve a blend of the advantageous features of the each of the sampling plan. The well known sampling systems are MIL- STD-105D (1963) and QSS of Romboski (1969).
Unit of Product

The unit of product is the thing being inspected in order to determine its classification as defective or non-conforming or to count the number of defects. It may be a single article, a set, a length, an operation, a component of an end product or the end product itself.

1.8 GLOSSARY OF SYMBOLS

The list of symbols and abbreviations used frequently in this thesis are as follows:

- \( p \) : submitted quality of lot or process
- \( p_j \) : submitted quality of lot or process ‘j’
- \( P_a(p) \) : probability of acceptance for given quality ‘p’
- \( p_0 \) : the submitted quality such that \( P_a(p_0) = 0.50 \)
- \( p_1 \) : the submitted quality such that \( P_a(p_1) = 0.95 \)
- \( p_2 \) : the submitted quality such that \( P_a(p_2) = 0.50 \)
- \( p^* \) : maximum allowable percent defective (MAPD)
- \( h^* \) : relative slope at ‘p^∗’
- \( s \) : criterion for Tightened inspection
- \( t \) : criterion for Normal inspection
- \( m \) : number of test specimens failed during the Life test.
- \( N \) : lot size
- \( n \) : sample size for each lot
- \( n_1 \) : sample size for Reliability based variable sampling plan
- \( n_2 \) : sample size for attribute sampling plan
- \( n_{1.1} \) : variable sample size for double sampling plan
- \( n_{1.2} \) : first attribute sample size for double sampling plan
- \( n_{2.2} \) : second attribute sample size for double sampling plan
- \( n_T \) : sample size for Tightened inspection
- \( n_N \) : sample size for Normal inspection
- \( c_1 \) : first attribute acceptance number
- \( c_2 \) : second attribute acceptance number
- \( c_3 \) : third attribute acceptance number
\[ \beta_j \] : probability of acceptance for lot quality \( p_j \)
\[ \beta_1 \] : probability of acceptance assigned to first stage for percent defective \( p_j \)
\[ \beta_2 \] : probability of acceptance assigned to second stage for percent defective \( p_j \)
\[ k' \] : variable factor such that a lot is accepted if \( \mu - k' \sigma > \text{L} \).

**AQL** : Acceptance quality level (\( p_1 \))
**IQL** : Indifference quality level (\( p_0 \))
**LQL** : Limiting quality level (\( p_2 \))

**MAAOQ** : Maximum allowable average outgoing quality.

**1.9 CHAPTER SCHEME**

The thesis is divided into six chapters.

The **chapter 1** describes Introduction, Statement of the problem, Objectives of the study, Limitations of the study, Scope of the study, Methodology and materials used and the chapter scheme.

The **chapter 2** describes the operating procedure of various sampling plans and a detailed Review of the Literature.

The **chapter 3** is presented with the construction and selection of RMSPs with single sampling plan and Double sampling plan as attribute plans indexed through various parameters.

The **chapter 4** describes the construction and selection of RMSPs with Chain sampling plans and Tightened-Normal-Tightened sampling plans as basic plans using various parameters.

The **chapter 5** is focussed with the construction and selection of RMSPs with Repetitive group sampling plan and Link sampling plan as basic plans indexed through various parameters.

The **chapter 6** is presented with the conclusions, findings and suggestions for future Research.
CHAPTER II
OPERATING PROCEDURE AND REVIEW OF SAMPLING PLANS

2.1 Operating procedure and Review of Single Sampling plan
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2.10 Operating procedure and Review of Repetitive Group Sampling Plan
2.11 Operating procedure and Review of Conditional Repetitive Group Sampling Plan
2.12 Operating procedure and Review of Link Sampling Plan
2.13 Operating procedure and Review of Reliability based mixed sampling plan.
2.14 Designing of Reliability based mixed sampling plan.
2.15 Summary.