CHAPTER I

INTRODUCTION

INTRODUCTION

The statistical theory and methods are of great help to study the life characteristic of some physical or biological body. For instance, we may desire knowledge concerning the life characteristic of certain type of electronic tube, a type of bacteria or perhaps of a complex system such as a high speed digital computer and so on. The first step in statistical analysis for any problem is collection of relevant information. In general, information are obtained either as the result of a planned laboratory experiment or through the analysis of data obtained from service use of the product. Data obtained from a life test may also be statistically analysed for arriving at certain conclusions. Thus, the basic problem in statistical analysis which arises at first is the summarisation of information contained in the data through a probability model that can describe it. The specification of model usually consists of the following two parts:
a) Assumption of the distribution function which will adequately represent the population of all possible observations (of which the data is a part).

b) The identification of parameters of this distribution(s) or possibly some non-parametric aspect of the distribution itself which we wish to know concerning the actual situation.

Out of these, (b) is more important, though we can develop methods of inference which does not depend on the form of the distribution.

The specification of a life time model is of fundamental importance because inferences are drawn on the basis of such a model and the validity of inferences depend on the appropriateness of the these models. However, situations do exist when there may be uncertainty regarding the specification of a suitable model. This may happen, if we have some additional information about the parameters, but these information may be inadequate and of uncertain validity. Such information may be available either from past experience of the experimenter in the field or from similar studies in the past. In either case the problem is to decide whether or not to use the given information in the analysis of the phenomenon under investigation.

If the model specification is fixed in advance, that is if no attempt is made to use the data from a single sample as an aid
in determining the model specification to be used in subsequent inferences, the analysis is said to be determined by a 'completely specified model'. Alternatively, if the data from a single sample is used to find certain rules of procedures as an aid in determining the final model to be used in subsequent inferences, the analysis is said to be determined by an 'incompletely specified model' and the inference procedure thus obtained is termed as 'inference for incompletely specified model'. In terminology of incompletely specified model, the rule of procedure which is a test and is used for final model specification for subsequent inference is called 'preliminary test of significance' (PTS) and subsequent inference as 'final inference'.

After specifying the model, attempts are made to draw conclusions on the basis of data in hand. The process of going from the known sample to unknown population has been called 'statistical inference'. There are two principal approaches to statistical inference; namely Classical and Bayesian. The classical approach prescribes inferential techniques that are based on the sample information alone and parameter(s) is considered to be fixed. In it, inductive reasoning is used in conjunction with the sample observation to produce inferences about unknown parameters in the assumed model. On the other hand,
in Bayesian approach to inference, the decision is based on an assumed or known prior distribution(s) of the unknown parameter(s).

Two problems in statistical inference are the estimation and the test of hypothesis. The problem of estimation of parameter involves the choice of a function (real or vector valued) of sample values which is independent of the unknown parameter $\theta$. This function is called 'Statistic'. The estimation of the parameter could however be done in two ways, viz., (i) point estimation, and (ii) interval estimation. The theory of estimation was propounded by Professor R.A. Fisher in a series of papers.

The problem of test of hypothesis deals with testing the statistical hypothesis (which is an assumption or statement about the population), by a certain rule or procedure. In both randomized and non-randomized tests, the size of the sample is fixed in advance as in Neyman-Pearson's theory or is a random variable in sequential procedure developed by Abraham Wald. The decision making process is amounts to choosing the test of hypothesis.

In drawing inferences for incompletely specified models, although the effect of preliminary test of significance must be
taken into account, it is assumed that the final inference is the main objective. In case final inference is point estimation, the Bias and Mean Squared Error (MSE) are used as criteria in evaluation and comparison of the estimator; in particular with those based on completely specified model. Since Minimum Mean Squared Error (MMSE) seems to be a desirable practical feature for a point estimator, the choice between different point estimators (unbiased or slightly biased) is made on the basis of the MSE.

In case final inference is interval estimation, the confidence coefficient and average length of the interval are used as criteria in evaluating the interval estimator and in comparing them with corresponding interval estimator(s) obtained from alternative procedure(s); in particular those based on completely specified models. The shortness of the average length of an interval is a desirable practical feature for an interval estimator and thus for the choice between different possible interval estimators with preassigned confidence coefficient shortness of the interval has been used as a basis.

In case, the final inference is hypothesis testing, control of size and power of the final test are used as criteria in evaluating the characteristic of the final test and in comparing such a test with corresponding tests obtained from alternative procedures.
The use of preliminary test of significance was initially proposed by Bancroft (1944) for the estimation of population variance. Later, a number of authors has considered the use of this procedure in different problems. Paull (1948,50), Bechhofer (1951 a,b), Bozivich et al. (1956 a,b), Srivastava (1960,64), Srivastava and Bozivich (1961), Gupta and Srivastava (1969), Singh and Lele (1970), Srivastava (1972), Singh (1977) among others have considered the use of preliminary use of significance for analysis of variance problem. The theory of incompletely specified model have also been discussed by Mosteller (1948) Kitagawa (1950,59), Bennett (1952), Huntsberger (1955,56), Davis and Arnold (1970), Saleh (1973 a,b).


Kitagawa (1963) and Bancroft (1964, b, 65, 75) have described a number of examples of Inference for incompletely specified models. Bancroft (1964 a) summarised the common features of the procedures used in the above special methodological investigations and formulated a general
statistical inference theory for incompletely specified models. From time to time bibliography related to the use of theory of Incompletely specified model has been published by various authors (cf. Bancroft and Han (1977), Rao and Ravichandran (1987) Han et al. (1988), etc.).

In life testing problem, classical inference has widely been used. As mentioned earlier, the data to which the statistical methods are applied in order to estimate the parameters of interest in estimation (point or interval) context normally result from life tests. In a life test, a number of items are subjected to test and data consist of recorded failure times of all or some of the items. No matter how efficient the manufacturing process is, one or more failures do occur. Naturally, the failure times will be order-statistics. The theory of order statistics plays an important role in the analysis of the life test data. Furthermore, since the item is likely to fail at any time, it is quite customary to assume that the life of the item is a random variable with cumulative distribution function $F(.)$ which is the probability that the items fail before time$(.)$.

If a random sample of items drawn from a population is tested until all the items fail, conventional statistical techniques may be employed; although in many cases, the
assumption that underlying frequency distributions are normal, will not be satisfied. A second difficulty encountered in using conventional methods in industrial life test is the expense and time involved in waiting for all the test items to fail. For this reason, many industrial life tests are terminated before all the items fail. A sample obtained from such a test is said to be censored. There are two main types of censoring viz. type I and type II.

If the life test is terminated at a specified time before all the n items have failed, one speaks of type I censoring of the life test. Type II censoring, on the other hand, occurs when the life test is terminated at the time of a particular failure (say, the rth run). In type I censoring, the number of failures and all the failure times are random variables; whereas in type II censoring the number of failures is considered fixed and the only random variables are failure times. Censoring may also be conducted progressively, that is, items may be removed from life test throughout the duration of the test. Apart from these censoring procedures, other procedures such as random censoring, hybrid censoring, etc., have also gained some acceptability in recent years e.g. Lawless (1982), Mann et al. (1978), Bain (1978); but a discussion of these is not considered in this thesis.
It has already been stated that the failure time or life time of an item is random variable with some probability distribution. It is therefore, necessary to appeal to a concept that makes it possible to distinguish between different distribution functions on the basis of a physical considerations of the test items. Such a concept is based on the failure rate or hazard rate and is defined as

\[ h(x) = \frac{f(x)}{1 - F(x)} \]  

(1.1)

where \( F(x) \) is the distribution function of the random variable \( x \) (the failure time) and \( f(x) \) is its probability density function. The hazard rate, which is a function of time has a probabilistic interpolation; namely, \( h(x) \, dx \) which represents the probability that a device of age \( x \) will fail in the interval \( (x, x+dx) \).

On the basis of physical considerations one is at liberty to choose the functional form of \( h(x) \) for a particular device. There are many plausible candidates for the distribution of \( x \), including the exponential, Weibull, gamma, log normal and even the normal distribution. There can be three types of failure rate models depending on \( h(x) \), increasing failure rate (IFR) models, decreasing failure rate (DFR) models and constant failure rate model (CFR). The exponential distribution is the constant failure rate model. The normal distribution is an IFR model but for this, the expression for \( h(x) \) cannot be obtained in closed form.
Since the present thesis deals with the inferential procedures for Exponential and Normal distributions only, the other failure time distributions are not discussed at all.

EXPONENTIAL DISTRIBUTION

The exponential distribution is perhaps the first lifetime model for which statistical methods were extensively developed. Several authors have used this particular model e.g. Sukhatme (1937), Epstein and Sobel (1953, 1954, 1955) and Epstein (1954, 1958, 1960) etc. and popularised it as a lifetime distribution, especially in the area of industrial life testing. Davis (1952) examined the different types of data and observed that the exponential distribution appears to fit quite well in most of the situations. Maguire et al. (1952) studied mine accidents and showed that time interval between accidents follows exponential distribution. Epstein (1958) has rightly remarked that the exponential distribution has the same important role in life testing experiments as the normal distribution in other fields of statistics.

Epstein and Sobel (1953) discussed the exponential distribution as a failure model in life testing with censored observations. Let $x_{(1)} \leq x_{(2)} \leq \ldots \leq x_{(r)}$ be first $r$ failure times out
of a total of \( n \) items put through a life test. The failure time \( x \) is assumed to follow a two-parameter exponential distribution with probability density function

\[
f(x; A, \theta) = \begin{cases} \frac{1}{\theta} \exp[-(x - A)/\theta] & , \; x \geq A \text{ and } \theta > 0 \\ 0 & , \; \text{otherwise} \end{cases} \tag{1.2}
\]

where \( \theta \) is scale parameter and \( A \) is location parameter. \( A \) is interpreted as an unknown point at which life begins or as minimum guarantee period (cf. Epstein and Sobel (1954)) or shift or threshold parameter (cf. Mann et al. (1974)) within which no failure can occur.

The maximum likelihood estimator (MLE) of the parameters \( A \) and \( \theta \) are obtained as

\[
\hat{A} = x(1)
\]

and

\[
\hat{\theta} = \frac{S_r}{r}
\]

respectively, where

\[
S_r = \sum_{i=1}^{r} (x(i) - x(1)) + (n - r)(x(r) - x(1))
\]

It has been shown that \( \hat{A} \) and \( \hat{\theta} \) are jointly sufficient for \( A \) and \( \theta \) and these statistics are also complete (cf. Tukey (1949) and Smith (1957)).
The uniformly minimum variance unbiased estimator (UMVUE) of \( \theta \) is obtained as

\[
\hat{\theta} = S_r / (r-1)
\]

with variance \( \theta^2 / (r-1) \). The statistics \( W = 2(\bar{x}_1 - A) / \theta \) and \( V = 2S_r / \theta \) follows independent chi-square distributions with 2 and \((2r-2)\) degrees of freedom respectively.

Epstein and Sobel (1954) obtained estimators of location and scale parameters as a function of MLE and showed that their estimators were minimum variance unbiased estimator (MVUE). Lloyd (1952) discussed a method for obtaining best linear unbiased estimators (BLUE) of the parameters of exponential distribution. Sarhan (1954) employed the method derived by Lloyd (1952) to obtain BLUE's of parameters for two-parameter exponential distribution in case of complete sampling. Several authors have considered the problems arising in singly censored sample \((k=1)\) from two-parameter exponential distribution; for example, Sarhan (1955), and Epstein (1956). These authors have mainly considered the BLUE's and simplified linear estimators involving linear function of order statistics. The main reason for studying these estimators instead of MLE's was their simplicity and uncertainty about the performance of MLE's in small samples. For \( k=1 \), approximate expressions for the MLE's
were given by Tiku (1967). Later Kambo (1978) obtained exact expressions for MLE's and showed that for the scale parameter $\theta$, the MLE $\hat{\theta}$ has a smaller MSE than that of BLUE $\hat{\theta}$. Anscombe (1960), Kale and Sinha (1971), and Barnett and Lewis (1978) have studied in detail problems of estimating the parameters in the presence of outlier for exponential distribution.

Pandey (1982), Pandey and Singh (1983), Pandey and Shrivastava (1985) applied the Shrinkage technique of Thompson (1968, a,b) in improving the estimates of the parameters in exponential distribution.

Pandey and Singh (1979) obtained MMSE estimator of common scale parameter $\theta$ based on complete sample from $k(=2)$ exponential distributions. BLUEs and MLE's of location parameters and common scale parameter based on type II doubly censored samples from $k(\geq 1)$ exponential distributions are obtained by Shetty and Joshi (1987). Several authors have studied the problems arising in doubly censored samples from $k$ exponential distributions; for example, Khatri (1981), Tiku (1981), Kambo and Awad (1985), and Samanta (1985). The general approach is to consider the estimation based on $k$ specific components or order statistics (cf. Sinha (1985)).

The confidence interval for $A$ and $\theta$ can be obtained by considering the pivotal quantities $T_2$ and $V$ where
\[ T_2 = \frac{n(r-1)(\hat{A}-A)}{\theta^2} \sim F(2, 2r-2) \]

and

\[ V = \sum_{i=1}^{n}(x_i - \bar{x}) \]

respectively.

Mann et al. (1974), Aitchenson and Dunsmore (1975) discussed a method for obtaining the prediction intervals for sample observations, based on the first \( r \) observations. More information about inferential procedures regarding two-parameter exponential distribution is given in Johnson and Kotz (1970), Martz and Waller (1982) and Sinha (1985) among others.

The concept of PTS has been used by different workers in different fields of investigation. Bancroft (1944) was the first mathematical-statistician to consider the impact of a PTS on subsequent estimation. He suggested the use of PTS to decide whether to use both samples or not. Effect of using PTS on final inference has been studied by many others. For a complete reference, bibliographies compiled by Bancroft and Han (1977) and Rao and Ravichandran (1987) may be used. Procedure based on PTS in life testing problems have also been studied by Richard (1963), Saxena and Gupta (1985), Gupta and Singh (1985) & Singh et al. (1989).

Bhattacharya and Shrivastava (1974) proposed the use of PTS to get a more efficient estimator of the exponential
distributions in the presence of an apriori estimate. Bhatkulikar (1978) has also considered a similar procedure. Recently, Gupta et al. (1991) proposed a preliminary test shrinkage estimator based on MMSE estimator of average life of exponential distribution in type II censored data and also used the PTS to decide whether to use a one or two-parameter exponential distribution in the given case.

In many situations, it is commonly noted that the population standard deviation is proportional to the population mean, i.e. coefficient of variation is known (cf. Sen (1978) and Ebrahimi (1984)). Assuming that there is a linear relationship between the parameters of a two-parameter exponential distribution, the distribution reduces to one with known coefficient of variation (CV) as

\[
f(x; \theta) = \begin{cases} 
\frac{1}{a\theta} \exp\left[-\frac{(x-\theta)}{a\theta}\right] & , x \geq \theta, \theta > 0 \\
0 & , \text{otherwise}
\end{cases} \tag{1.3}
\]

where \( \theta > 0 \) is unknown, but \( a > 0 \) is known and its choice depends on the value of CV. Let \( x^{(1)} \leq x^{(2)} \leq \ldots \leq x^{(r)} \) be the ordered first failure time of a random sample of size \( n \) from an exponential distribution and thus, the failure times constitute a type II censored sample.
The MLE of $\theta$ is obtained as
\[ \hat{\theta} = \min \left( \chi_{(1)}, \theta^{-1} (Sr + n \chi_{(1)}) \right). \]

It has been shown that $(\chi_{(1)}, Sr)$ is minimal sufficient for $\theta$ but not complete.

The MVUE among all the unbiased estimators of the form $c_1 \chi_{(1)} + c_2 Sr$ for $\theta$ is obtained as
\[ \hat{\theta}^{**} = \frac{n(n+a) \chi_{(1)} + a Sr}{(a+n)^2 + a^2 (r-1)} \]

with variance $a^2 \theta^2 / ((a+n)^2 + a^2 (r-1))$.

The statistics $T_1 = 2(\chi_{(1)} - \theta) / a \theta$ and $T_2 = 2Sr / a \theta$ follow independent chi-square distributions with 2 and $2r-2$ degrees of freedom respectively.

Ghosh and Razmpour (1982) have considered the estimation problem of $\theta$ with known CV for complete sample case and have proposed several estimators including the MLE and best scale invariant estimator. Problem of inference related to the above mentioned model (1.3) have also been considered by Joshi and Sathe (1983), Samanta (1984 & 1985) and Ebrahimi (1985).

Joshi and Nabar (1991) studied the testing problem of the scale parameter of an exponential distribution with known coefficient of variation when location parameter is known constant multiple of scale parameter for uncensored sample situation. Both sequential and non-sequential testing procedures
have been proposed by them and studies regarding expected sample size in null case has also been made.

The problem of testing of hypotheses has also been studied by many authors for complete as well as censored samples in two-parameter exponential distribution. Epstein and Tsao (1953) have discussed the likelihood ratio (LR) test procedure based on right censored sample. Kumar and Patel (1971) have proposed a test based on intuitive considerations for right censored samples. This has been extended by Tiku (1981) and Khatri (1981) for doubly censored samples. Test against one-sided alternatives have been studied by Shetty and Joshi (1986). Singh (1983) considered the problem of testing \( H_0: \theta_1 = \theta_2 = \ldots = \theta_k \) under type II censored sample from two-parameter exponential distribution. LR test procedure for testing equality of location parameters of two two-parameter exponential distributions from doubly censored samples have been discussed by Shetty and Joshi (1989). Carlos and Samual (1983) suggested two new tests for two-parameter exponential distribution. For complete data, generalized LR tests for testing the equality of location and/or the equality of the scale parameters are derived in Sukhatme (1937) and Khatri (1974). Mantelle and Ghosh (1987) considered generalized LR tests for the equality of the location parameters and/or the failure rates of \( K \) independent location and scale parameter exponentials when observations are censored in time.
NORMAL DISTRIBUTION

Normal distribution plays a very important role in statistical theory as well as method. Epstein (1958) remarked that the exponential distribution plays as important a role in life testing experiment as the part played by the normal distribution in agricultural experiments for the effect of different treatments on the yield. On the other hand, suitability of normal distribution as a life time model has been highlighted by many authors including Davis (1952) and Bazovsky (1961), among others. It gives quite a good fit for failure time data relating to, for example, failure times for a large number of incandescent lamps. Let \( x_1, x_2, \ldots, x_n \) be a random sample of size \( n \) from a normal distribution with mean \( \mu \) and variance \( \sigma^2 \), denoted by \( N(\mu, \sigma^2) \). The MLE's of \( \mu \) and \( \sigma^2 \) are obtained as

\[
\hat{\mu} = \overline{x}, \quad \text{and} \quad \hat{\sigma}^2 = \frac{S^2}{n},
\]

where \( \overline{x} \) and \( S^2 \) are sample mean and sum of squares of deviation and given as

\[
\overline{x} = \frac{1}{n} \sum_{i=1}^{n} x_i,
\]

and

\[
S^2 = \sum_{i=1}^{n} (x_i - \overline{x})^2.
\]
Lehmann and Scheffe (1955) shown that \((\bar{x}, s^2)\) are jointly complete for \((\mu, \sigma^2)\).

The MVUE of \(\mu\) and \(\sigma^2\) are obtained as

\[ \hat{\mu} = \bar{x}, \]

and

\[ \hat{\sigma}^2 = \frac{s^2}{n - 1}. \]

The familiarity with the experimental material in practical fields, often enables the investigator to acquire quite accurate knowledge of the CV, say \(C = \pi / \theta\). (cf. Snedecor (1946), Davis and Goldsmith (1976)). This knowledge has been utilized in improving the usual estimator of some unknown parameter.

Searls (1964) has proposed an improved estimator of mean, of the type \(\overline{Mx}\) which can be used if the CV is known. Hirano (1973) showed that irrespective of the correctness of the known value of \(C\), the proposed estimator is more efficient than usual estimator \(\bar{x}\) if \(0 < r < \sqrt{2n/(n-C^2)}\), where \(r\) is the ratio of the prior value and true value of \(C\).

Knowledge of the coefficient of kurtosis \(\beta_2\) has been used by Singh et al. (1973) for improving the estimator of variance. Pandey (1973) has also proposed improved estimators of the common mean and common variance of two populations when CV and kurtosis, respectively, were known for both the populations.
Khan (1968) proposed a linear combination of sample mean and the sample standard deviation for estimating the mean of a normal population $N(\theta, \sigma^2)$, where $\sigma > 0$, is known. Under the same condition Govindarajulu and Sahai (1972) have proposed various estimators of $\theta$ which are based on order statistics. The estimator of $\sigma^2$ proposed by them are linear combination of $x^2$ and $S^2$. Since the estimators of $\theta$ and $\sigma^2$ proposed by Khan (1968) and Govindarajulu and Sahai (1972) become negative with positive probability in sampling from normal population, Das (1975) suggested alternative estimators of $\sigma^2$, which are always positive.

Singh and Pandey (1975) have considered the problem of estimation of variance when CV is known. Considering, in particular, a normal population, they suggested a number of estimators for $\sigma^2$. Utilizing the prior information on CV several authors also discussed the problem of estimating the parameters $\theta$ and $\sigma^2$ of a normal population $N(\theta, \sigma^2)$ and suggested a number of estimators (cf. Searls (1967), Gleser and Healy (1976), Joshi & Sathe (1976), Hinkley (1977), Sen (1978, 1979), Prasad and Sahai (1983), Ebrahimi (1984), Upadhyaya and Singh (1984), Singh (1985), Singh and Upadhyaya (1985)).

Very few authors have paid attention to the estimation of common parameter of two normal distributions utilizing the prior
information on CV (cf. Pandey and Singh (1978), Sahai et al (1983), and Singh and Katyar (1988)). Estimation of variance of sample mean using knowledge of CV has been studied by Lee (1981) and Singh (1986).

The problem of testing the mean of normal distribution using known CV has been considered by Khan (1978). In spite of this model, the estimation of mean of an inverse Gaussian distribution with known CV has been studied by Hirano and Iwas (1989), and Joshi and Shah (1991).

PROBLEMS UNDER INVESTIGATION

The present investigation deals with some inferential procedures for lifetime distributions. We have confined ourself to two-parameter exponential and normal distributions only. Besides these, a number of other distributions are also proposed in literature which may be suitable model for life data in certain situations. However, we aim to describe certain procedures for point estimation and interval estimation of the parameters of exponential distribution. Test and estimation procedures for the parameters of the assumed models have also been dealt with.

This thesis consists of five Chapters. The present Chapter discusses a general idea of the statistical inference and life
testing concept. A brief description of the models considered along with relevant references is also given. The organisation of thesis appears at the end of this Chapter.

For the problems of Chapter II and Chapter III, let \( x_{11} \leq x_{12} \leq \ldots \leq x_{1r_1} \) and \( x_{21} \leq x_{22} \leq \ldots \leq x_{2r_2} \) be the samples singly censored on the right from two parameter exponential distribution with parameter \( A_i, \theta_i, i=1,2 \) and we are interested in point estimation of \( \theta_1 \), when it is suspected that \( \theta_1 = \theta_2 \) and/or \( A_1 = A_2 \). In such a case we apply a PTS for testing the hypothesis \( H_{p_0} : \theta_1 = \theta_2 \) against \( H_{p_1} : \theta_1 > \theta_2 \) and \( H_{p_0} : A_1 = A_2 \) against \( H_{p_1} : A_1 > A_2 \). If the preliminary test provides no evidence against the hypotheses \( H_{p_0} \) and \( H_{p_0} \), we use both set of observations for the point estimation and for finding lower confidence limit. On the other hand, if \( H_{p_0} \) and \( H_{p_0} \) are rejected, we use only the first set of observations. The test statistics for testing the hypotheses \( H_{p_0} \) and \( H_{p_0} \) have been given by Epstein and Tsao (1953). Therefore in Chapter II, a preliminary test estimator for the estimation of scale parameter \( \theta_1 \), when it is suspected that \( \theta_1 \)'s and \( A_1 \)'s may be equal, has been proposed. We have derived the mean value and MSE of the proposed estimator of \( \theta_1 \) for life data based on PTS. The results of Bias, MSE and relative efficiency of the preliminary test estimator are discussed for selected degrees of freedom and PTS and recommendations regarding the use of proposed estimator have been made.
In Chapter III, a preliminary test lower confidence limit for $\theta$, when it is suspected that $\theta_i$'s and $A_i$'s may be equal, has been proposed. The expression for confidence coefficient and mean value of the confidence limit based on PTS have been derived. The results have been discussed for selected combination of degrees of freedom and PTS and recommendations have also been made regarding the use of proposed confidence limit.

In many experiments, particularly in physical and biological sciences, the population standard deviation is proportional to the population mean, i.e. CV exhibits stability and its value may be fairly and accurately known which may be gainfully employed in development of estimation and testing procedures. Chapter IV provides the test procedures for testing the location parameter under the assumption that there is a linear relationship between the parameters of a two-parameter exponential distribution i.e. CV is known. In order to compare the performance of these tests procedures their powers have been obtained. The proposed test procedures have been compared and recommendations regarding their use have been made.

In a field of life testing experiments, besides exponential distribution, several situations in physical sciences have been cited by authors Davis (1952) and Bazovsky (1961)
among others when normal distribution provides a good fit for failure time data. Therefore, Chapter V that deals with the problem of estimation of scale parameter for exponential and normal distribution for failure time data, has been divided into two parts—Part A and Part B. For the Problem in Part A, we may recall that when a producer of a costly electronic item desires to find out the average excess life of his products on the basis of k sets of items, the estimation of common average excess life (common scale parameter) requires due attention. Therefore, first part of the Chapter V, we have considered the problem of estimation of common scale parameter of k two-parameter exponential distributions and have proposed the improved estimator under each of the three situations that is (i) when location parameters are known, (ii) when location parameters are equal but common value is unknown and, (iii) when locations parameters are unknown. The expression for MSE in each case has been derived. Efficiency of the proposed estimators vis-à-vis usual estimator in the three situations has been discussed and conclusions thereon have been given. Part B of the Chapter deals with the problem of estimation of scale parameter of the normal distribution case with known CV. In this part we have proposed a MMSE estimator for scale parameter and expression for Bias and MSE have been developed. Efficiency of the proposed MMSE
estimator relative to the estimator that was best in the group suggested by Singh and Pondey (1975) has been discussed along with recommendations regarding use of the proposed MMSE estimator.