Chapter 6

Conclusion and future works

Software reliability is the probability that the software will be functioning without
failure during a specified period of time under the given environmental conditions.

One of the most challenging problems faced in the software industry is to develop
reliable software and software reliability is the most significant component of contin-
uous application availability. Software reliability models play an important role in
developing software systems and enhancing the performance of computer software.

The concept of ageing has an important role in reliability analysis and in identifying
life distributions. Ageing describe how a system improves or deteriorates with age.
Many classes of life distributions are categorized or defined according to their ageing
properties.

One of the well established branch of statistics is the reliability analysis, that deals
with the statistical study of different aspects of lifetimes of a system or components of a system. We have already pointed out earlier that major part of the theory and applications in connection with reliability analysis were discussed based on the measures in terms of distribution function. In the beginning chapters of this work, we have described some attractive features of quantile functions and the relevance of its use in reliability analysis. [Parzen, 1979] emphasized the representation of a distribution in terms of quantile function and its role in data analysis and modelling. [Gilchrist, 2000] systematically presented various properties of quantile function and its use in statistical modelling. Motivated by the works of [Parzen, 1979] and [Gilchrist, 2000], who indicated the scope of quantile functions in reliability analysis and as a follow up of the systematic study in this connection by [Nair and Sankaran, 2009b], in the present thesis we tried to extend their ideas to develop necessary theoretical framework for lifetime data analysis.

The study of the reliability properties associated along with probability distribution function $F(x)$, density function $f(x)$ and survival function $\bar{F}(x) = 1 - F(x)$ along with various other characteristics such as failure rate, mean, percentiles, higher moments of residual life, etc., are used for understanding how the failure time data arises in practice. A systematic study on the application of quantile function in reliability studies have been carried out by [Nair and Sankaran, 2009b]. They have discussed commonly used reliability measures in terms of quantile functions and various relationships connecting them were derived. They have also analysed quantile function model discussed in [Hankin and Lee, 2006] in the context of reliability
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analysis. Our present work extended these ideas to develop necessary theoretical framework for modelling and data analysis of software reliability data based on quantile functions. This new approach provides us an alternative methodology and new models that have desirable properties. In this study we considered quantile based reliability analysis such as identifying quantile functions that are useful in software reliability, defining new families of quantile functions using various properties of reliability functions and related measures.

In Chapter 2 we gave brief description of definitions and properties of quantile functions, some measures like hazard function, mean residual function, moments, percentiles etc., based on distribution function approach as well as quantile function approach. We explained L-moments which are alternative to conventional moments and have several advantages over usual moments. Different reliability characteristics based on distribution function and their equivalent quantile based functions were also discussed. The total time on test transform (TTT) and various other relationships were also presented. We described the Q-Q plot, a useful tool to check the validity of the quantile function for a given dataset.

In Chapter 3 we have introduced a software reliability model using quantile function and studied its various properties. It is observed that the proposed class has several desirable properties and several existing well known distributions are members of the class of distributions as special cases or through approximations. Various reliability characteristics were discussed. The parameters of the model were estimated using L-moments and the model was applied to a real data set. The approximation to two
well known distributions, ie, inverse Gaussian distribution and Weibull distribution, were also carried out.

We also presented a class of distributions based on the hazard quantile function and studied its various properties in Chapter 4. Several existing well known lifetime distributions are members of the class of distributions as special cases or through approximations. Various reliability characteristics were discussed. The parameters of the model were estimated using the method of L-moments and the model was applied to a real data set. Non parametric estimator of $H(u)$ given in [Nair and Sankaran, 2009a] can be employed in practice to identify the approximate lifetime model for a given dataset.

We have discussed a family of distributions having inverse linear form for mean residual function $M(u)$ and studied its various properties in Chapter 5. The proposed class has several desirable properties and various reliability characteristics. Several existing well known distributions were members of the class of distributions as special cases or through approximations. We have also derived useful characterizations connecting identities among $M(u)$, $H(u)$, $V(u)$ and $T(u)$. The parameters of the model were estimated using L-moments and the model was applied to two real data sets.
6.0.1 Future works

On the basis of the present study and continuing demand for new models in software reliability theory, the following problems need resolution.

- In the present work we have introduced new classes of quantile function models based on various functional forms of hazard quantile function and mean residual quantile. Concepts such as variance residual quantile function and reversed hazard quantile function can also be employed to develop new models. The works in this direction will be carried out later.

- In reliability theory censoring is common due to various reasons. The development of inference procedures of the proposed models under censoring is a topic to be addressed.

- In this thesis we have employed the method of L-moments for the estimation of parameters. Other methods of estimation like method of maximum likelihood, method of absolute deviation and method of percentiles can also be used for the analysis of software reliability data. A comparative study on efficiency of these methods is an area of research that remains to be explored.

- In reliability regression models are often used to understand and study the relationship of covariates and lifetimes. Quantile regression models are recently employed to assess the effect of covariates on the lifetime. The analysis of
software reliability data in the presence of covariates is a topic of study that yet to be carried out.