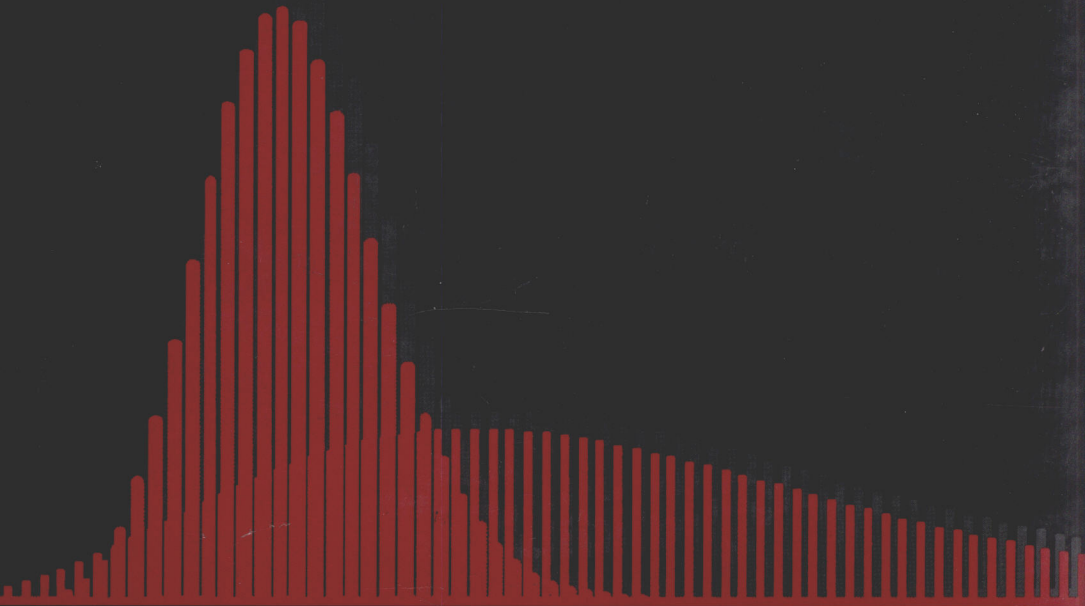


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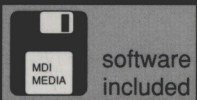
A Practical Guide



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Reliability Engineering and Risk Analysis

A Practical Guide

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About the Series

The genesis of modern methods of quality and reliability will be found in a sample memo dated May 16, 1924, in which Walter A. Shewhart proposed the control chart for the analysis of inspection data. This led to a broadening of the concept of inspection from emphasis on detection and correction of defective material to control of quality through analysis and prevention of quality problems. Subsequent concern for product performance in the hands of the user stimulated development of the systems and techniques of reliability. Emphasis on the consumer as the ultimate judge of quality serves as the catalyst to bring about the integration of the methodology of quality with that of reliability. Thus, the innovations that came out of the control chart spawned a philosophy of control of quality and reliability that has come to include not only the methodology of the statistical sciences and engineering, but also the use of appropriate management methods together with various motivational procedures in a concerted effort dedicated to quality improvement.

This series is intended to provide a vehicle to foster interaction of the elements of the modern approach to quality, including statistical applications, quality and reliability engineering, management, and motivational aspects. It is a forum in which the subject matter of these various areas can be brought together to allow for effective integration of appropriate techniques. This will promote the true benefit of each, which can be achieved only through their interaction. In this sense, the whole of quality and reliability is greater than the sum of its parts, as each element augments the others.

The contributors to this series have been encouraged to discuss fundamental concepts as well as methodology, technology, and procedures at the leading edge of the discipline. Thus, new concepts are placed in proper perspective in these evolving disciplines. The series is intended for those in manufacturing,

engineering, and marketing and management, as well as the consuming public, all of whom have an interest and stake in the products and services that are the lifeblood of the economic system.

The modern approach to quality and reliability concerns excellence: excellence when the product is designed, excellence when the product is made, excellence as the product is used, and excellence throughout its lifetime. But excellence does not result without effort, and products and services of superior quality and reliability require an appropriate combination of statistical, engineering, management, and motivational effort. This effort can be directed for maximum benefit only in light of timely knowledge of approaches and methods that have been developed and are available in these areas of expertise. Within the volumes of this series, the reader will find the means to create, control, correct, and improve quality and reliability in ways that are cost effective, that enhance productivity, and that create a motivational atmosphere that is harmonious and constructive. It is dedicated to that end and to the readers whose study of quality and reliability will lead to greater understanding of their products, their processes, their workplaces, and themselves.

Edward G. Schilling

Preface

This book provides a practical and comprehensive overview of reliability and risk analysis techniques. It is written both for engineering students at the undergraduate and graduate levels and for practicing engineers. The book concentrates mainly on reliability analysis. In addition, elementary performance and risk analysis techniques have also been presented. Since reliability analysis is a multidisciplinary subject, the scope is not limited to any one engineering discipline; rather, the material is applicable to most engineering disciplines. The contents of the book are based primarily on the materials used in three courses at the senior and undergraduate and graduate levels at the University of Maryland, College Park. These courses have been offered over the past 15 years. This book has benefited greatly from the contribution of many talented students who actively participated in gathering and updating practical and useful materials. Therefore, the book presents a large number of examples to clarify technical subjects. Additionally, there are many end-of-chapter exercises that are based mainly on the prior exams and homework problem sets of the reliability and risk analysis courses at the University of Maryland.

The emphasis of the book is the introduction and explanation of methods and techniques used in reliability and risk studies, and discussion of their use and limitations rather than detailed derivations. These methods and techniques cover a wide range of topics that arise in routine reliability engineering and risk analysis activities. The book assumes that the readers have little or no background in probability and statistics. Thus, following an introductory chapter (Chapter 1) that defines reliability, availability, and risk analysis, Chapter 2 provides a detailed review of probability and statistics essential to understanding the reliability methods discussed in the book.

We have developed a software tool (called RARE—Reliability and Risk Evaluator) using Microsoft's Excel™ that automates the techniques and methods

discussed in this book. This software is educational in nature and is intended to help students practice applications of these important methods and to reduce the computational burden. Furthermore, it is a finalized software tool that can be used to analyze a wide variety of real-world reliability data. The RARE software has a simple interface that allows users to easily perform their calculations. Also, the results of the calculations are summarized in a useful and simple graphical and/or tabular format for report generation. The reliability methods for which an application routine has been developed in RARE have been clearly identified in the book. Appendix D contains a user's manual for RARE.

We have structured the book so that reliability methods applied to component reliability are described first (Chapter 3). This is because components are the most basic building blocks of engineering systems. The techniques discussed in Chapter 3 provide a comprehensive overview of the state-of-the-art in transforming basic field data into estimates of component reliability. Chapter 4 describes these analytical methods in the context of a more complex engineering unit; that is, a system containing many interacting components. Chapter 4 introduces new analysis methods using the results of the component reliability analysis described in Chapter 3 to calculate estimates of the reliability of the whole system that is composed of these components. The material in Chapters 1 through 4 are appropriate for an advanced undergraduate course in reliability engineering, or an introductory graduate level course.

Chapters 3 and 4 assume that the components (or systems) are "replaceable." That is, upon a failure, the component is replaced with a new one. However, many components are "repairable." That is, upon a failure they are repaired and placed back into service. In this case, availability as a metric becomes the key measure of performance. The techniques for availability and reliability analysis of repairable components and systems are discussed in Chapter 5. This chapter also explains the corresponding use of the analytical methods discussed in Chapters 3 and 4 when performing availability analysis of components and engineering systems.

Chapter 6 discusses a number of important methods frequently used in modeling reliability, availability, and risk problems. For example, in Section 6.2, we discuss the concept of uncertainty, sources of uncertainty, parameter and model uncertainty, and probabilistic methods for quantifying and propagating parameter uncertainties in engineering systems (or models). Similar to Chapter 6, Chapter 7 describes special topics related to reliability and availability data analysis. For example Section 7.1 describes accelerated life testing methods. Examples clarifying uses of modeling and data analysis methods and their shortcomings are also presented in Chapters 6 and 7.

In Chapter 8, we discuss the method of risk analysis. A number of the analytical methods explained in the preceding chapters have been integrated to

perform risk assessment or risk management. Recently, probabilistic risk assessment (PRA) has been a major topic of interest in light of hazards imposed by many engineering designs and processes. Steps involving performance of a PRA are discussed in this chapter.

A complete solution set booklet has been developed by W. M. Webb and M. Modarres. This booklet may be provided to educators and industrial users by sending a written request to the publisher.

The authors are especially thankful to Dr. Daniel Young for writing the discussions on Electrical Failure Mechanisms in Section 1.3. The book could have not been completed without the help and corrections of our students and colleagues at the University of Maryland. It would be difficult to name all, but some names to mention include: Drs. L. Chen, H. Dezfuli, Y. Guan, H. Hadavi, K. Hsueh, N. Kececi, D. Koo, A. Mosleh, J. Ruiz, C. Smidts, and J. N. Wang. We would also like to acknowledge J. Case of Ford Motor Company for his review and valuable suggestions on the FMEA and reliability growth sections of the book. Special thanks goes to Y. S. Hu for his unfailing technical and organizational support without which this work would have not been possible. Finally, the editorial help of D. Grimsman and typing and graphical support of W. M. Webb are highly appreciated.

Mohammad Modarres
Mark Kaminskiy
Vasiliy Krivtsov

Reliability Engineering and Risk Analysis

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