Table of contents

Preface v

Contributors xix

PART I. RELIABILITY MODELS

Ch. 1. Basic Probabilistic Models in Reliability 1
N. Balakrishnan, N. Limnios and C. Papadopoulos

1. Introduction 2
2. Discrete time Markov chains and reliability 3
3. Continuous time Markov chains and reliability 11
4. Semi-Markov processes and reliability 15
5. Monte Carlo methods in reliability 21
6. Variance reduction methods 25
7. Simulation for semi-Markov systems 36
References 40

Ch. 2. The Weibull Nonhomogeneous Poisson Process 43
Asit P. Basu and Steven E. Rigdon

1 The Poisson processes 43
2. Models for the reliability of repairable systems 45
3. Some data sets 46
4. Point and interval estimation for the power law process 49
5. Goodness-of-fit tests 57
6. Estimation of the intensity function 58
7. Multiple systems modeled with the power law process 60
8. An extension of the power law process 66
References 68

PART II. LIFE DISTRIBUTIONS

Ch. 3. Bathtub-Shaped Failure Rate Life Distributions 69
C. D. Lai, M. Xie and D. N. P. Murthy

1. Introduction 69
2. Notions of aging 70
3. Bathtub-shaped failure rate life distributions 72
4. Families of bathtub-shaped failure rate distributions 76
5. Construction techniques for BFR distributions 81
6. Tests of exponentiality versus bathtub distribution 83
7. Change point estimations for BFR distributions 85
8. Applications 86
9. Mean residual life and bathtub shaped life distributions 88
10. Optimal burn-in time for bathtub distributions 91
11. Models extending the traditional BFR distributions 95
References 99

Ch. 4. Equilibrium Distribution – its Role in Reliability Theory 105
A. Chatterjee and S. P. Mukherjee

1. Introduction 105
2. History and genesis 106
3. Equilibrium distributions and dominance relations 107
4. Equilibrium distributions of higher orders: Properties and generalized order relations 108
5. Closure of generalized order relations 114
6. Equilibrium distribution in higher dimension 124
7. Equilibrium distribution in the context of repairable system 131
8. Characterization of exponential distribution 134
9. Concluding remarks 135
Acknowledgement 135
References 135

PART III. RELIABILITY PROPERTIES

Ch. 5. Reliability and Hazard Based on Finite Mixture Models 139
Essam K. AL-Hussaini and Khalaf S. Sultan

1. Introduction 139
2. Concepts, notation and definitions 142
3. Models with components belonging to the same family 147
4. Models with components belonging to different families 165
5. Summary and remarks 176
References 177

Ch. 6. Mixtures and Monotonicity of Failure Rate Functions 185
Moshe Shaked and Fabio Spizzichino

1. Introduction 185
2. Monotonicity of the hazard rate of a mixture 186
3. Limiting behavior of the hazard rate of a mixture 191
4. Negative aging properties of multivariate exchangeable mixtures 193
5. Some results on univariate scale mixtures 194
References 197

Ch. 7. Hazard Measure and Mean Residual Life Orderings: A Unified Approach 199
Majid Asadi and D. N. Shanbhag

1. Introduction 199
2. Some basic definitions and auxiliary results 200
3. Hazard measure ordering and its relationships with other partial orderings 203
4. Some closure properties of the hazard measure ordering 206
References 214

Ch. 8. Some Comparison Results of the Reliability Functions of Some Coherent Systems 215
Jie Mi

1. Introduction 215
2. Main result 216
3. Applications 220
References 225

Ch. 9. On the Reliability of Hierarchical Structures 227
Lev B. Klebanov and Gabor J. Szekely

1. Introduction 227
2. The main equation and its analytic solutions 228
3. The general solution of the main equation 231
4. Other normalizations 233
5. Reconstruction of the reliability polynomial from the limit distribution 233
6. A generalization of the main equation 234
7. A general limit result 235
References 235

PART IV. RELIABILITY SYSTEMS

Ch. 10. Consecutive k-out-of-n Systems 237
N. A. Mokhlis

1. Introduction 238
2. Exact reliability formulas 241
3. Approximation formulas and bounds 264
References 279

Ch. 11. Exact Reliability and Lifetime of Consecutive Systems 281
Sigeo Aki

1. Introduction 281
2. Reliability of consecutive systems on directed trees 283
3. Algorithms for exact reliability and numerical examples 286
4. Lifetime of consecutive systems 292
References 298

Ch. 12. Sequential k-out-of-n Systems 301
E. Cramer and U. Kamps

1. Introduction 302
2. Sequential order statistics 309
3. Sampling situation 317
4. Maximum likelihood estimators of model parameters for arbitrary distributions 317
5. Test procedures for model selection 320
6. A location-scale family of distributions 325
7. Joint maximum likelihood estimation of model and distribution parameters 334
8. Estimation of the scale parameter 337
9. Joint estimation of location and scale parameters 345
10. Estimation of a common location parameter and of scale parameters 351
11. Estimation of $P(X < Y)$ with data from sequential k-out-of-n systems 355
12. Reliability properties of sequential order statistics 362
Acknowledgement 367
References 367

PART V. PROGRESSIVE CENSORING

Ch. 13. Progressive Censoring: A Review 373
Rita Aggarwala

1. Introduction 373
2. Review and notation 374

3. Moment determination 376
4. Inference under progressive censoring 395
5. Related topics in progressive censoring 412
References 426

Ch. 14. Point and Interval Estimation for Parameters of the Logistic Distribution Based on Progressively Type-II Censored Samples 431
N. Balakrishnan and N. Kannan

1. Introduction 431
2. Maximum likelihood estimators 433
3. Approximate estimators 434
4. Weighted least squares estimation 437
5. Observed and expected Fisher information 438
6. Simulation results 442
7. Coverage probabilities 446
8. Illustrative example 454
9. Conclusions 455
References 455

Ch. 15. Progressively Censored Variables-Sampling Plans for Life Testing 457
Uditha Balasooriya

1. Introduction 457
2. Design of variables-sampling plans for progressively censored life-test experiments 459
3. Illustrations 465
References 466

PART VI. ANALYSIS FOR REPAIRABLE SYSTEMS

Ch. 16. Graphical Techniques for Analysis of Data From Repairable Systems 469
Per Anders Akersten, Bengt Klefsjö and Bo Bergman

1. Introduction 469
2. Some concepts for repairable systems 470
3. The TTT-plot 472
4. Plotting inter-event times 474
5. Plotting event epochs 475
6. Combination of the two plots 476
7. Some useful test statistics 476
8. An example 478

9. A TTT-plot based on transformed data 479
10. Another example 481
11. Conclusions and comments 483
References 483

Ch. 17. A Bayes Approach to the Problem of Making Repairs 485
Gary C. McDonald

1. Formulation of the problem 485
2. Bayes decision procedures 486
3. A univariate observation example 487
4. A bivariate observation example 491
5. Further comments on Bayes strategies 495
References 497

PART VII. ANALYSIS FOR MASKED DATA

Ch. 18. Statistical Analysis for Masked Data 499
Betty J. Flehinger†, Benjamin Reiser and Emmanuel Yashchin

1. Introduction 500
2. Pass/fail case 502
3. Life time data: Independent competing risks 506
4. Life time data: Dependent competing risks 519
Acknowledgement 521
References 521

Ch. 19. Analysis of Masked Failure Data under Competing Risks 523
Ananda Sen, Sanjib Basu and Mousumi Banerjee

1. Introduction 523
2. Parametric inference procedures 524
3. Non-parametric methodologies 534
4. Extensions and other directions 536
Acknowledgement 538
References 538

PART VIII. ANALYSIS FOR WARRANTY DATA

Ch. 20. Warranty and Reliability 541
D. N. P. Murthy and W. R. Blischke

1. Introduction 541
2. Some common warranty policies 545
3. Warranty cost analysis 551
4. Engineering and management of reliability and warranty 568
5. Reliability and warranty data sources and analyses 577
6. Conclusions 580
References 581

Ch. 21. Statistical Analysis of Reliability Warranty Data 585
Kazuyuki Suzuki, Md. Rezaul Karim and Lianhua Wang

1. Introduction 585
2. Estimation of the number of warranty claims 592
3. Estimation of the failure time distribution using follow-up information 597
4. Estimation using the usage time distribution 601
5. Refinement 604
6. Conclusion 606
Acknowledgements 606
References 607

PART IX. ACCELERATED TESTING

Ch. 22. Prediction of Field Reliability of Units, Each under Differing Dynamic Stresses, from Accelerated Test Data 611
Wayne Nelson

1. Introduction 611
2. Constant-stress model 612
3. A cumulative-exposure model for varying stresses 613
4. Model fitting 615
5. Estimate population reliability 617
6. Further work 620
Acknowledgments 621
References 621

Ch. 23. Step-Stress Accelerated Life Test 623
E. Gouno and N. Balakrishnan

1. Introduction 623
2. Step-stress testing: Definitions 624
3. Acceleration models 625
4. Lifetime distribution under step-stress pattern 627
5. Inference 630
6. Non-parametric approach 633
7. Bayesian analysis 634
8. Optimal test plan 637
9. Conclusion 638
References 638

PART X. DESTRUCTIVE TESTING

Ch. 24. Estimation of Correlation under Destructive Testing 641
Richard Johnson and Wenqing Lu

1. Introduction 641
2. Current designs for estimating correlation 642
3. A new double proof load design 646
4. An example using the bivariate Weibull distribution 652
5. Nonparametric estimation of correlation and conditional survival 653
References 657

PART XI. TEST PLANS

Ch. 25. System-Based Component Test Plans for Reliability Demonstration: A Review and Survey of the State-of-the-Art 659
Jayant Rajgopal and Mainak Mazumdar

1. Introduction 659
2. Review of research literature 664
3. Summary and future work 674
References 676

Ch. 26. Life-Test Planning for Preliminary Screening of Materials: A Case Study 679
Jeff Stein and Necip Doganaksoy

1. Introduction 679
2. Case study background 680
3. Proposed approach to life-test planning 681
4. Life-test planning results for the proposed approach 686
5. Further considerations 686
Acknowledgments 691
Appendix A: Pseudo-code for simulation algorithm assuming a Weibull failure time distribution 691
Appendix B: Derivation of the scale parameter (α) for a fixed shape parameter (β) of a Weibull distribution 691
References 692

Ch. 27. Analysis of Reliability Data from In-House Audit Laboratory Testing 693
Rekha Agrawal and Necip Doganaksoy

1. Introduction 693
2. The role of audit testing in reliability 694
3. Case study background 696
4. Using the mean cumulative function as a monitoring tool 698
5. Application to the case study 699
6. Observations, recommendations and conclusions 702
Acknowledgements 704
References 704

PART XII. SOFTWARE RELIABILITY

Ch. 28. Software Reliability Modeling, Estimation and Analysis 707
M. Xie and G. Y. Hong

1. Introduction 707
2. Classification of software reliability models 707
3. Some important NHPP software reliability models 708
4. Markov software reliability models 721
5. Some Bayesian approaches 724
6. Some forecasting methods 727
7. Final remarks 729
References 730

Ch. 29. Bayesian Analysis for Software Reliability Data
Jorge Alberto Achcar 733

1. Introduction 733
2. A Bayesian analysis for a special type-I strategy model: The Goel and Okumoto model 736
3. Bayesian inference for NHPP-I software reliability models 737
4. Bayesian inference for the superposition model 739
5. A superposition model in the presence of a covariate 741
6. Bayesian inference and model determination 744
7. Some examples 745
References 747

PART XIII. INFERENTIAL METHODS

Ch. 30. Direct Graphical Estimation for the Parameters in a Three-Parameter Weibull Distribution 749
Peter R. Nelson and K. B. Kulasekera

1. Introduction 750
2. Parameter estimation 751
3. Choice of r_1, r_2, and r_3 754
4. A graphical solution 757
5. Comparison with other graphical procedures 762
6. Conclusion 772
Appendix 772
References 775

Ch. 31. Bayesian and Frequentist Methods in Change-Point Problems 777
Nader Ebrahimi and Sujit K. Ghosh

1. Introduction 777
2. Continuous change-point problem 778
3. Discrete change-point problem 782
4. Concluding remarks 785
References 786

Ch. 32. The Operating Characteristics of Sequential Procedures in Reliability 789
S. Zacks

1. Introduction 789
2. Sequential estimation of reliability with prescribed proportional closeness 790
3. Sequential testing 797
4. Reliability estimation after testing 802
5. The total operating time of repairable systems 805
6. Sequential detection of wearout 807
7. Sequential methods in software reliability 808
References 810

Ch. 33. Simultaneous Selection of Extreme Populations from a Set of Two-Parameter Exponential Populations 813
Khaled Hussein and S. Panchapakesan

1. Introduction 813
2. Selection in terms of the location parameter; IZ approach 815
3. Selection in terms of the location parameter; SS approach 819
4. Selection in terms of the scale parameter; IZ approach 822
5. Selection in terms of the scale parameter; SS approach 824
6. Selection based on Type-II censored sample 827
7. Concluding remarks 829
References 829

Subject Index 831

Contents of Previous Volumes 839