
Contents

List of figures	xi
Preface	xv
1 Basic Concepts	1
1.1 Introduction	1
1.2 Events and probability	1
1.3 Rules of probability	3
1.4 Dependent events	5
1.5 Random variables and probability distributions	8
1.6 The reliability function	11
1.7 The hazard function	16
1.8 Expectation	19
2 Common Lifetime Models	21
2.1 Introduction	21
2.2 The Poisson process	22
2.3 The Weibull distribution	24
2.4 The Gumbel distribution	27
2.5 The normal and lognormal distributions	29
2.6 The gamma distribution	31
2.7 The logistic and log logistic distributions	33
2.8 The Pareto distribution	33
2.9 Order statistics and extreme value distributions	35
3 Model Selection	37
3.1 Introduction	37
3.2 Non-parametric estimation of $R(t)$ and $h(t)$	37
3.3 Censoring	39
3.4 Kaplan–Meier estimator	41
3.5 Graphical methods	44
3.6 Straight line fitting	45

3.7	Weibull plotting	45
3.8	Normal plotting	47
3.9	Other model family plots	49
3.10	Comparison of distributions	52
4	Model Fitting	55
4.1	Parameter estimation	55
4.2	The variance of estimators	55
4.3	Confidence interval estimates	56
4.4	Maximum likelihood	58
4.5	Estimating quantiles	63
4.6	Estimation methods using sample moments	65
4.7	General probability plots	67
4.8	Goodness of fit	70
4.9	Pearson's χ^2 test	72
4.10	Kolmogorov–Smirnov test	75
4.11	Tests for normality	77
4.12	A^2 and W^2 tests	78
4.13	Stabilized probability plots	80
4.14	Censored data	80
5	Repairable Systems	81
5.1	Introduction	81
5.2	Graphical methods	82
5.3	Testing for trend	86
5.4	Repair time	92
5.5	Maintainability and availability	92
5.6	Introduction to renewal theory	93
5.7	Laplace transforms	94
5.8	The renewal function	95
5.9	Alternating renewal processes	98
5.10	The distribution of $N(t)$	100
6	System Reliability	101
6.1	Systems and system logic	101
6.2	Tie and cut sets	103
6.3	Probability bounds	104
6.4	Fault trees	107
6.5	Failure over time	110
6.6	Quorum or m -out-of- n systems	
6.7	Redundancy	113
6.8	Analysis of systems using state spaces	115

6.9	Mean time to failure (MTTF)	121
6.10	Considerations due to 'switching'	122
6.11	Common cause failures	125
7	Models for Functions of Random Variations	127
7.1	Combinations and transformations of random variables	127
7.2	Expectations of functions of random variables	127
7.3	Approximations for $E[g(\mathbf{X})]$ and $V[g(\mathbf{X})]$	129
7.4	Distribution of a function of random variables	131
7.5	Probabilistic engineering design	133
7.6	Stress and strength distributions	134
7.7	Interference theory and reliability computations	135
7.8	Normally distributed stress and strength	138
7.9	Safety factors and reliability	142
7.10	Graphical approach for empirically determined distributions	143
8	Maintenance Strategies	149
8.1	Maintained systems	149
8.2	Availability	151
8.3	Markovian systems	153
8.4	Mean time between failures (MTBF)	156
8.5	Age replacement	160
8.6	Scheduled maintenance	166
8.7	Systems with failure detection/fail safe devices	169
8.8	Down-time distributions	173
9	Life Testing and Inference	175
9.1	Life test plans	175
9.2	Prediction of time on test	177
9.3	Inference for the exponential distribution	180
9.4	The effect of data rounding	183
9.5	Parametric reliability bounds	184
9.6	Likelihood-based methods	187
9.7	The likelihood ratio test	190
9.8	Binomial experiments	195
9.9	Non-parametric estimation and confidence intervals for $R(t)$	200
9.10	Estimating system reliability from subsystem test data	202
9.11	Accelerated testing	208

10	Advanced Models	211
10.1	Covariates	211
10.2	Proportional hazards models	212
10.3	Accelerated life models	216
10.4	Mixture models	217
10.5	Competing risks	221
10.6	Dependent failures	225
10.7	Load-sharing systems	226
10.8	Bayesian reliability	228
10.9	Case studies	232
	Appendix	239
A.1	Partial fractions	239
A.2	Series	240
A.3	Taylor expansions	241
A.4	Newton–Raphson iteration	242
A.5	Numerical integration	243
A.6	Matrix algebra	244
A.7	The principle of least squares	246
	References	249
	Index	253