

Contents

<i>Preface</i>	<i>xi</i>
CHAPTER 1	
Introduction	1
1-1 Why Study Risk Analysis?	1
1-2 An Overview of Risk Analysis	2
General References	6
PART I	
METHODS	
CHAPTER 2	
Probability Concepts	11
2-1 Interpretations and Laws of Probability	11
2-2 The Bayes Equation	16
2-3 Probability Distribution Functions	20
2-4 Probability Concepts for Failure Analyses	21
Exercises	28
References	29
CHAPTER 3	
Probability Distributions for Describing Failures	30
3-1 Discrete Distributions	30
3-2 Continuous Distributions	34
3-3 Synthesized Distributions	46
3-4 Extreme-Value Distributions	50
Exercises	54
References	57

CHAPTER 4	
Data Manipulation Concepts	58
4-1 Curve Fitting of Data	58
4-2 Introduction to Estimation Theory	65
4-3 Point Estimates for Continuous Distributions	68
Exercises	76
References	77
CHAPTER 5	
Failure Data	79
5-1 Introduction	79
5-2 Sources of Failure Data	80
5-3 Examples of Failure Data for Hardware	84
5-4 Examples of Failure Data for Human Error	85
5-5 Common Cause and Common Mode Failures	88
References	90
CHAPTER 6	
Reliability of Simple Systems	91
6-1 System Reliability for Series and Active-Parallel Units	91
6-2 System Reliability for Sequentially Operating Units	96
6-3 System Reliability as Derived by the Decomposition Method	98
6-4 Reliability Obtained Using a Signal Flow Graph	103
6-5 Cut-Set Method for Determining Reliability	105
6-6 Systems with Common Cause Failures	110
Exercises	111
References	116
CHAPTER 7	
Reliability and Availability of Systems with Repair	117
7-1 Reliability, Availability, and Maintainability	117
7-2 Periodic Maintenance	118
7-3 Introduction to Markov Models	120
7-4 Markov Models for Systems	127
7-5 Time-Dependent Availability and Reliability	136
7-6 Time-Dependent Unavailability for Rare Failures	142
7-7 Steady-State Availability	144
7-8 Mean Time to Failure	145
7-9 Models for Common Cause Failures	147
7-10 Other Analysis Techniques	149
Exercises	150
References	152

CHAPTER 8		
Fault Tree Analysis		154
8-1	Introduction	154
8-2	Fault Tree Construction	157
8-3	Fault Tree Evaluation	162
8-4	Examples of Simple Fault Trees	166
8-5	Light Water Reactor Trip System Fault Trees	175
8-6	Light Water Reactor Safety Fault Trees	179
8-7	Spent Nuclear Fuel Truck Transport Fault Trees	184
8-8	Geologic Waste Disposal Fault Trees	184
	Exercises	185
	References	189
 CHAPTER 9		
Event Tree Analysis		190
9-1	Event Tree Construction	190
9-2	Event Trees for Reactor Safety Analysis	193
9-3	Event Trees for Safeguards Analysis	207
	Exercises	211
	References	213
 CHAPTER 10		
Computer Programs for Fault Tree Analysis		214
10-1	Qualitative and Quantitative Evaluations	214
10-2	Fault Tree Analysis with Common Cause Failures	221
10-3	Analysis of Data Uncertainties in a Fault Tree	223
10-4	Automated Fault Tree Construction	226
	References	227
 PART II		
NUCLEAR POWER RISKS		
 CHAPTER 11		
Risk Concepts		231
11-1	Definition of Risk	231
11-2	Probabilistic Risk Assessment Procedure	235
	Exercises	238
	References	238

CHAPTER 12		
Risks for Light Water Reactors		240
12-1	Introduction	240
12-2	Radioactive Inventory	241
12-3	Reactor Accidents	242
12-4	Methods for Consequence Analysis	245
12-5	Quantification of Radioactive Releases	251
12-6	Predicted Frequencies for Accident Sequences	259
12-7	Reactor Safety Study Findings	271
12-8	Limitations of the Reactor Safety Study	280
12-9	Critiques of the Reactor Safety Study	282
12-10	Follow-Up Reactor Safety Studies	284
12-11	Three Mile Island Accident	286
	Exercises	286
	References	287
CHAPTER 13		
Risks for Liquid Metal Fast Breeder and High Temperature Gas Reactors		290
13-1	Liquid Metal Fast Breeder Reactor	290
13-2	High Temperature Gas Reactor	300
	Exercise	303
	References	303
CHAPTER 14		
Risks for Nuclear Materials Transportation		305
14-1	Analysis Procedure	305
14-2	Spent Nuclear Fuel Transport	306
14-3	Uranium Hexafluoride Transport	309
14-4	Plutonium Transport	310
14-5	Nuclear Wastes Transport	314
	Exercise	314
	References	315
CHAPTER 15		
Risks for Nuclear Waste Disposal		316
15-1	Risks from Preclosure Accidents	316
15-2	Introduction to Risks from Postclosure Accidents	316
15-3	Interim Storage	323
15-4	Permanent Waste Disposal	325
	Exercises	326
	References	327

**PART III
OTHER RISK ASSESSMENTS**

CHAPTER 16

Comparison of Risks 331

16-1 Conventional Energy Sources 331

16-2 Conventional and Nonconventional Energy Sources 335

16-3 Canvey Island 343

16-4 Dams 347

16-5 Other Risks 349

 Exercises 353

 References 354

CHAPTER 17

Risk-Benefit Assessments 355

17-1 Economic Considerations 355

17-2 Different Approaches 358

17-3 Cost-Benefit Analysis of PWR Engineered Safety Features 359

17-4 Cost-Benefit Analyses of Various Health and Safety Measures 363

 Exercises 365

 References 365

CHAPTER 18

Risk Acceptance 367

18-1 Factors Affecting Risk Acceptance 367

18-2 Statistical Risk Acceptance Analyses 368

18-3 Psychometric Risk Acceptance Analyses 373

18-4 Perception of Risks 374

18-5 Criteria for Risk Acceptance 377

18-6 Pathways Toward Risk Acceptance 379

 Exercises 381

 References 381

CHAPTER 19

Epilogue 383

 References 386

APPENDIXES

APPENDIX A

Some Useful Mathematical Functions 387

APPENDIX B Failure Data	391
APPENDIX C Some Matrix Mathematics	396
APPENDIX D Failure Modes and Effects Analysis	398
APPENDIX E Light Water Reactor Safety Systems	403
APPENDIX F Additional Light Water Reactor Safety Study Fault Trees	414
APPENDIX G The GO Method	421
Answers to Selected Exercises	427
<i>Index</i>	431