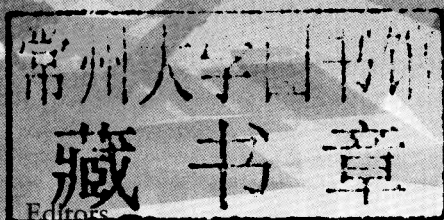


Syouji Nakamura ■ Toshio Nakagawa

*Editors*

# Stochastic Reliability Modeling, Optimization and Applications

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Stochastic Reliability  
Modeling, Optimization  
and Applications

# Preface

One small research group with an organizer Toshio Nakagawa of Aichi Institute of Technology and fifteen members was started in Nagoya, Japan on February, 1989. This group was named *Nagoya Computer and Reliability Research* (NCR) with the objective of presenting and writing research papers studied by each member. The NCR has no rule and no duty, however, has a strong desire to study computer and reliability problems in one's daily life and place of work. The NCR has continued for twenty years unexpectedly, and during this interval, each member has presented actively many papers in the following international conferences:

- The First Australia-Japan Workshop on Stochastic Models in Engineering, Technologies and Management, July 14–16, 1993, Gold Coast, Australia.
- UK-Japanese Workshop on Stochastic Modeling in Innovative Manufacturing, July 20–21, 1995, Cambridge, UK.
- The Second Australia-Japan Workshop on Stochastic Models in Engineering, Technologies and Management, July 17–19, 1996, Gold Coast, Australia.
- The First Euro-Japanese Workshop on Stochastic Risk Modelling for Finance, Insurance, Production and Reliability, September 7–9, 1998, Brussels, Belgium.
- The First Western Pacific/Third Australia-Japan Workshop on Stochastic Models in Engineering, Technology and Management, September 23–25, 1999, Christchurch, New Zealand.
- International Conference on Applied Stochastic System Modeling, March 29–30, 2000, Kyoto, Japan.
- The Second Euro-Japanese Workshop on Stochastic Risk Modelling

for Finance, Insurance, Production and Reliability, September 18–20, 2002, Chamonix, France.

- 9th ISSAT International Conference Reliability and Quality in Design. August 6–8, 2003, Waikiki, Hawaii, USA.
- 10th ISSAT International Conference Reliability and Quality in Design, August 5–7, 2004, Las Vegas, Nevada, USA.
- 2004 Asian International Workshop on Advanced Reliability Modeling, August 26–27, 2004, Hiroshima, Japan.
- International Workshop on Recent Advances in Stochastic Operations Research, August 25–26, 2005, Canmore, Canada.
- 2006 Asian International Workshop on Advanced Reliability Modeling, August 24–26, 2006, Busan, Korea.
- 13th ISSAT International Conference Reliability and Quality in Design, August 2–4, 2007, Seattle, Washington, USA.
- 2008 Asian International Workshop on Advanced Reliability Modeling, October 23–25, 2008, Taichung, Taiwan.

Several good papers selected from the above conferences have published in some research journals and on book forms.

In memory of twenty th anniversary, we make a plan of publishing the book written by each member titled on *Stochastic Reliability Modeling, Optimization and Applications* from World Scientific Publishing. The book is composed of three parts: Reliability Theory, Computer System Reliability, and Reliability Applications. Throughout this book, we formulate stochastic models by applying mainly renewal, Markov renewal and cumulative processes in stochastic processes, and analyze them by using the techniques of reliability theory. Furthermore, we obtain the availability, the expected cost and the overhead as an objective function, and discuss analytically optimal policies which minimize them. Such methods and results would be more useful for studying and applying other reliability models in practical fields.

Part I consists of three chapters, focusing on discussing optimal policies for standard reliability models: Chapter 1 presents a generalization of basic concepts of binary state to multistate coherent systems, and gives the existence theorems of series and parallel systems, IFRA and NBU theorems and their properties of coherent systems. The treatment of  $k$ -out-of- $n$  systems is newly presented in this chapter. Chapter 2 considers three replacement policies for cumulative damage models in which an item is replaced at time, shock number, damage level, and at failure, whichever occurs first. Another

three replacement policies for the failure interaction and the opportunistic models are taken up, and optimal policies are discussed analytically, using the techniques of cumulative processes. Chapter 3 extends the standard inspection model to four inspection policies for a two-unit system, a system with two types of inspection, a system with self-testing, and a system with a finite operation time. The expected cost rates for each model are obtained, and optimal policies which minimize them are derived by using the methods of inspection policies.

Part II consists of five chapters, focusing on analyzing a various of computer systems by using reliability theory: Chapter 4 discusses hybrid state saving schemes with realistic restrictions. Optimal checkpoint intervals are derived by using approximations for overhead evaluation. The implemented logic circuit simulator and numerical examples are also presented. Chapter 5 formulates three stochastic models of a system with networks by using Markov renewal processes. Optimal policies which minimize the expected cost rates are derived analytically, and numerical examples are presented. Chapter 6 studies three stochastic models of a communication system with the recovery techniques of checkpoint and rollback, a mobile communication system with recovery scheme and a communication system with window flow control scheme. Some reliability measures of each model are obtained by using Markov renewal processes, and optimal policies which minimize them are discussed. Chapter 7 considers two backup models of a database system. The expected cost rates of each model are obtained, and optimal backup policies are discussed by using theory of cumulative processes. Chapter 8 considers two-level recovery schemes of soft and hard checkpoints, and multiple and modified modular systems with sequential checkpoint times, increasing error rates and random processing times. Optimal checkpoint intervals of each model which minimize the total overhead are derived by using reliability theory.

Part III consists of two chapters, focusing on maintenances of miscellaneous systems and optimization problems in management science: Chapter 9 takes up optimal maintenance models of five different systems such as missile, phased array radar, FADEC, co-generation system, and power plant. Some reliability measures of each model are obtained by using reliability theory, and optimal maintenance policies which minimize them are discussed. Chapter 10 formulates three stochastic models associated with the monetary facility, and considers optimization problems which maximize an expected liquidation of holdings, minimize the prepayment risk for a monetary risk, and determine a loan interest rate of banks. Optimal policies

for each model are derived analytically, using reliability theory.

We are strongly convinced that the NCCR has run over twenty years by great help and hearty assistance of many peoples: We wish to thank to Professor Shunji Osaki, Nanzan University, Professor Prabhakar Murthy, The University of Queensland, Professor Hoang Pham, Rutgers University, Professor Shigeru Yamada, Tottori University, and Professor Tadashi Dohi, Hiroshima University for having presented the papers at some national conferences. We wish to express our special thanks to Professor Kazumi Yasui, Aichi Institute of Technology, Professor Hiroaki Sandoh, Osaka University, and the other members of NCCR; Mr. Takehiko Nishimaki, Professor Shinichi Koike, Professor Yoshihisa Harada, and Mr. Esturo Shima for their cooperation and valuable discussions. Furthermore, we would like to thank Kinjo Gakuin University Research Grant for the support and Editor Chelsea Chin, World Scientific Publishing Co. Pte. Ltd for providing the opportunity to write this book.

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# Contents

<i>Preface</i>	v
<i>List of Contributors</i>	ix
<b>RELIABILITY MODELS</b>	<b>1</b>
1. Multistate Coherent Systems	3
<i>FUMIO OHI</i>	
1 Introduction . . . . .	3
2 Coherent Systems . . . . .	6
3 $k$ -out-of- $n$ systems . . . . .	13
4 Modules of Coherent Systems . . . . .	17
5 Probabilistic Aspect of Coherent Systems . . . . .	21
6 Hazard Transform of Multistate Coherent Systems . . . . .	25
7 Concluding Remarks . . . . .	32
References . . . . .	33
2. Cumulative Damage Models	35
<i>TAKASHI SATOW</i>	
1 Introduction . . . . .	35
2 Standard Cumulative Damage Model . . . . .	38
2.1 Shock Arrival . . . . .	38
2.2 Cumulative Damage . . . . .	39
2.3 Cumulative Damage Model . . . . .	40
3 Failure Interaction Models . . . . .	41

3.1	Age and Damage Limit Model . . . . .	42
3.2	Numerical Examples . . . . .	44
3.3	Shock Number and Damage Limit $(N, k)$ Model . . . . .	45
3.4	Numerical Examples . . . . .	47
3.5	Age and Shock Number Model . . . . .	49
3.6	Numerical examples . . . . .	50
3.7	Conclusions . . . . .	51
4	Oppotunistic Replacement Model . . . . .	52
4.1	Age Model . . . . .	53
4.2	Numerical examples . . . . .	55
4.3	Damage Limit Model . . . . .	57
4.4	Numerical Examples . . . . .	59
4.5	Conclusions . . . . .	60
	References . . . . .	61
3.	Extended Inspection Models . . . . .	63
	<i>SATOSHI MIZUTANI</i>	
1	Introduction . . . . .	63
2	Periodic Policy for a Two-Unit System . . . . .	65
2.1	Model and Assumptions . . . . .	65
2.2	Optimal Policy . . . . .	68
2.3	Numerical Examples . . . . .	68
3	Periodic Policy for a System with Two Types of Inspection . . . . .	69
3.1	Model and Assumptions . . . . .	70
3.2	Optimal Policy . . . . .	72
3.3	Numerical Example . . . . .	73
4	Periodic Policy for a System with Self-Testing . . . . .	73
4.1	Model and Assumptions . . . . .	74
4.2	Optimal Policy . . . . .	76
4.3	Numerical Examples . . . . .	78
5	Optimal Policies for a Finite Interval . . . . .	79
5.1	Periodic Inspection Policy . . . . .	80
5.2	Sequential Inspection Policy . . . . .	81
5.3	Numerical Examples . . . . .	82
6	Conclusions . . . . .	83
	References . . . . .	84

<b>COMPUTER SYSTEMS</b>	<b>87</b>
4. Stochastic Analyses for Hybrid State Saving and Its Experimental Validation	89
<i>MAMORU OHARA, MASAYUKI ARAI and SATOSHI FUKUMOTO</i>	
1 Introduction . . . . .	89
2 Time Warp Simulation and Hybrid State Saving . . . . .	91
3 Analytical Model . . . . .	97
4 Implementation of A Concrete Application: A Parallel Distributed Logic Circuit Simulator . . . . .	106
5 Numerical Examples . . . . .	109
6 Concluding Remarks . . . . .	115
References . . . . .	116
5. Reliability Analysis of a System Connected with Networks	117
<i>MITSUHIRO IMAIZUMI</i>	
1 Introduction . . . . .	117
2 Optimal Reset Number of a Microprocessor System with Network Processing . . . . .	119
2.1 Model and Analysis . . . . .	120
2.2 Optimal Policies . . . . .	124
2.3 Numerical Example . . . . .	126
3 Reliability Analysis for an Applet Execution Process . . . . .	127
3.1 Model and Analysis . . . . .	128
3.2 Optimal Policy . . . . .	133
3.3 Numerical Example . . . . .	134
4 Reliability Analysis of a Network Server System with DoS Attacks . . . . .	135
4.1 Model and Analysis . . . . .	135
4.2 Optimal Policy . . . . .	141
4.3 Numerical Example . . . . .	142
5 Conclusions . . . . .	143
References . . . . .	144

6. Reliability Analysis of Communication Systems 147

MITSUTAKA KIMURA

- 1 Introduction . . . . . 147
- 2 Communication System with Rollback Recovery . . . . . 149
  - 2.1 Reliability Quantities . . . . . 150
  - 2.2 Optimal Policy . . . . . 153
- 3 Mobile Communication System with Error Recovery Schemes . . . . . 157
  - 3.1 Reliability Quantities . . . . . 158
  - 3.2 Optimal Policy . . . . . 162
- 4 Communication System with Window Flow Control Scheme . . . . . 163
  - 4.1 Reliability Quantities . . . . . 164
  - 4.2 Optimal Policy . . . . . 170
- 5 Conclusions . . . . . 172
- References . . . . . 173

7. Backup Policies for a Database System 177

CUN-HUA QIAN

- 1 Introduction . . . . . 177
- 2 Cumulative Damage Model . . . . . 180
  - 2.1 Standard Cumulative Damage Model . . . . . 181
  - 2.2 Modified Cumulative Damage Model . . . . . 183
- 3 Comparison of Backup Schemes and Policies . . . . . 184
  - 3.1 Incremental and Cumulative Backups . . . . . 184
  - 3.2 Incremental Backup Policy . . . . . 186
  - 3.3 Total and Cumulative Backups . . . . . 187
  - 3.4 Cumulative Backup Policy . . . . . 190
- 4 Periodic Backup Policies . . . . . 195
  - 4.1 Periodic Incremental Backup Policy . . . . . 196
  - 4.2 Periodic Cumulative Backup Policies . . . . . 198
- 5 Conclusions . . . . . 202
- References . . . . . 203

8. Optimal Checkpoint Intervals for Computer Systems 205

KENICHIRO NARUSE and SAYORI MAEJI

- 1 Introduction . . . . . 205

2	Two-level Recovery Schemes . . . . .	207
2.1	Performance Analysis . . . . .	208
2.2	Expected Overhead . . . . .	212
3	Error Detection by Multiple Modular Redundancies . . . . .	213
3.1	Multiple Modular System . . . . .	214
3.2	Performance Analysis . . . . .	214
4	Sequential Checkpoint Intervals for Error Detection . . . . .	217
4.1	Performance Analysis . . . . .	218
4.2	Modified Model . . . . .	222
5	Random Checkpoint Models . . . . .	226
5.1	Performance Analysis . . . . .	227
5.2	Majority Decision System . . . . .	235
6	Conclusion . . . . .	237
	References . . . . .	237

**RELIABILITY APPLICATIONS 241**

9. Maintenance Models of Miscellaneous Systems 243

*KODO ITO*

1	Introduction . . . . .	243
2	Missile Maintenance . . . . .	245
2.1	Expected Cost . . . . .	247
2.2	Optimal Policies . . . . .	248
2.3	Concluding Remarks . . . . .	250
3	Phased Array Radar Maintenance . . . . .	251
3.1	Cyclic Maintenance . . . . .	252
3.2	Delayed Maintenance . . . . .	255
3.3	Concluding Remarks . . . . .	256
4	Self-diagnosis for FADEC . . . . .	257
4.1	Double Module System . . . . .	259
4.2	Triple Module System . . . . .	261
4.3	$N$ Module System . . . . .	263
4.4	Concluding Remarks . . . . .	264
5	Co-generation System Maintenance . . . . .	264
5.1	Model and Assumptions . . . . .	265
5.2	Expected Cost . . . . .	266
5.3	Optimal Policy . . . . .	267

5.4	Concluding Remarks . . . . .	269
6	Aged Fossil-fired Power Plant Maintenance . . . . .	269
6.1	Model 1 . . . . .	271
6.2	Model 2 . . . . .	274
6.3	Concluding Remarks . . . . .	276
	References . . . . .	276
10.	Management Policies for Stochastic Models with Monetary Facilities . . . . .	279
	<i>SYOUJI NAKAMURA</i>	
1	Introduction . . . . .	279
2	Liquidation Profit Policy . . . . .	280
2.1	Model 1 . . . . .	282
2.2	Model 2 . . . . .	283
3	Prepayment Risk . . . . .	286
3.1	Model 1: Interval Estimation . . . . .	288
3.2	Model 2: Linear Estimation . . . . .	289
3.3	Optimal Policies . . . . .	289
3.4	Numerical Example . . . . .	290
4	Loan Interest Rate . . . . .	292
4.1	Expected Earning without Bankruptcy . . . . .	293
4.2	Expected Earning with Bankruptcy . . . . .	294
4.3	Numerical Examples . . . . .	297
	References . . . . .	299

**PART 1**  
**RELIABILITY MODELS**



