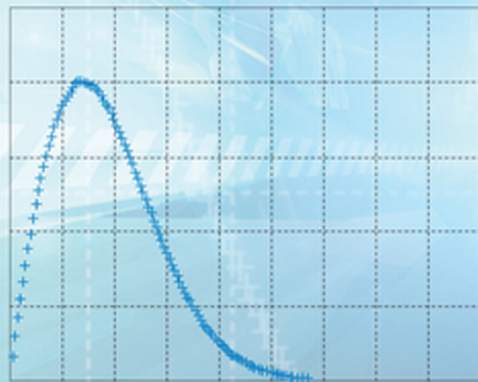


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PROBABILISTIC MODELS AND STATISTICAL INFERENCE

Editors

Ilia B. Frenkel

SCE – Shamoon College of Engineering, Beer Sheva, Israel

Alex Karagrigoriou

University of Cyprus, Nicosia, Cyprus

Anatoly Lisnianski

The Israel Electric Corporation Ltd., Haifa, Israel

Andre Kleyner

Delphi Electronics & Safety, Indiana, USA

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Contents

Remembering Boris Gnedenko	xvii
List of Contributors	xxv
Preface	xxix
Acknowledgements	xxxv
Part I DEGRADATION ANALYSIS, MULTI-STATE AND CONTINUOUS-STATE SYSTEM RELIABILITY	
1 Methods of Solutions of Inhomogeneous Continuous Time Markov Chains for Degradation Process Modeling	3
<i>Yan-Fu Li, Enrico Zio and Yan-Hui Lin</i>	
1.1 Introduction	3
1.2 Formalism of ICTMC	4
1.3 Numerical Solution Techniques	5
1.3.1 <i>The Runge–Kutta Method</i>	5
1.3.2 <i>Uniformization</i>	6
1.3.3 <i>Monte Carlo Simulation</i>	7
1.3.4 <i>State-Space Enrichment</i>	9
1.4 Examples	10
1.4.1 <i>Example of Computing System Degradation</i>	10
1.4.2 <i>Example of Nuclear Component Degradation</i>	11
1.5 Comparisons of the Methods and Guidelines of Utilization	13
1.6 Conclusion	15
References	15
2 Multistate Degradation and Condition Monitoring for Devices with Multiple Independent Failure Modes	17
<i>Ramin Moghaddass and Ming J. Zuo</i>	
2.1 Introduction	17

2.2	Multistate Degradation and Multiple Independent Failure Modes	19
2.2.1	<i>Notation</i>	19
2.2.2	<i>Assumptions</i>	20
2.2.3	<i>The Stochastic Process Model</i>	21
2.3	Parameter Estimation	23
2.4	Important Reliability Measures of a Condition-Monitored Device	25
2.5	Numerical Example	27
2.6	Conclusion	28
	Acknowledgements	30
	References	30
3	Time Series Regression with Exponential Errors for Accelerated Testing and Degradation Tracking	32
	<i>Nozer D. Singpurwalla</i>	
3.1	Introduction	32
3.2	Preliminaries: Statement of the Problem	33
3.2.1	<i>Relevance to Accelerated Testing, Degradation and Risk</i>	33
3.3	Estimation and Prediction by Least Squares	34
3.4	Estimation and Prediction by MLE	35
3.4.1	<i>Properties of the Maximum Likelihood Estimator</i>	35
3.5	The Bayesian Approach: The Predictive Distribution	37
3.5.1	<i>The Predictive Distribution of Y_{T+1} when $\lambda > A$</i>	38
3.5.2	<i>The Predictive Distribution of Y_{T+1} when $\lambda \leq A$</i>	39
3.5.3	<i>Alternative Prior for β</i>	40
	Acknowledgements	42
	References	42
4	Inverse L_z-Transform for a Discrete-State Continuous-Time Markov Process and Its Application to Multi-State System Reliability Analysis	43
	<i>Anatoly Lisnianski and Yi Ding</i>	
4.1	Introduction	43
4.2	Inverse L_z -Transform: Definitions and Computational Procedure	44
4.2.1	<i>Definitions</i>	44
4.2.2	<i>Computational Procedure</i>	47
4.3	Application of Inverse L_z -Transform to MSS Reliability Analysis	50
4.4	Numerical Example	52
4.5	Conclusion	57
	References	58
5	On the L_z-Transform Application for Availability Assessment of an Aging Multi-State Water Cooling System for Medical Equipment	59
	<i>Ilia Frenkel, Anatoly Lisnianski and Lev Khvatskin</i>	
5.1	Introduction	59
5.2	Brief Description of the L_z -Transform Method	61

5.3	Multi-state Model of the Water Cooling System for the MRI Equipment	62
5.3.1	<i>System Description</i>	62
5.3.2	<i>The Chiller Sub-System</i>	64
5.3.3	<i>The Heat Exchanger Sub-System</i>	66
5.3.4	<i>The Pump Sub-System</i>	67
5.3.5	<i>The Electric Board Sub-System</i>	69
5.3.6	<i>Model of Stochastic Demand</i>	71
5.3.7	<i>Multi-State Model for the MRI Cooling System</i>	73
5.4	Availability Calculation	75
5.5	Conclusion	76
	Acknowledgments	76
	References	77
6	Combined Clustering and L_z-Transform Technique to Reduce the Computational Complexity of a Multi-State System Reliability Evaluation	78
	<i>Yi Ding</i>	
6.1	Introduction	78
6.2	The L_z -Transform for Dynamic Reliability Evaluation for MSS	79
6.3	Clustering Composition Operator in the L_z -Transform	81
6.4	Computational Procedures	83
6.5	Numerical Example	83
6.6	Conclusion	85
	References	85
7	Sliding Window Systems with Gaps	87
	<i>Gregory Levitin</i>	
7.1	Introduction	87
7.2	The Models	89
7.2.1	<i>The k/eSWS Model</i>	89
7.2.2	<i>The mCSWS Model</i>	89
7.2.3	<i>The mGSWS Model</i>	90
7.2.4	<i>Interrelations among Different Models</i>	90
7.3	Reliability Evaluation Technique	91
7.3.1	<i>Determining u-functions for Individual Elements and their Groups</i>	91
7.3.2	<i>Determining u-functions for all the Groups of r Consecutive Elements</i>	92
7.3.3	<i>Detecting the System Failure</i>	93
7.3.4	<i>Updating the Counter</i>	94
7.3.5	<i>Recursive Determination of System Failure Probability</i>	95
7.3.6	<i>Computational Complexity Reduction</i>	95
7.3.7	<i>Algorithm for System Reliability Evaluation</i>	95
7.4	Conclusion	96
	References	96

8	Development of Reliability Measures Motivated by Fuzzy Sets for Systems with Multi- or Infinite-States	98
	<i>Zhaojun (Steven) Li and Kailash C. Kapur</i>	
8.1	Introduction	98
8.2	Models for Components and Systems Using Fuzzy Sets	100
	8.2.1 <i>Binary Reliability and Multi-State Reliability Model</i>	100
	8.2.2 <i>Definition of Fuzzy Reliability</i>	101
	8.2.3 <i>Fuzzy Unreliability: A Different Perspective</i>	102
	8.2.4 <i>Evolution from Binary State to Multi-State and to Fuzzy State Reliability Modeling</i>	102
8.3	Fuzzy Reliability for Systems with Continuous or Infinite States	103
8.4	Dynamic Fuzzy Reliability	104
	8.4.1 <i>Time to Fuzzy Failure Modeled by Fuzzy Random Variable</i>	105
	8.4.2 <i>Stochastic Performance Degradation Model</i>	106
	8.4.3 <i>Membership Function Evaluation for the Expectation of Time to Fuzzy Failure</i>	107
	8.4.4 <i>Performance Measures for Dynamic Fuzzy Reliability</i>	108
8.5	System Fuzzy Reliability	110
8.6	Examples and Applications	111
	8.6.1 <i>Reliability Performance Evaluation Based on Time to Fuzzy Failure</i>	111
	8.6.2 <i>Example for System Fuzzy Reliability Modeling</i>	113
	8.6.3 <i>Numerical Results</i>	115
8.7	Conclusion	117
	References	118
9	Imperatives for Performability Design in the Twenty-First Century	119
	<i>Krishna B. Misra</i>	
9.1	Introduction	119
9.2	Strategies for Sustainable Development	120
	9.2.1 <i>The Internalization of Hidden Costs</i>	120
	9.2.2 <i>Mitigation Policies</i>	121
	9.2.3 <i>Dematerialization</i>	121
	9.2.4 <i>Minimization of Energy Requirement</i>	124
9.3	Reappraisal of the Performance of Products and Systems	124
9.4	Dependability and Environmental Risk are Interdependent	126
9.5	Performability: An Appropriate Measure of Performance	126
	9.5.1 <i>Performability Engineering</i>	127
9.6	Towards Dependable and Sustainable Designs	129
9.7	Conclusion	130
	References	130

Part II NETWORKS AND LARGE-SCALE SYSTEMS

10	Network Reliability Calculations Based on Structural Invariants	135
	<i>Ilya B. Gertsbakh and Yoseph Shpungin</i>	
10.1	First Invariant: D-Spectrum, Signature	135
10.2	Second Invariant: Importance Spectrum. Birnbaum Importance Measure (BIM)	139
10.3	Example: Reliability of a Road Network	141
10.4	Third Invariant: Border States	142
10.5	Monte Carlo to Approximate the Invariants	144
10.6	Conclusion	146
	References	146
11	Performance and Availability Evaluation of IMS-Based Core Networks	148
	<i>Kishor S. Trivedi, Fabio Postiglione and Xiaoyan Yin</i>	
11.1	Introduction	148
11.2	IMS-Based Core Network Description	149
11.3	Analytic Models for Independent Software Recovery	151
11.3.1	<i>Model 1: Hierarchical Model with Top-Level RBD and Lower-Level MFT</i>	152
11.3.2	<i>Model 2: Hierarchical Model with Top-Level RBD and Lower-Level FT</i>	153
11.3.3	<i>Model 3: Hierarchical Model with Top-Level RBD and Lower-Level SRN</i>	154
11.4	Analytic Models for Recovery with Dependencies	155
11.4.1	<i>Model 4: Hierarchical Model with Top-Level RBD, Middle-Level MFT and Lower-Level CTMC</i>	155
11.4.2	<i>Model 5: Alternative Approach for Model 4 based on UGF</i>	156
11.4.3	<i>Model 6: Hierarchical Model with Top-Level RBD and Lower-Level SRN</i>	158
11.5	Redundancy Optimization	158
11.6	Numerical Results	159
11.6.1	<i>Model Comparison</i>	159
11.6.2	<i>Influences of Performance Demand and Redundancy Configuration</i>	162
11.7	Conclusion	165
	References	165
12	Reliability and Probability of First Occurred Failure for Discrete-Time Semi-Markov Systems	167
	<i>Stylianos Georgiadis, Nikolaos Limnios and Irene Votsi</i>	
12.1	Introduction	167
12.2	Discrete-Time Semi-Markov Model	168

12.3	Reliability and Probability of First Occurred Failure	170
	12.3.1 <i>Rate of Occurrence of Failures</i>	171
	12.3.2 <i>Steady-State Availability</i>	171
	12.3.3 <i>Probability of First Occurred Failure</i>	172
12.4	Nonparametric Estimation of Reliability Measures	172
	12.4.1 <i>Estimation of ROCOF</i>	173
	12.4.2 <i>Estimation of the Steady-State Availability</i>	174
	12.4.3 <i>Estimation of the Probability of First Occurred Failure</i>	175
12.5	Numerical Application	176
12.6	Conclusion	178
	References	179
13	Single-Source Epidemic Process in a System of Two Interconnected Networks	180
	<i>Ilya B. Gertsbakh and Yoseph Shpungin</i>	
13.1	Introduction	180
13.2	Failure Process and the Distribution of the Number of Failed Nodes	181
13.3	Network Failure Probabilities	184
13.4	Example	185
13.5	Conclusion	187
13.A	Appendix D: Spectrum (Signature)	188
	References	189

Part III MAINTENANCE MODELS

14	Comparisons of Periodic and Random Replacement Policies	193
	<i>Xufeng Zhao and Toshio Nakagawa</i>	
14.1	Introduction	193
14.2	Four Policies	195
	14.2.1 <i>Standard Replacement</i>	195
	14.2.2 <i>Replacement First</i>	195
	14.2.3 <i>Replacement Last</i>	196
	14.2.4 <i>Replacement Over Time</i>	196
14.3	Comparisons of Optimal Policies	197
	14.3.1 <i>Comparisons of T_S^* and T_F^*, T_L^*, and T_O^*</i>	197
	14.3.2 <i>Comparisons of T_O^* and T_F^*, T_L^*</i>	198
	14.3.3 <i>Comparisons of T_F^* and T_L^*</i>	199
14.4	Numerical Examples 1	199
14.5	Comparisons of Policies with Different Replacement Costs	201
	14.5.1 <i>Comparisons of T_S^*, and T_F^*, T_L^*</i>	201
	14.5.2 <i>Comparisons of T_S^* and T_O^*</i>	201
14.6	Numerical Examples 2	202
14.7	Conclusion	203
	Acknowledgements	204
	References	204

15	Random Evolution of Degradation and Occurrences of Words in Random Sequences of Letters	205
	<i>Emilio De Santis and Fabio Spizzichino</i>	
15.1	Introduction	205
15.2	Waiting Times to Words' Occurrences	206
	15.2.1 <i>The Markov Chain Approach</i>	207
	15.2.2 <i>Leading Numbers and Occurrences Times</i>	208
15.3	Some Reliability-Maintenance Models	209
	15.3.1 <i>Model 1 (Simple Machine Replacement)</i>	209
	15.3.2 <i>Model 2 (Random Reduction of Age)</i>	210
	15.3.3 <i>Model 3 (Random Number of Effective Repairs in a Parallel System)</i>	211
	15.3.4 <i>Degradation and Words</i>	212
15.4	Waiting Times to Occurrences of Words and Stochastic Comparisons for Degradation	213
15.5	Conclusions	216
	Acknowledgements	217
	References	217
16	Occupancy Times for Markov and Semi-Markov Models in Systems Reliability	218
	<i>Alan G. Hawkes, Lirong Cui and Shijia Du</i>	
16.1	Introduction	218
16.2	Markov Models for Systems Reliability	220
16.3	Semi-Markov Models	222
	16.3.1 <i>Joint Distributions of Operational and Failed Times</i>	223
	16.3.2 <i>Distribution of Cumulative Times</i>	224
16.4	Time Interval Omission	225
16.5	Numerical Examples	226
16.6	Conclusion	229
	Acknowledgements	229
	References	229
17	A Practice of Imperfect Maintenance Model Selection for Diesel Engines	231
	<i>Yu Liu, Hong-Zhong Huang, Shun-Peng Zhu and Yan-Feng Li</i>	
17.1	Introduction	231
17.2	Review of Imperfect Maintenance Model Selection Method	233
	17.2.1 <i>Estimation of the Parameters</i>	234
	17.2.2 <i>The Proposed GOF Test</i>	234
	17.2.3 <i>Bayesian Model Selection</i>	235
17.3	Application to Preventive Maintenance Scheduling of Diesel Engines	236
	17.3.1 <i>Initial Failure Intensity Estimation</i>	237
	17.3.2 <i>Imperfect Maintenance Model Selection</i>	237
	17.3.3 <i>Implementation in Preventive Maintenance Decision-Making</i>	240

17.4	Conclusion	244
	Acknowledgment	245
	References	245
18	Reliability of Warm Standby Systems with Imperfect Fault Coverage	246
	<i>Rui Peng, Ola Tannous, Liudong Xing and Min Xie</i>	
18.1	Introduction	246
18.2	Literature Review	247
18.3	The BDD-Based Approach	250
	<i>18.3.1 The BDD Construction</i>	251
	<i>18.3.2 System Unreliability Evaluation</i>	251
	<i>18.3.3 Illustrative Examples</i>	252
18.4	Conclusion	253
	Acknowledgments	254
	References	254
 Part IV STATISTICAL INFERENCE IN RELIABILITY		
19	On the Validity of the Weibull-Gnedenko Model	259
	<i>Vilijandas Bagdonavičius, Mikhail Nikulin and Ruta Levuliene</i>	
19.1	Introduction	259
19.2	Integrated Likelihood Ratio Test	261
19.3	Tests based on the Difference of Non-Parametric and Parametric Estimators of the Cumulative Distribution Function	264
19.4	Tests based on Spacings	266
19.5	Chi-Squared Tests	267
19.6	Correlation Test	269
19.7	Power Comparison	269
19.8	Conclusion	272
	References	272
20	Statistical Inference for Heavy-Tailed Distributions in Reliability Systems	273
	<i>Ilia Vonta and Alex Karagrigoriou</i>	
20.1	Introduction	273
20.2	Heavy-Tailed Distributions	274
20.3	Examples of Heavy-Tailed Distributions	277
20.4	Divergence Measures	280
20.5	Hypothesis Testing	284
20.6	Simulations	286
20.7	Conclusion	287
	References	287

21	Robust Inference based on Divergences in Reliability Systems	290
	<i>Abhik Ghosh, Avijit Maji and Ayanendranath Basu</i>	
21.1	Introduction	290
21.2	The Power Divergence (PD) Family	291
	21.2.1 <i>Minimum Disparity Estimation</i>	293
	21.2.2 <i>The Robustness of the Minimum Disparity Estimators (MDEs)</i>	294
	21.2.3 <i>Asymptotic Properties</i>	295
21.3	Density Power Divergence (DPD) and Parametric Inference	296
	21.3.1 <i>Connections between the PD and the DPD</i>	298
	21.3.2 <i>Influence Function of the Minimum DPD estimator</i>	299
	21.3.3 <i>Asymptotic Properties of the Minimum DPD estimator</i>	300
21.4	A Generalized Form: The <i>S</i> -Divergence	301
	21.4.1 <i>The Divergence and the Estimating Equation</i>	301
	21.4.2 <i>Influence Function of the Minimum <i>S</i>-Divergence estimator</i>	303
	21.4.3 <i>Minimum <i>S</i>-Divergence Estimators: Asymptotic Properties</i>	303
21.5	Applications	304
	21.5.1 <i>Reliability: The Generalized Pareto Distribution</i>	304
	21.5.2 <i>Survival Analysis</i>	305
	21.5.3 <i>Model Selection: Divergence Information Criterion</i>	306
21.6	Conclusion	306
	References	306
22	COM-Poisson Cure Rate Models and Associated Likelihood-based Inference with Exponential and Weibull Lifetimes	308
	<i>N. Balakrishnan and Suvra Pal</i>	
22.1	Introduction	308
22.2	Role of Cure Rate Models in Reliability	310
22.3	The COM-Poisson Cure Rate Model	310
22.4	Data and the Likelihood	311
22.5	EM Algorithm	312
22.6	Standard Errors and Asymptotic Confidence Intervals	314
22.7	Exponential Lifetime Distribution	314
	22.7.1 <i>Simulation Study: Model Fitting</i>	315
	22.7.2 <i>Simulation Study: Model Discrimination</i>	319
22.8	Weibull Lifetime Distribution	322
	22.8.1 <i>Simulation Study: Model Fitting</i>	322
	22.8.2 <i>Simulation Study: Model Discrimination</i>	328
22.9	Analysis of Cutaneous Melanoma Data	334
	22.9.1 <i>Exponential Lifetimes with Log-Linear Link Function</i>	334
	22.9.2 <i>Weibull Lifetimes with Logistic Link Function</i>	335
22.10	Conclusion	337
22.A1	Appendix A1: E-Step and M-Step Formulas for Exponential Lifetimes	337
22.A2	Appendix A2: E-Step and M-Step Formulas for Weibull Lifetimes	341

22.B1	Appendix B1: Observed Information Matrix for Exponential Lifetimes	344
22.B2	Appendix B2: Observed Information Matrix for Weibull Lifetimes	346
	References	347
23	Exponential Expansions for Perturbed Discrete Time Renewal Equations	349
	<i>Dmitrii Silvestrov and Mikael Petersson</i>	
23.1	Introduction	349
23.2	Asymptotic Results	350
23.3	Proofs	353
23.4	Discrete Time Regenerative Processes	358
23.5	Queuing and Risk Applications	359
	References	361
24	On Generalized Extreme Shock Models under Renewal Shock Processes	363
	<i>Ji Hwan Cha and Maxim Finkelstein</i>	
24.1	Introduction	363
24.2	Generalized Extreme Shock Models	364
	24.2.1 'Classical' Extreme Shock Model for Renewal Process of Shocks	364
	24.2.2 History-Dependent Extreme Shock Model	365
24.3	Specific Models	367
	24.3.1 Stress-Strength Model	367
	24.3.2 Model A in Cha and Finkelstein (2011)	369
	24.3.3 State-Dependent Shock Model	370
24.4	Conclusion	373
	Acknowledgements	373
	References	373
Part V SYSTEMABILITY, PHYSICS-OF-FAILURE AND RELIABILITY DEMONSTRATION		
25	Systemability Theory and its Applications	377
	<i>Hoang Pham</i>	
25.1	Introduction	377
25.2	Systemability Measures	378
25.3	Systemability Analysis of k -out-of- n Systems	379
	25.3.1 Variance of Systemability Calculations	380
25.4	Systemability Function Approximation	380
25.5	Systemability with Loglog Distribution	383
	25.5.1 Loglog Distribution	383

25.6	Sensitivity Analysis	384
25.7	Applications: Red Light Camera Systems	385
25.8	Conclusion	387
	References	387
26	Physics-of-Failure based Reliability Engineering	389
	<i>Pedro O. Quintero and Michael Pecht</i>	
26.1	Introduction	389
26.2	Physics-of-Failure-based Reliability Assessment	393
	26.2.1 <i>Information Requirements</i>	393
	26.2.2 <i>Failure Modes, Mechanisms, and Effects Analysis (FMMEA)</i>	396
	26.2.3 <i>Stress Analysis</i>	397
	26.2.4 <i>Reliability Assessment</i>	397
26.3	Uses of Physics-of-Failure	398
	26.3.1 <i>Design-for-Reliability (DfR)</i>	398
	26.3.2 <i>Stress Testing Conditions</i>	398
	26.3.3 <i>Qualification</i>	399
	26.3.4 <i>Screening Conditions</i>	399
	26.3.5 <i>Prognostics and Health Management (PHM)</i>	399
26.4	Conclusion	400
	References	400
27	Accelerated Testing: Effect of Variance in Field Environmental Conditions on the Demonstrated Reliability	403
	<i>Andre Kleyner</i>	
27.1	Introduction	403
27.2	Accelerated Testing and Field Stress Variation	404
27.3	Case Study: Reliability Demonstration Using Temperature Cycling Test	405
27.4	Conclusion	408
	References	408
Index		409

Remembering Boris Gnedenko

Andre Kleyner¹ and Ekaterina Gnedenko²

¹*Editor of Wiley Series in Quality and Reliability Engineering,*

²*Granddaughter of Boris Gnedenko, Faculty, Department of Economics, Tufts University*



Boris Gnedenko was one of the most prominent mathematicians of the twentieth century. He contributed greatly to the area of probability theory, and his name is permanently linked to pioneering and developing mathematical methods in reliability engineering. Gnedenko is best known for his contributions to the study of probability theory, such as the extreme value theorem (the Fisher–Tippett–Gnedenko theorem). He first became famous for his work on the definitive treatment of limit theorems for sums of independent random variables. He was later known as a leader of Russian work in applied probability and as the author and coauthor of outstanding textbooks on probability, mathematical methods in reliability and queuing theory.

Boris Gnedenko was born on January 1, 1912, in Simbirsk (later Ulianovsk), a Russian city on the Volga River. He was admitted to the University of Saratov at the young age of 15 by special permission from the Minister of Culture and Education of the Soviet Union.

After graduation from the university, Gnedenko took a teaching job at the Textile Institute in Ivanovo, the city east of Moscow, which for many years was the center of the Soviet textile industry. While lecturing at the university, Gnedenko simultaneously was involved in the solution of some practical problems for the textile industry. This is when he wrote his first works, concerning queuing theory, and became fond of the theory of

probability. That triggered his later works on the applications of statistics to reliability and quality control in manufacturing.

In 1934, Gnedenko decided to resume his university studies at the graduate level. He was awarded a scholarship which allowed him to undertake research at the Institute of Mathematics at Moscow State University. He became a graduate student under the direction of Alexander Khinchin and Andrei Kolmogorov. The latter became one of the most famous mathematicians of the twentieth century (the Kolmogorov-Smirnov test in statistics, the Kolmogorov-Arnold-Moser theorem in Dynamics, the Kolmogorov Complexity, and other landmark achievements). As a graduate student, Gnedenko became interested in limiting theorems for the sums of independent random variables. In 1937, he defended his dissertation on “Some Results in the Theory of Infinitely Divisible Distributions,” and, soon after the defense, he was appointed a researcher at the Institute of Mathematics at Moscow State University.

Years later, Kolmogorov would say:

Boris Gnedenko is recognized by an international mathematics community as one of the most prominent mathematicians who is currently working in the area of probability theory. He combines an exceptional skill and proficiency in classical mathematical methods with deep understanding of a wide range of modern probability problems and a perpetual interest to their practical applications.

In 1937, during the infamous Stalin’s Purges, Gnedenko was falsely accused of “anti-Soviet” activity and thrown in jail. The NKVD (the Soviet secret police at that time) were trying to coerce him to testify against Kolmogorov, who was not yet arrested but was under investigation by the NKVD for running a conspiracy “against the Soviet people,” a very common bogus charge at the time. However, Gnedenko survived brutal treatment at the hands of the NKVD and refused to support the false accusations against his mentor. He was released six months later, though his health suffered.

He returned to Moscow University as an assistant professor in the Department of the Theory of Probability in 1938 and as a research secretary (an academic title in Russia) at the Institute of Mathematics. During this period at Moscow State University, he solved two important problems. The first problem involved the construction of asymptotic distributions of the maximum term of the variation series and defining the nature of limit distributions and the conditions for convergence (Gnedenko 1941b). The second problem involved the construction of the theory of corrections to the Geiger–Muller counter readings used in many fields of physics and technology (Gnedenko 1941a). This paper is a landmark in what later became “the theory of reliability”.

In 1939, Gnedenko married Natalia Konstantinovna and subsequently they had two sons.

During World War II, Gnedenko continued his research work at Moscow State University, although for two years, together with all the university colleagues, he had to temporarily relocate to Turkmenistan and later to the Ural mountains because of Moscow’s proximity to the front lines. Some of his work during the war was of national defense nature, including quality and process control at military plants. During that time Gnedenko continued working on a variety of mathematical problems, including the limit theorem for the sums of independent variables, and discovering the classification of the possible types

of limit behavior for the maximum in an increasing sequence of independent random variables. The Weibull distribution, one of the most popular time-to-failure distributions in reliability engineering, is occasionally referred to as ‘Weibull-Gnedenko’ (see, e.g. Pecht 1995, or Chapter 19 in this book). Gnedenko developed this model at about the same time as Waloddi Weibull in Sweden, however, due to the relative isolation of the Soviet Union at that time, this was not common knowledge. Only in 1943, two years after Gnedenko had published his results in Russian, due to the warming relationship between the USA and the Soviet Union during World War II, did Gnedenko receive an invitation to publish his hallmark paper on extreme value limit theorem in the American journal, *Annals of Mathematics*. His research into limit theorems continued and in 1949 this resulted in a monograph with Kolmogorov, entitled “Limit Distributions for Sums of Independent Random Variables”. This monograph was awarded the Chebyshev Prize in 1951 and was translated into many languages. It was later published in English by Addison-Wesley publishing (Gnedenko and Kolmogorov 1954) and underwent a second edition in 1968.



Boris Gnedenko and his wife Natalia, 1978

During World War II, the western part of the Soviet Union was devastated by the German occupation, therefore after the war in 1945, Gnedenko was sent to Lviv, the largest city in Western Ukraine, to help rebuild Lviv University and undertake the restoration of the overall Ukrainian system of higher education. He accepted this challenging job with great energy and enthusiasm.

Building on the works of Kolmogorov and Smirnov establishing the limit distributions for the maximum deviation of an empirical distribution function from the theoretical,

Gnedenko developed effective methods to obtain the exact distributions in the case of finite samples in these and other related problems. This work received worldwide recognition, because it served as the basis for compiling tables which were very valuable in applied statistics at that time.

In 1948, Gnedenko was elected a full member of the Ukrainian Academy of Science and in 1950 he was transferred to Kiev, the capital of the Ukraine, to become Head of the recently created Department of the Theory of Probability at the Institute of Mathematics of the Ukrainian Academy of Sciences and also Head of the Physics, Mathematics and Chemistry Section of the Ukrainian Academy of Sciences. At the same time he served as the Chair of the Department of Probability Theory and Algebra at Kiev State University. Later he became Director of the Kiev Institute of Mathematics.

His work in Kiev followed several directions. Besides mathematics and statistics, his contribution was instrumental in developing computer programming and setting up a computing laboratory and encouraging his younger colleagues to study programming. His earlier efforts at the Ukrainian Academy of Science helped to create, in 1951, one of the first fully operational electronic computers in continental Europe.

In 1958, Gnedenko was a plenary speaker at the International Congress of Mathematicians in Edinburgh with a talk entitled, "Limit Theorems of Probability Theory". One of Gnedenko's most famous books is called *Theory of Probability*, which first appeared in 1950. Written in a clear and concise manner, the book was very successful in providing an introduction to probability and statistics. It has undergone six Russian editions and has been translated into English (Gnedenko 1998), German, Polish and Arabic. Earlier, in 1946, Gnedenko also co-authored, with Khinchin, the book, *Elementary Introduction to the Theory of Probability*, which also has been published many times in the USSR and abroad.

In 1960, Boris Gnedenko returned to Moscow State University and later, in 1966 became Head of the Department of Probability holding this post until his death in 1995. He took over from Andrei Kolmogorov, who became Head of the Interdepartmental Laboratory of Probability and Statistics in Moscow.

During the sixties, Gnedenko's interests turned to mathematical problems with industrial application, namely, the queuing theory and mathematical methods in reliability. In 1961, with several of his students and colleagues, he organized and chaired the Moscow Reliability Engineering Seminars. This was a very successful undertaking with around 800 participants: academics, engineers and mathematicians. Many attendees traveled from other cities, and besides academic activities, it resulted in a number of practical consultations helping engineers in various industries. This seminar was also a big promoter of reliability engineering, which at that time was in its infancy.

As Professor Vere-Jones, then a British graduate student at Moscow State University, remembers: "It was into this seminar that I strayed in 1961. I was much impressed, not so much by the academic level, which varied from excellent to indifferent, as by the strong impression I received that this was an environment in which everyone's contribution was valued" (Vere-Jones 1997). This "owed a great deal to Boris Vladimirovich Gnedenko's own personality and convictions, and the influence he had on his colleagues". Later, at the end of 1965, Vere-Jones managed to arrange for Gnedenko a two-month trip "down under". Gnedenko was invited by the Australian National University in Canberra, which had a special exchange agreement with Moscow State University. Unfortunately, Gnedenko was not able to take his family with him on this exciting trip – the Soviet

government, afraid of losing Gnedenko to the foreign capitalistic country, did not allow his wife and sons to accompany him. According to Vere-Jones, Gnedenko lectured on two themes: one was reliability theory (estimation and testing of the life-time distribution); and the second was mathematical education in the Soviet Union, which generated the greatest interest. Throughout his visit, Gnedenko displayed great interest in everything: the people, the birds and animals, the scenery, the universities and schools, shops, etc. He was particularly fascinated by the koala in Australia and by the kiwi and its huge egg in New Zealand. "His interest in matters 'down under' continued well past this visit. I believe he became a president or patron of the USSR side of the New Zealand-USSR friendship society".

Most people who met Gnedenko remember their personal interactions very fondly and pay tribute to his disposition and personal qualities. Vere-Jones says:

I consider myself extraordinarily fortunate in having happened to drift into his seminar in October 1961. Not only was it a chance to step inside the legendary world of Russian probability theory, it was a chance to come to know a rare human being, to see him at home and with his family, and to work briefly alongside him.

(Vere-Jones 1997)

In 1991, Gnedenko visited the USA. Professor Igor Ushakov, his longtime colleague, who was his host during this trip, remembers:

I was blessed in life to have an opportunity to work closely with Boris Gnedenko. I accompanied him on various academic business trips and spent many evenings at his house and in the company of his family. It would not be an exaggeration to say that I've never met another person with more zest for life and more willingness to share his kindness and help others in need.

(Ushakov 2011)

During that trip Gnedenko, accompanied by his son Dmitry, visited the University of North Carolina, where he lectured and had several research meetings. Then he went to Washington, DC, to give a lecture at the Department of Operations Research of George Washington University. Upon learning about Gnedenko's arrival, the university photographers took a lot of photos and the university newspaper published an article about his visit. While in Washington, DC, Gnedenko met quite a few local mathematicians. Many invited him to their homes and he was always the center of attention. Since this was an international crowd, his knowledge of German and French (in addition to English) came in very handy.

During that visit he was also interviewed by Professor Nozer Singpurwalla at George Washington University. Answering questions, Gnedenko recalled many important events in his life, his work with Kolmogorov and other prominent Russian mathematicians, as well as other significant milestones (Singpurwalla and Smith 1992). During his professional life he held a number of high administrative positions, both at a university and the Academy of Science levels, however, his heart was clearly in academic work and research. Gnedenko said: "I prefer scientific work, lecturing and writing. I enjoy working with students. I have had over a hundred doctoral students, of whom 30 are professors in my country or in other countries". Seven of his students became members of the Academy of Science, the highest academic distinction in Russia and the former Soviet Republics.

His teaching activities extended beyond academia, Boris Gnedenko had also contributed greatly to popularizing math and science. Besides the book on history of mathematics mentioned earlier, he also wrote for primary and secondary school. Gnedenko said: “This year I have also written a short book for school children on mathematics and life”, and later, “The second book I plan is for school children – a trip into a mathematical country”.



Boris Gnedenko and his colleague and friend, Igor Ushakov, at Gnedenko’s home, 1970

Besides studying and doing research in mathematics, Gnedenko also took a keen interest in the history of this discipline, which he considered very important to a future development of mathematics. According to O’Connor and Robertson (2000), Gnedenko’s interest in the history of mathematics extended well beyond his text aimed at secondary school pupils. He published much on this topic, including the important *Outline of the History of Mathematics in Russia* which was not published until 1946, although he wrote it before the start of World War II. It is a fascinating book which looks at the history of mathematics in Russia in its cultural background.

Later in 1993, Gnedenko visited the USA again, now by invitation from the MCI Corporation, at that time a telecommunication giant, where Professor Ushakov was a consultant at the time. Gnedenko was 81, but despite his health problems he put together a rigorous plan to visit all the technical and academic centers he was invited to. The first visit was to the MCI Headquarters in Dallas, where he lectured to a large audience about statistical problems in the telecommunications industry. Introducing him to the audience, Chris Hardy, the MCI Chief Scientist, said: “I did not have any difficulties inviting Prof. Gnedenko, I just said to our CEO that for us hosting Professor Gnedenko would be like for Los Alamos Labs hosting Norbert Wiener.”

Next stop was at Harvard University, hosted by Eugene Litvak, professor at the School of Public Health. For his lecture topic Gnedenko chose, “Probability and Statistics from

Middle Ages to Our Days”. Gnedenko always had a sixth sense and a feel for his audience; therefore, because this time he was not speaking to expert mathematicians, he chose one of his favorite subjects: the history of mathematics.

During his lifetime Gnedenko produced a remarkable number of published works. One of the most complete lists of his publications can be found in Gnedenko D.B. (2011). Interestingly enough, all his life, even after the introduction of word processors, Gnedenko still used a typewriter. When asked during one interview how many drafts it took for a paper or book, Gnedenko answered, “one draft only”. It was difficult to believe one draft would have no errors or need for improvement. Gnedenko replied, “it is necessary to think first and only then to write. At this stage I am almost finished” (Singpurwalla and Smith 1992).

Many of the facts and events of Gnedenko’s life that are presented here are also recounted in greater detail by the great man himself in his memoirs (Gnedenko 2012). More information about Boris Gnedenko can be found on a dedicated website, Gnedenko Forum, an informal association of specialists in reliability (Gnedenko Forum 2013). The Forum, created by Gnedenko’s followers, I. Ushakov and A. Bochkov, is designed to commemorate his legacy and also to promote contacts between members of the global reliability community. It contains the latest professional news in the areas of probability theory, statistics, reliability engineering, risk analysis, mathematical methods in reliability, safety, security and other related fields. Many contributors of this book are members of the Gnedenko Forum and were inspired or influenced in some way by the lifelong work of this great mathematician. This book commemorates the centennial of his birth and pays tribute to his immense contribution to the probability theory and reliability mathematics and also celebrates his legacy.

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List of Contributors

Vilijandas Bagdonavičius, Department of Mathematical Statistics, Faculty of Mathematics and Informatics, Vilnius University, Lithuania
Vilijandas.Bagdonavicius@mif.vu.lt

N. Balakrishnan, Department of Mathematics and Statistics, McMaster University, Canada and Department of Statistics, King Abdulaziz University, Saudi Arabia
bala@univmail.cis.mcmaster.ca

Ayanendranath Basu, Indian Statistical Institute, India ayanbasu@isical.ac.in

Ji Hwan Cha, Department of Statistics, Ewha Womans University, Korea
jhcha@ewha.ac.kr

Lirong Cui, School of Management & Economics, Beijing Institute of Technology, P.R. China lirongcui@bit.edu.cn

Emilio De Santis, Department of Mathematics, University La Sapienza, Italy
desantis@mat.uniroma1.it

Yi Ding, Department of Electrical Engineering, Technical University of Denmark, Denmark yding@elektro.dtu.dk

Shijia Du, School of Management & Economics, Beijing Institute of Technology, China
dushijia111@126.com

Maxim Finkelstein, Department of Mathematical Statistics, University of the Free State, South Africa FinkelM@ufs.ac.za

Ilia B. Frenkel, Center for Reliability and Risk Management, Industrial Engineering and Management Department, SCE - Shamoon College of Engineering, Israel iliaf@sce.ac.il

Stylios Georgiadis, Laboratoire de Mathématiques Appliquées de Compiègne, Université de Technologie de Compiègne, Centre de Recherches de Royallieu, France
stylios.georgiadis@utc.fr

Ilya B. Gertsbakh, Department of Mathematics, Ben-Gurion University, Israel,
elyager@bezeqint.net

Abhik Ghosh, Indian Statistical Institute, India abhianik@gmail.com

Alan G. Hawkes, School of Business and Economics, Swansea University, UK
alanhawkes@virginmedia.com

Hong-Zhong Huang, School of Mechanical, Electronic, and Industrial Engineering,
University of Electronic Science and Technology of China, China hzhuang@uestc.edu.cn

Kailash (Kal) C. Kapur, Industrial & Systems Engineering, University of Washington,
USA kkapur@u.washington.edu

Alex Karagrigoriou, Department of Mathematics and Statistics, University of Cyprus,
Cyprus alex@ucy.ac.cy, alex.karagrigoriou@gmail.com

Lev Khvatskin, Center for Reliability and Risk Management, Industrial Engineering
and Management Department, SCE - Shamoon College of Engineering, Israel
khvat@sce.ac.il

Andre V. Kleyner, Delphi Electronics & Safety, USA andre.v.kleyner@delphi.com,
kleyner.consulting@sbcglobal.net

Gregory Levitin, The Israel Electric Corporation Ltd., Israel levitin@iec.co.il

Ruta Levuliene, Department of Mathematical Statistics, Faculty of Mathematics and
Informatics, Vilnius University, Vilnius, Lithuania Ruta.levuliene@mif.vu.lt

Yan-Feng Li, School of Mechanical, Electronic, and Industrial Engineering, University
of Electronic Science and Technology of China, China lyfmoon@gmail.com

Yan-Fu Li, Ecole Centrale Paris LGI-Supelec, France yanfu.li@ecp.fr,
yanfu.li@supelec.fr

Zhaojun (Steven) Li, Electro-Motive Diesel – A Caterpillar Company, USA
zjli@uw.edu

Nikolaos Limnios, Laboratoire de Mathématiques Appliquées de Compiègne, Université
de Technologie de Compiègne, Centre de Recherches de Royallieu, France
nikolaos.limnios@utc.fr

Yan-Hui Lin, Ecole Centrale Paris LGI-Supelec, Paris, France yanhui.lin@ecp.fr

Anatoly Lisnianski, The Israel Electric Corporation Ltd., Israel anatoly-l@iec.co.il

Yu Liu, School of Mechanical, Electronic, and Industrial Engineering, University of Electronic Science and Technology of China, China yuliu@uestc.edu.cn

Avijit Maji, Indian Statistical Institute, India avijit.maji@hotmail.com

Krishna B. Misra, International Journal of Performability Engineering, India kbmisra@gmail.com

Ramin Moghaddass, Reliability Research Lab, Department of Mechanical Engineering, University of Alberta, USA rmoghadd@ualberta.ca

Toshio Nakagawa, Department of Business Administration, Aichi Institute of Technology, Japan toshi-nakagawa@aitech.ac.jp

Mikhail Nikulin, IMB, University Victor Segalen Bordeaux 2, France mikhail.nikouline@u-bordeaux2.fr

Suvra Pal, Department of Mathematics and Statistics, McMaster University, Canada pals3@math.mcmaster.ca

Michael Pecht, Center for Advanced Life Cycle Engineering (CALCE), Department of Mechanical Engineering, University of Maryland, USA pecht@calce.umd.edu

Rui Peng, University of Science & Technology Beijing, China pengrui1988@gmail.com

Mikael Petersson, Department of Mathematics, University, Stockholm, Sweden mikpe@math.su.se

Hoang Pham, Department of Industrial and Systems Engineering, Rutgers, The State University of New Jersey, USA hopham@rci.rutgers.edu

Fabio Postiglione, Department of Electronic and Computer Engineering, University of Salerno, Italy fpostiglione@unisa.it

Pedro O. Quintero, Department of Mechanical Engineering, University of Puerto Rico at Mayagüez, Puerto Rico pqintero@me.uprm.edu

Yoseph Shpungin, Software Engineering Department, SCE – Shamon College of Engineering, Israel yosefs@sce.ac.il

Dmitrii Silvestrov, Department of Mathematics, Stockholm University, Sweden dmitrii.silvestrov@mdh.se, silvestrov@math.su.se

Nozer D. Singpurwalla, Department of System Engineering and Engineering Management, and Department of Management Science, City University of Hong Kong, Hong Kong nozer@gwu.edu

Fabio Spizzichino, Department of Mathematics, University La Sapienza, Italy
fabio.spizzichino@uniroma1.it

Ola Tannous, Reliability and Quality Engineering Department, Electro Motive Diesels,
USA ola.tannous@electromotivediesels.com

Kishor S. Trivedi, Department of Electrical and Computer Engineering, Duke
University, USA kst@ee.duke.edu

Ilia Vonta, Department of Mathematics, School of Applied Mathematical and Physical
Sciences, National Technical University of Athens, Greece vonta@math.ntua.gr

Irene Votsi, Laboratoire de Mathématiques Appliquées de Compiègne, Université de
Technologie de Compiègne, Centre de Recherches de Royallieu, France
irene.votsi@utc.fr

Min Xie, Department of Systems Engineering & Engineering Management, City
University of Hong Kong, Hong Kong, China minxie@cityu.edu.hk

Liudong Xing, University of Massachusetts Dartmouth, USA lxing@umassd.edu

Xiaoyan Yin, Department of Electrical and Computer Engineering, Duke University,
USA xy15@duke.edu

Xufeng Zhao, School of Economics and Management, Nanjing University of
Technology, China g09184gg@aitech.ac.jp

Shun-Peng Zhu, School of Mechanical, Electronic, and Industrial Engineering,
University of Electronic Science and Technology of China, China
zspeng2007@uestc.edu.cn

Enrico Zio, Ecole Centrale Paris LGI-Supelec, France and Dipartimento di Energia,
Politecnico di Milano, Italy enrico.zio@ecp.fr, enrico.zio@polimi.it,
enrico.zio@supelec.fr

Ming J. Zuo, Reliability Research Lab, Department of Mechanical Engineering,
University of Alberta, USA ming.zuo@ualberta.ca, mzu@ualberta.ca