Contents

Preface xix

Preface to the Second Edition xxi

Preface to the First Edition xxiii

PART I FUNDAMENTAL QUALITY IMPROVEMENT AND
STATISTICAL CONCEPTS

1 Introduction 3

1.1 Quality and Productivity, 4
1.2 Quality Costs (or Does It?), 5
1.3 The Need for Statistical Methods, 5
1.4 Early Use of Statistical Methods for Improving Quality, 6
1.5 Influential Quality Experts, 7
1.6 Summary, 9
References, 10

2 Basic Tools for Improving Quality 13

2.1 Histogram, 13
2.2 Pareto Charts, 17
2.3 Scatter Plots, 21
2.3.1 Variations of Scatter Plots, 24
2.4 Control Chart, 24
2.5 Check Sheet, 26
2.6 Cause-and-Effect Diagram, 26
2.7 Defect Concentration Diagram, 28
CONTENTS

2.8 The Seven Newer Tools, 28
  2.8.1 Affinity Diagram, 28
  2.8.2 Interrelationship Digraph, 29
  2.8.3 Tree Diagram, 29
  2.8.4 Prioritization Matrix, 29
  2.8.5 Matrix Diagram, 30
  2.8.6 Process Decision Program Chart, 30
  2.8.7 Activity Network Diagram, 30

2.9 Software, 30

2.10 Summary, 31

References, 31

Exercises, 32

3 Basic Concepts in Statistics and Probability 33

3.1 Probability, 33

3.2 Sample Versus Population, 35

3.3 Location, 36

3.4 Variation, 38

3.5 Discrete Distributions, 41
  3.5.1 Binomial Distribution, 43
  3.5.2 Beta-Binomial Distribution, 50
  3.5.3 Poisson Distribution, 50
  3.5.4 Geometric Distribution, 52
  3.5.5 Negative Binomial Distribution, 52
  3.5.6 Hypergeometric Distribution, 53

3.6 Continuous Distributions, 55
  3.6.1 Normal Distribution, 55
  3.6.2 $t$ Distribution, 59
  3.6.3 Exponential Distribution, 61
  3.6.4 Lognormal Distribution, 62
  3.6.5 Weibull Distribution, 64
  3.6.6 Extreme Value Distribution, 64
  3.6.7 Gamma Distribution, 64
  3.6.8 Chi-Square Distribution, 65
  3.6.9 Truncated Normal Distribution, 65
  3.6.10 Bivariate and Multivariate Normal Distributions, 66
  3.6.11 $F$ Distribution, 67
  3.6.12 Beta Distribution, 68
  3.6.13 Uniform Distribution, 68
CONTENTS

3.7 Choice of Statistical Distribution, 69
3.8 Statistical Inference, 69
   3.8.1 Central Limit Theorem, 70
   3.8.2 Point Estimation, 71
      3.8.2.1 Maximum Likelihood Estimation, 71
   3.8.3 Confidence Intervals, 72
   3.8.4 Tolerance Intervals, 74
   3.8.5 Hypothesis Tests, 76
      3.8.5.1 Probability Plots, 76
      3.8.5.2 Likelihood Ratio Tests, 78
   3.8.6 Bonferroni Intervals, 80
3.9 Enumerative Studies Versus Analytic Studies, 81
References, 81
Exercises, 83

PART II CONTROL CHARTS AND PROCESS CAPABILITY

4 Control Charts for Measurements With Subgrouping
   (for One Variable) 89
   4.1 Basic Control Chart Principles, 89
   4.2 Real-Time Control Charting Versus Analysis of Past Data, 92
   4.3 Control Charts: When to Use, Where to Use, How Many to Use, 94
   4.4 Benefits from the Use of Control Charts, 94
   4.5 Rational Subgroups, 95
   4.6 Basic Statistical Aspects of Control Charts, 95
   4.7 Illustrative Example, 96
      4.7.1 $R$-Chart, 100
      4.7.2 $R$-Chart with Probability Limits, 102
      4.7.3 $S$-Chart, 103
      4.7.4 $S$-Chart with Probability Limits, 103
      4.7.5 $S^2$-Chart, 107
      4.7.6 $X$-Chart, 108
      4.7.7 Recomputing Control Limits, 111
      4.7.8 Applying Control Limits to Future Production, 112
      4.7.9 Combining an $X$- and an $S$-Chart, 113
      4.7.10 Standards for Control Charts, 113
      4.7.11 Deleting Points, 114
      4.7.12 Target Values, 114
CONTENTS

4.8 Illustrative Example with Real Data, 114
4.9 Determining the Point of a Parameter Change, 116
4.10 Acceptance Sampling and Acceptance Control Chart, 117
  4.10.1 Acceptance Control Chart, 119
    4.10.1.1 Acceptance Chart with Control Limits, 121
    4.10.1.2 Acceptance Charts Versus Target Values, 123
4.11 Modified Limits, 124
4.12 Difference Control Charts, 124
4.13 Other Charts, 126
4.14 Average Run Length (ARL), 127
  4.14.1 Weakness of the ARL Measure, 128
4.15 Determining the Subgroup Size, 129
  4.15.1 Unequal Subgroup Sizes, 130
4.16 Out-of-Control Action Plans, 131
4.17 Assumptions for the Charts in This Chapter, 132
  4.17.1 Normality, 132
  4.17.2 Independence, 136
4.18 Measurement Error, 140
  4.18.1 Monitoring Measurement Systems, 142
4.19 Software, 142
4.20 Summary, 143
Appendix, 144
  4.A Derivation of Control Chart Constants, 144
  4.B ARL Calculations, 146
References, 146
Exercises, 151

5 Control Charts for Measurements Without Subgrouping
(for One Variable) 157

5.1 Individual Observations Chart, 158
  5.1.1 Control Limits for the X-Chart, 159
  5.1.2 X-Chart Assumptions, 161
  5.1.3 Illustrative Example: Random Data, 162
  5.1.4 Example with Particle Counts, 163
  5.1.5 Illustrative Example: Trended Data, 164
  5.1.6 Trended Real Data, 168
5.2 Transform the Data or Fit a Distribution?, 170
5.3 Moving Average Chart, 171
CONTENTS

5.4 Controlling Variability with Individual Observations, 173
5.5 Summary, 175
Appendix, 176
References, 176
Exercises, 177

6 Control Charts for Attributes 181

6.1 Charts for Nonconforming Units, 182
  6.1.1 np-Chart, 182
  6.1.2 p-Chart, 184
  6.1.3 Stage 1 and Stage 2 Use of p-Charts and np-Charts, 185
  6.1.4 Alternative Approaches, 187
    6.1.4.1 Arcsin Transformations, 188
    6.1.4.2 Q-Chart for Binomial Data, 192
    6.1.4.3 Regression-Based Limits, 193
    6.1.4.4 ARL-Unbiased Charts, 195
    6.1.4.5 Unit and Group-Runs Chart, 196
    6.1.4.6 Monitoring a Multinomial Process, 196
  6.1.5 Using Software to Obtain Probability Limits for p- and np-Charts, 197
  6.1.6 Variable Sample Size, 198
  6.1.7 Charts Based on the Geometric and Negative Binomial Distributions, 199
  6.1.8 Overdispersion, 201

6.2 Charts for Nonconformities, 202
  6.2.1 c-Chart, 202
  6.2.2 Transforming Poisson Data, 204
  6.2.3 Illustrative Example, 204
  6.2.4 Regression-Based Limits, 208
  6.2.5 Using Software to Obtain Probability Limits for c-Charts, 211
  6.2.6 u-Chart, 211
    6.2.6.1 Regression-Based Limits, 213
    6.2.6.2 Using Computer Software to Obtain u-Chart Probability Limits, 214
  6.2.7 Overdispersion, 215
  6.2.8 D-Chart, 216
    6.2.8.1 Probability-Type D-Chart Limits, 218

6.3 Summary, 218
7 Process Capability

7.1 Data Acquisition for Capability Indices, 225
  7.1.1 Selection of Historical Data, 226

7.2 Process Capability Indices, 227
  7.2.1 \( C_p \), 227
  7.2.2 \( C_{pm} \), 228
  7.2.3 \( C_{pk} \), 229
    7.2.3.1 \( CPU \) and \( CPL \) as Process Capability Indices, 231
  7.2.4 \( C_{pmk} \), 231
  7.2.5 Other Capability Indices, 232

7.3 Estimating the Parameters in Process Capability Indices, 232
  7.3.1 \( X \)-Chart, 233
  7.3.2 \( \overline{X} \)-Chart, 233
  7.3.3 Case Study, 234

7.4 Distributional Assumption for Capability Indices, 235

7.5 Confidence Intervals for Process Capability Indices, 236
  7.5.1 Confidence Interval for \( C_p \), 236
  7.5.2 Confidence Interval for \( C_{pk} \), 237
  7.5.3 Confidence Interval for \( C_{pm} \), 239
  7.5.4 Confidence Interval for \( C_{pmk} \), 239
  7.5.5 Confidence Intervals Computed Using Data in Subgroups, 239
  7.5.6 Nonparametric Capability Indices and Confidence Limits, 240
    7.5.6.1 Robust Capability Indices, 241
    7.5.6.2 Capability Indices Based on Fitted Distributions, 242
    7.5.6.3 Data Transformation, 242
    7.5.6.4 Capability Indices Computed Using Resampling Methods, 243

7.6 Asymmetric Bilateral Tolerances, 243
  7.6.1 Examples, 244

7.7 Capability Indices That Are a Function of Percent Nonconforming, 245
  7.7.1 Examples, 246

7.8 Modified \( k \) Index, 250

7.9 Other Approaches, 251

7.10 Process Capability Plots, 251
CONTENTS

7.11 Process Capability Indices Versus Process Performance Indices, 252
7.12 Process Capability Indices with Autocorrelated Data, 253
7.13 Software for Process Capability Indices, 253
7.14 Summary, 253
References, 254
Exercises, 257

8 Alternatives to Shewhart Charts 261
8.1 Introduction, 261
8.2 Cumulative Sum Procedures: Principles and Historical Development, 263
  8.2.1 CUSUM Procedures Versus \( \bar{X} \)-Chart, 263
  8.2.2 Fast Initial Response CUSUM, 271
  8.2.3 Combined Shewhart–CUSUM Scheme, 273
  8.2.4 CUSUMs with Estimated Parameters, 276
  8.2.5 Computation of CUSUM ARLs, 276
  8.2.6 Robustness of CUSUM Procedures, 277
  8.2.7 CUSUM Procedures for Individual Observations, 282
8.3 CUSUM Procedures for Controlling Process Variability, 283
8.4 Applications of CUSUM Procedures, 286
8.5 Generalized Likelihood Ratio Charts: Competitive Alternative to CUSUM Charts, 286
8.6 CUSUM Procedures for Nonconforming Units, 286
8.7 CUSUM Procedures for Nonconformity Data, 290
8.8 Exponentially Weighted Moving Average Charts, 294
  8.8.1 EWMA Chart for Subgroup Averages, 295
  8.8.2 EWMA Misconceptions, 298
  8.8.3 EWMA Chart for Individual Observations, 298
  8.8.4 Shewhart–EWMA Chart, 299
  8.8.5 FIR–EWMA, 299
  8.8.6 Designing EWMA Charts with Estimated Parameters, 299
  8.8.7 EWMA Chart with Variable Sampling Intervals, 299
  8.8.8 EWMA Chart for Grouped Data, 300
  8.8.9 EWMA Chart for Variances, 300
  8.8.10 EWMA for Attribute Data, 300
8.9 Software, 301
8.10 Summary, 301
References, 301
Exercises, 306
CONTENTS

9 Multivariate Control Charts for Measurement and Attribute Data 309

9.1 Hotelling’s $T^2$ Distribution, 312
9.2 A $T^2$ Control Chart, 313
  9.2.1 Robust Parameter Estimation, 314
  9.2.2 Identifying the Sources of the Signal, 315
  9.2.3 Regression Adjustment, 319
  9.2.4 Recomputing the UCL, 320
  9.2.5 Characteristics of Control Charts Based on $T^2$, 320
  9.2.6 Determination of a Change in the Correlation Structure, 322
  9.2.7 Illustrative Example, 322
9.3 Multivariate Chart Versus Individual $\overline{X}$-Charts, 326
9.4 Charts for Detecting Variability and Correlation Shifts, 327
  9.4.1 Application to Table 9.2 Data, 328
9.5 Charts Constructed Using Individual Observations, 330
  9.5.1 Retrospective (Stage 1) Analysis, 331
  9.5.2 Stage 2 Analysis: Methods for Decomposing $Q$, 333
    9.5.2.1 Illustrative Example, 334
  9.5.3 Other Methods, 335
  9.5.4 Monitoring Multivariate Variability with Individual Observations, 335
9.6 When to Use Each Chart, 335
9.7 Actual Alpha Levels for Multiple Points, 336
9.8 Requisite Assumptions, 336
9.9 Effects of Parameter Estimation on ARLs, 337
9.10 Dimension-Reduction and Variable Selection Techniques, 337
9.11 Multivariate CUSUM Charts, 338
9.12 Multivariate EWMA Charts, 339
  9.12.1 Design of a MEWMA Chart, 341
  9.12.2 Searching for Assignable Causes, 342
  9.12.3 Unequal Sample Sizes, 342
  9.12.4 Self-Starting MEWMA Chart, 342
  9.12.5 Combinations of MEWMA Charts and Multivariate Shewhart Charts, 343
    9.12.6 MEWMA Chart with Sequential Sampling, 343
    9.12.7 MEWMA Chart for Process Variability, 343
9.13 Effect of Measurement Error, 343
9.14 Applications of Multivariate Charts, 344
9.15 Multivariate Process Capability Indices, 344
CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.16</td>
<td>Summary</td>
<td>344</td>
</tr>
<tr>
<td></td>
<td>Appendix</td>
<td>345</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>345</td>
</tr>
<tr>
<td></td>
<td>Exercises</td>
<td>350</td>
</tr>
<tr>
<td>10</td>
<td>Miscellaneous Control Chart Topics</td>
<td>353</td>
</tr>
<tr>
<td>10.1</td>
<td>Pre-control</td>
<td>353</td>
</tr>
<tr>
<td>10.2</td>
<td>Short-Run SPC</td>
<td>356</td>
</tr>
<tr>
<td>10.3</td>
<td>Charts for Autocorrelated Data</td>
<td>359</td>
</tr>
<tr>
<td>10.3.1</td>
<td>Autocorrelated Attribute Data</td>
<td>363</td>
</tr>
<tr>
<td>10.4</td>
<td>Charts for Batch Processes</td>
<td>364</td>
</tr>
<tr>
<td>10.5</td>
<td>Charts for Multiple-Stream Processes</td>
<td>364</td>
</tr>
<tr>
<td>10.6</td>
<td>Nonparametric Control Charts</td>
<td>365</td>
</tr>
<tr>
<td>10.7</td>
<td>Bayesian Control Chart Methods</td>
<td>366</td>
</tr>
<tr>
<td>10.8</td>
<td>Control Charts for Variance Components</td>
<td>367</td>
</tr>
<tr>
<td>10.9</td>
<td>Control Charts for Highly Censored Data</td>
<td>367</td>
</tr>
<tr>
<td>10.10</td>
<td>Neural Networks</td>
<td>367</td>
</tr>
<tr>
<td>10.11</td>
<td>Economic Design of Control Charts</td>
<td>368</td>
</tr>
<tr>
<td>10.11.1</td>
<td>Economic-Statistical Design</td>
<td>370</td>
</tr>
<tr>
<td>10.12</td>
<td>Charts with Variable Sample Size and/or Variable Sampling Interval</td>
<td>370</td>
</tr>
<tr>
<td>10.13</td>
<td>Users of Control Charts</td>
<td>371</td>
</tr>
<tr>
<td>10.13.1</td>
<td>Control Chart Nonmanufacturing Applications</td>
<td>372</td>
</tr>
<tr>
<td>10.13.1.1</td>
<td>Health Care</td>
<td>372</td>
</tr>
<tr>
<td>10.13.1.2</td>
<td>Financial</td>
<td>373</td>
</tr>
<tr>
<td>10.13.1.3</td>
<td>Environmental</td>
<td>373</td>
</tr>
<tr>
<td>10.13.1.4</td>
<td>Clinical Laboratories</td>
<td>373</td>
</tr>
<tr>
<td>10.13.1.5</td>
<td>Analytical Laboratories</td>
<td>373</td>
</tr>
<tr>
<td>10.13.1.6</td>
<td>Civil Engineering</td>
<td>373</td>
</tr>
<tr>
<td>10.13.1.7</td>
<td>Education</td>
<td>373</td>
</tr>
<tr>
<td>10.13.1.8</td>
<td>Law Enforcement/Investigative Work</td>
<td>373</td>
</tr>
<tr>
<td>10.13.1.9</td>
<td>Lumber</td>
<td>373</td>
</tr>
<tr>
<td>10.13.1.10</td>
<td>Forest Operations</td>
<td>374</td>
</tr>
<tr>
<td>10.13.1.11</td>
<td>Athletic Performance</td>
<td>374</td>
</tr>
<tr>
<td>10.13.1.12</td>
<td>Animal Production Systems</td>
<td>374</td>
</tr>
<tr>
<td>10.14</td>
<td>Software for Control Charting</td>
<td>374</td>
</tr>
<tr>
<td></td>
<td>Bibliography</td>
<td>375</td>
</tr>
<tr>
<td></td>
<td>Exercises</td>
<td>384</td>
</tr>
</tbody>
</table>
PART III  BEYOND CONTROL CHARTS: GRAPHICAL AND STATISTICAL METHODS

11  Graphical Methods  387
11.1  Histogram,  388
11.2  Stem-and-Leaf Display,  389
11.3  Dot Diagrams,  390
   11.3.1  Digidot Plot,  391
11.4  Boxplot,  392
11.5  Normal Probability Plot,  396
11.6  Plotting Three Variables,  398
11.7  Displaying More Than Three Variables,  399
11.8  Plots to Aid in Transforming Data,  399
11.9  Summary,  401
References,  402
Exercises,  404

12  Linear Regression  407
12.1  Simple Linear Regression,  407
12.2  Worth of the Prediction Equation,  411
12.3  Assumptions,  413
12.4  Checking Assumptions Through Residual Plots,  414
12.5  Confidence Intervals and Hypothesis Test,  415
12.6  Prediction Interval for \( Y \),  416
12.7  Regression Control Chart,  417
12.8  Cause-Selecting Control Charts,  419
12.9  Linear, Nonlinear, and Nonparametric Profiles,  421
12.10  Inverse Regression,  423
12.11  Multiple Linear Regression,  426
12.12  Issues in Multiple Regression,  426
   12.12.1  Variable Selection,  427
   12.12.2  Extrapolation,  427
   12.12.3  Multicollinear Data,  427
   12.12.4  Residual Plots,  428
   12.12.5  Regression Diagnostics,  428
   12.12.6  Transformations,  429
12.13  Software For Regression,  429
12.14  Summary,  429
# Design of Experiments

13.1 A Simple Example of Experimental Design Principles, 435  
13.2 Principles of Experimental Design, 437  
13.3 Statistical Concepts in Experimental Design, 439  
13.4 *-Tests, 441  
13.4.1 Exact *-Test, 442  
13.4.2 Approximate *-Test, 444  
13.4.3 Confidence Intervals for Differences, 444  
13.5 Analysis of Variance for One Factor, 445  
13.5.1 ANOVA for a Single Factor with More Than Two Levels, 447  
13.5.2 Multiple Comparison Procedures, 451  
13.5.3 Sample Size Determination, 452  
13.5.4 Additional Terms and Concepts in One-Factor ANOVA, 453  
13.6 Regression Analysis of Data from Designed Experiments, 455  
13.7 ANOVA for Two Factors, 460  
13.7.1 ANOVA with Two Factors: Factorial Designs, 461  
13.7.1.1 Conditional Effects, 463  
13.7.2 Effect Estimates, 463  
13.7.3 ANOVA Table for Unreplicated Two-Factor Design, 464  
13.7.4 Yates’s Algorithm, 467  
13.8 The 2^3 Design, 469  
13.9 Assessment of Effects Without a Residual Term, 474  
13.10 Residual Plot, 477  
13.11 Separate Analyses Using Design Units and Uncoded Units, 479  
13.12 Two-Level Designs with More Than Three Factors, 480  
13.13 Three-Level Factorial Designs, 482  
13.14 Mixed Factorials, 483  
13.15 Fractional Factorials, 483  
13.15.1 2^{k-1} Designs, 484  
13.15.2 2^{k-2} Designs, 490  
13.15.3 More Highly Fractionated Two-Level Designs, 492  
13.15.4 Fractions of Three-Level Factorials, 492  
13.15.5 Incomplete Mixed Factorials, 493  
13.15.6 Cautions, 493
13.16 Other Topics in Experimental Design and Their Applications, 493
  13.16.1 Hard-to-Change Factors, 493
  13.16.2 Split-Lot Designs, 494
  13.16.3 Mixture Designs, 494
  13.16.4 Response Surface Designs, 494
  13.16.5 Designs for Measurement System Evaluation, 495
  13.16.6 Fraction of Design Space Plots, 496
  13.16.7 Computer-Aided Design and Expert Systems, 496
  13.16.8 Sequential Experimentation, 497
  13.16.9 Supersaturated Designs and Analyses, 497
  13.16.10 Multiple Responses, 498
13.17 Summary, 500
References, 500
Exercises, 506

14 Contributions of Genichi Taguchi and Alternative Approaches 513
  14.1 "Taguchi Methods", 513
  14.2 Quality Engineering, 514
  14.3 Loss Functions, 514
  14.4 Distribution Not Centered at the Target, 518
  14.5 Loss Functions and Specification Limits, 518
  14.6 Asymmetric Loss Functions, 518
  14.7 Signal-to-Noise Ratios and Alternatives, 522
  14.8 Experimental Designs for Stage One, 524
  14.9 Taguchi Methods of Design, 525
    14.9.1 Inner Arrays and Outer Arrays, 526
    14.9.2 Orthogonal Arrays as Fractional Factorials, 527
    14.9.3 Other Orthogonal Arrays Versus Fractional
          Factorials, 529
    14.9.4 Product Arrays Versus Combined Arrays, 535
    14.9.5 Application of Product Array, 541
      14.9.5.1 Cautions, 551
    14.9.6 Desirable Robust Designs and Analyses, 551
      14.9.6.1 Designs, 552
      14.9.6.2 Analyses, 552
      14.9.6.3 Experiment to Compare Product Array
          and Combined Array, 552
  14.10 Determining Optimum Conditions, 553
CONTENTS

14.11 Summary, 558
References, 560
Exercises, 563

15 Evolutionary Operation 565
15.1 EVOP Illustrations, 566
15.2 Three Variables, 576
15.3 Simplex EVOP, 578
15.4 Other EVOP Procedures, 581
15.5 Miscellaneous Uses of EVOP, 581
15.6 Summary, 582
Appendix, 582
15.A Derivation of Formula for Estimating $\sigma$, 582
References, 583
Exercises, 584

16 Analysis of Means 587
16.1 ANOM for One-Way Classifications, 588
16.2 ANOM for Attribute Data, 591
16.2.1 Proportions, 591
16.2.2 Count Data, 594
16.3 ANOM When Standards Are Given, 594
16.3.1 Nonconforming Units, 594
16.3.2 Nonconformities, 595
16.3.3 Measurement Data, 595
16.4 ANOM for Factorial Designs, 596
16.4.1 Assumptions, 600
16.4.2 An Alternative Way of Displaying Interaction Effects, 600
16.5 ANOM When at Least One Factor Has More Than Two Levels, 601
16.5.1 Main Effects, 601
16.5.2 Interaction Effects, 605
16.6 Use of ANOM with Other Designs, 610
16.7 Nonparametric ANOM, 610
16.8 Summary, 611
Appendix, 611
References, 611
Exercises, 613
CONTENTS

17 Using Combinations of Quality Improvement Tools 615

17.1 Control Charts and Design of Experiments, 616
17.2 Control Charts and Calibration Experiments, 616
17.3 Six Sigma Programs, 616
  17.3.1 Components of a Six Sigma Program, 621
  17.3.2 Six Sigma Applications and Programs, 622
  17.3.3 Six Sigma Concept for Customer Satisfaction, 622
  17.3.4 Six Sigma Training, 623
  17.3.5 Lean Six Sigma, 623
  17.3.6 Related Programs/Other Companies, 623
    17.3.6.1 SEMATECH’s Qual Plan, 624
    17.3.6.2 AlliedSignal’s Operational Excellence Program, 624

17.4 Statistical Process Control and Engineering Process Control, 624

References, 625

Answers to Selected Exercises 629

Appendix: Statistical Tables 633

Author Index 645

Subject Index 657