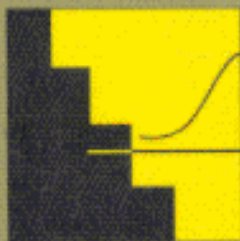




STATISTICAL PROCESS ANALYSIS



L a y t h C. A l w a n



McGRAW-HILL INTERNATIONAL EDITIONS
Management & Organization Series

CONTENTS

Chapter 1

Data Analysis and Process Management 1

- 1.1 Quality Management: A Brief Overview 2
- 1.2 Quality Pioneers 4
 - Walter A. Shewhart 4
 - W. Edwards Deming 6
 - Joseph M. Juran 8
 - Armand V. Feigenbaum 10
 - Kaoru Ishikawa 11
 - Genichi Taguchi 12
 - George E. P. Box 14
- 1.3 Focus on Processes 14
- 1.4 Reliance on Data 16
- 1.5 Role of Statistics 19
- 1.6 Basic Process Improvement Toolbox 23
 - Flowchart 24
 - Check Sheet 24
 - Pareto Diagram 25
 - Cause-and-Effect Diagram 27
 - Scatter Plot 30
 - Histogram 32
 - Control Chart 34

Chapter 2

A Review of Some Basic Statistical Concepts 41

- 2.1 Populations, Processes, and Samples 42
 - Finite Populations 42
 - Conceptual Populations 43
- 2.2 Types of Process Data 45
- 2.3 Characterizing Process Data: Visual Displays 46
 - Time-Series Display 46
 - Histogram 55
- 2.4 Time versus Distribution Behavior 61
- 2.5 Summarizing Process Data: Numerical Measures 64
 - Measures of Central Tendency 65
 - Measures of Variability 69

- 2.6 Random Variables and Probability Distributions 72
 - Properties of Random Variables 77
- 2.7 Some Useful Discrete Distributions 80
 - Bernoulli Distribution 80
 - Binomial Distribution 81
 - Poisson Distribution 84
- 2.8 Normal Distribution 86
- 2.9 Sample Statistics as Random Variables 91
 - Sampling Distribution of the Sample Mean \bar{X} : σ Known 92
 - Sampling Distribution of the Sample Mean \bar{X} : σ Unknown 95
 - Sampling Distribution of the Sample Variance S^2 97
- 2.10 Estimation of Parameters 98
 - Criteria for Choosing an Estimator 98
 - Point Estimation 100
 - Interval Estimation 100

Chapter 3

Modeling Process Data 117

- 3.1 Diagnostic Checks for Randomness 118
 - Runs Test 119
 - Autocorrelation Function 126
- 3.2 Diagnostic Checks for Normality 133
 - Standardized Data 133
 - Normal Probability Plot 135
- 3.3 Dealing with Nonnormal Data 139
 - Normalizing Transformations 141
- 3.4 Conceptual Framework for Processes 147
 - Random Process Model 147
 - General Process Model 148
- 3.5 Model Fitting Based on Least-Squares Estimation 150
- 3.6 Modeling a Simple Linear Trend Process 152
 - Detailed Breakdown of Regression Output 160
 - Diagnostic Checking of Fitted Model 166
 - Prediction of Future Outcomes 169

- 3.7 Modeling a Nonlinear Trend Process 171
- 3.8 Modeling a Meandering Process 180
- 3.9 Modeling a Combination of Process Effects 192
- 3.10 Summary of Process Modeling Steps 202

Chapter 4

Introduction to the Control Chart Concept 215

- 4.1 Approaches to Process Control 216
- 4.2 Common- and Special-Cause Variation: Basic Breakdown 217
 - Managerial Implications 218
- 4.3 State of Statistical Control: Historical Perspective 220
- 4.4 Statistical Nature of Special-Cause Variation 223
- 4.5 Hazards of Overcontrol 225
 - Funnel Experiment—Time-Series Perspective 227
- 4.6 Basic Statistical Framework for Control Charts 230
 - Hypothesis-Testing Connection 232
 - Three-Sigma Control Limits 234
- 4.7 Average Run Length Concept 239
- 4.8 Control Limits versus Specification Limits: Distinct Concepts 240
- 4.9 Supplementary Rules for Detecting Special-Cause Variation 242
- 4.10 Classification of Standard Control Charts 247
- 4.11 Five Basic Assumptions Underlying Use of Standard Control Charts 250
- 4.12 Limitations of Standard Control Charts 251
 - Challenges to Assumption 1 252
 - Challenges to Assumptions 2 and 3 259
 - Challenges to Assumptions 4 and 5 262
- 4.13 Control Charts and PDCA 263
- 4.14 Summary 267

Chapter 5

Monitoring Individual Variable Measurements 277

- 5.1 Standard Control Limits for Individual Measurements: \bar{X} Chart 278

- 5.2 Example of Appropriate \bar{X} Chart Application 280
- 5.3 Monitoring a Simple Linear Trend Process 287
 - Trend Control Chart 291
 - Fitted-Values Chart and Special-Cause Chart 292
- 5.4 Monitoring a Nonrandom and Nonnormal Process 298
 - Regression Model Revision for Prospective Control 301
- 5.5 Monitoring a Process Influenced by Lagged Effects Only 307
- 5.6 Monitoring a Process Influenced by Trend and Lagged Effects 315
- 5.7 Monitoring Variability for Individual Measurements 319
 - Standard Moving-Range Chart 319
 - Half-Normal Based Chart 322
 - Data Analysis Approach to Monitoring Moving Ranges 324

Chapter 6

Monitoring Subgroup Variable Measurements 339

- 6.1 Designing Subgroup Control Charts: Preliminary Considerations 340
 - Rational Subgrouping 341
 - Subgroup Size 342
 - Sampling Frequency 344
- 6.2 Subgroup Control Charts Based on the Range 345
 - \bar{x} and R Charts 345
 - Revision of Retrospective Control Limits and Control Chart Maintenance 351
 - Practical Issues Concerning the Range Statistic 352
 - Obtaining an Estimate for σ 353
 - Probability Limits for the \bar{x} Chart 354
 - Probability Limits for the R Chart 355
- 6.3 Performance Measures of \bar{x} and R Charts 357
 - Operating-Characteristic Curve 357
 - Average Run Length for the \bar{x} Chart 360
- 6.4 Subgroup Control Charts Based on the Sample Standard Deviation 362

- \bar{x} and s Charts with Constant Subgroup Size 362
- \bar{x} and s Charts with Variable Subgroup Size 366
- S^2 chart 370

- 6.5 Assumptions Underlying Development of Subgroup Charts 371
- 6.6 Practical Challenges to Standard Subgroup Charts 373
 - Dangers of Studying Subgroup Statistics Only 373
 - Consequences of Within-Subgroup Correlation 378
 - Gapping Strategy 384
 - R Chart in the Presence of Within-Subgroup Correlation 390

Appendix to Chapter 6 393

Chapter 7

Monitoring Attribute Data 413

- 7.1 Monitoring Binomial-Based Statistics 415
 - Control Chart for Proportion Nonconforming: p Chart 416
 - Control Chart for Number of Nonconforming: np Chart 421
 - Subgroup Selection 422
 - Variable Control Limits 425
 - Control Chart for Standardized Proportion Data 427
 - Control Limits Based on Average Subgroup Size 430
 - Beyond Special-Cause Searching 432
- 7.2 Violations of p Chart Assumptions 434
 - Testing the Binomial Assumption 440
- 7.3 Monitoring Poisson-Based Statistics 445
 - Control Chart for Number of Nonconformities: c Chart 446
 - Control Chart for Nonconformities When Unit Interval Varies: u Chart 451
 - Control Chart for Weighted Nonconformities: D Chart 455
- 7.4 Violations of the c Chart Assumptions 457
 - Testing the Poisson Assumption 460
- 7.5 Systematic Variation in Attribute Processes 463
 - Seasonal Behavior 464
 - Seasonal and Trend Behavior 470
 - Autoregressive Behavior 475

Chapter 8

Memory Control Charts 493

- 8.1 The Cumulative-Sum Control Chart 494
 - Basic Idea of a CUSUM-Type Statistic 496
 - V-Mask CUSUM Procedure for Monitoring the Process Mean 501
 - Tabular CUSUM Procedure for Monitoring the Process Mean 508
 - FIR CUSUM 517
 - Combined Shewhart-CUSUM Scheme 521
 - Monitoring Variability of Individual Observations Using CUSUM 523
 - Violation of Standard CUSUM Assumptions 526
- 8.2 The Moving-Average Control Chart for Monitoring the Process Mean 535
- 8.3 The Exponentially Weighted Moving-Average Control Chart 540
 - EWMA Chart for Monitoring the Process Mean 540
 - Monitoring Process Variability with EWMA 547
 - Violations of Standard EWMA Assumptions 552

Chapter 9

Process Capability 567

- 9.1 Process Capability Studies 568
- 9.2 The Need for Process Stability 573
- 9.3 Reporting Nonconformance Rates in Parts per Million Units 575
- 9.4 Process Capability Indices 577
 - Potential Capability Index C_p 577
 - Estimating Process Standard Deviation 579
 - One-Sided Capability Indices C_{pl} and C_{pu} 585
 - Performance Capability Index C_{pk} 591
 - Target-Focused Capability Index C_{pm} 594
- 9.5 Nonnormality and Process Capability Indices 596
- 9.6 Capability Indices and Sampling Variation 605
- 9.7 Measurement Error 608
 - Estimating Accuracy 609
 - Estimating Precision Components: Repeatability and Reproducibility 611

- 9.8 Measurement Error Variability and
Process Capability 619

Chapter 10

Related Special Topics 629

- 10.1 SPC Methods for Short-Run
Production 630
 Short-Run Variable Charts: Constant Variation
 across Batches 632
 Testing the Equality of Variances 634
 Standardized Short-Run Charts 639
- 10.2 Multivariate Quality Control 641
 Chi-Square Multivariate Control Chart:
 Parameters Known 646
 Hotelling T^2 Control Chart: Parameters
 Unknown 651
 Special-Cause Searching and Multivariate
 Signals 664
 Multivariate Monitoring of Process
 Variability 665
 Assumptions for Standard Multivariate
 Charts 669
- 10.3 All-Purpose Model Strategy 672
- 10.4 Relationship between Processes: A Broader
Modeling Perspective 675
- 10.5 Reducing Process Variability by
Adjustment 679
- 10.6 Further Opportunities 691
- Appendix to Chapter 10 694
- Appendix 722
- Basic Overview of Minitab 742
- Index 746