Contents

Foreword xi
Preface xiii
Acknowledgements xvii
About the Author xix

1 Introduction 1
  1.1 Quality and Quality Improvement 2
  1.2 Six Sigma Quality Improvement 3
  1.3 The Six Sigma Roadmap and DMAIC 6
  1.4 The Role of Statistical Methods in Six Sigma 8
  1.5 Minitab and its Role in the Implementation of Statistical Methods 10
  1.6 Exercises and Follow-Up Activities 11

2 Data Display, Summary and Manipulation 13
  2.1 The Run Chart – a First Minitab Session 13
     2.1.1 Input of Data Via Keyboard and Creation of a Run Chart in Minitab 13
     2.1.2 Minitab Projects and Their Components 20
  2.2 Display and Summary of Univariate Data 27
     2.2.1 Histogram and Distribution 27
     2.2.2 Shape of a Distribution 30
     2.2.3 Location 30
     2.2.4 Variability 38
  2.3 Data Input, Output, Manipulation and Management 43
     2.3.1 Data Input and Output 43
     2.3.2 Stacking and Unstacking of Data; Changing Data Type and Coding 44
     2.3.3 Case Study Demonstrating Ranking, Sorting and Extraction of Information from Date/Time Data 54
  2.4 Exercises and Follow-Up Activities 61

3 Exploratory Data Analysis, Display and Summary of Multivariate Data 63
  3.1 Exploratory Data Analysis 63
     3.1.1 Stem-and-Leaf Displays 63
     3.1.2 Outliers and Outlier Detection 67
     3.1.3 Boxplots 68
     3.1.4 Brushing 70
  3.2 Display and Summary of Bivariate and Multivariate Data 72
     3.2.1 Bivariate Data – Scatterplots and Marginal Plots 72
     3.2.2 Covariance and Correlation 74
3.2.3 Multivariate Data – Matrix Plots 79
3.2.4 Multi-Vari Charts 82
3.3 Other Displays 84
3.3.1 Pareto Charts 84
3.3.2 Cause-and-Effect Diagrams 87
3.4 Exercises and Follow-Up Activities 90

4 Statistical Models 93
4.1 Fundamentals of Probability 93
4.1.1 Concept and Notation 93
4.1.2 Rules for Probabilities 95
4.2 Probability Distributions for Counts and Measurements 99
4.2.1 Binomial Distribution 99
4.2.2 Poisson Distribution 105
4.2.3 Normal (Gaussian) Distribution 108
4.3 Distribution of Means and Proportions 118
4.3.1 Two Preliminary Results 118
4.3.2 Distribution of the Sample Mean 120
4.3.3 Distribution of the Sample Proportion 125
4.4 Multivariate Normal Distribution 127
4.5 Statistical Models Applied to Acceptance Sampling 129
4.5.1 Acceptance Sampling by Attributes 129
4.5.2 Acceptance Sampling by Variables 132
4.6 Exercises and Follow-Up Activities 134

5 Control Charts 141
5.1 Shewhart Charts for Measurement Data 141
5.1.1 I and MR Charts for Individual Measurements 141
5.1.2 Tests for Evidence of Special Cause Variation on Shewhart Charts 148
5.1.3 Xbar and R Charts for Samples (Subgroups) of Measurements 151
5.2 Shewhart Charts for Attribute Data 160
5.2.1 P Chart for Proportion Nonconforming 160
5.2.2 NP Chart for Number Nonconforming 167
5.2.3 C Chart for Count of Nonconformities 168
5.2.4 U Chart for Nonconformities Per Unit 169
5.2.5 Funnel Plots 170
5.3 Time-Weighted Control Charts 171
5.3.1 Moving Averages and their Applications 171
5.3.2 Exponentially Weighted Moving Average Control Charts 179
5.3.3 Cumulative Sum Control Charts 181
5.4 Process Adjustment 186
5.4.1 Process Tampering 186
5.4.2 Autocorrelated Data and Process Feedback Adjustment 189
5.5 Multivariate Control Charts 193
5.6 Exercises and Follow-Up Activities 194
CONTENTS

6  Process Capability Analysis 203
   6.1  Process Capability 203
       6.1.1  Process Capability Analysis with Measurement Data 203
       6.1.2  Process Capability Indices and Sigma Quality Levels 212
       6.1.3  Process Capability Analysis with Nonnormal Data 214
       6.1.4  Tolerance Intervals 217
       6.1.5  Process Capability Analysis with Attribute Data 220
   6.2  Exercises and Follow-Up Activities 222

7  Process Experimentation with a Single Factor 225
   7.1  Fundamentals of Hypothesis Testing 226
   7.2  Tests and Confidence Intervals for the Comparison of Means and
       Proportions with a Standard 234
       7.2.1  Tests Based on the Standard Normal Distribution – z-Tests 234
       7.2.2  Tests Based on the Student t-Distribution – t-Tests 243
       7.2.3  Tests for Proportions 247
       7.2.4  Nonparametric Sign and Wilcoxon Tests 249
   7.3  Tests and Confidence Intervals for the Comparison of Two
       Means or Two Proportions 252
       7.3.1  Two-Sample t-Tests 252
       7.3.2  Tests for Two Proportions 256
       7.3.3  Nonparametric Mann–Whitney Test 259
   7.4  The Analysis of Paired Data – t-Tests and Sign Tests 261
   7.5  Experiments with a Single Factor Having More Than Two Levels 264
       7.5.1  Design and Analysis of a Single-Factor Experiment 264
       7.5.2  The Fixed Effects Model 274
       7.5.3  The Random Effects Model 276
       7.5.4  The Nonparametric Kruskal–Wallis Test 281
   7.6  Blocking in Single-Factor Experiments 283
   7.7  Experiments with a Single Factor, with More Than Two Levels,
       where the Response is a Proportion 291
   7.8  Tests for Equality of Variances 294
   7.9  Exercises and Follow-Up Activities 296

8  Process Experimentation with Two or More Factors 303
   8.1  General Factorial Experiments 304
       8.1.1  Creation of a General Factorial Experimental Design 304
       8.1.2  Display and Analysis of Data from a General Factorial
              Experiment 306
       8.1.3  The Fixed Effects Model, Comparisons 313
       8.1.4  The Random Effects Model, Components of Variance 321
   8.2  Full Factorial Experiments in the 2^k Series 326
       8.2.1  2^k Factorial Experimental Designs, Display and Analysis
              of Data 326
       8.2.2  Models and Associated Displays 334
       8.2.3  Examples of 2^3 and 2^4 Experiments, the Use of Pareto and
              Normal Probability Plots of Effects 343