

# CONTENTS

---

	Preface .....	xiii
<b>PART I</b>	<b>Six Sigma Implementation and Management</b>	
<b>CHAPTER 1</b>	<b>Building the Responsive Six Sigma Organization .....</b>	<b>3</b>
	What Is Six Sigma? .....	3
	<i>Why Six Sigma?</i> .....	4
	<i>The Six Sigma Philosophy</i> .....	6
	<i>Six Sigma Versus Traditional Three Sigma Performance</i> .....	8
	<i>The Change Imperative</i> .....	12
	Implementing Six Sigma .....	17
	<i>Timetable</i> .....	18
	<i>Infrastructure</i> .....	21
	<i>Integrating Six Sigma and Related Initiatives</i> .....	38
	<i>Deployment to the Supply Chain</i> .....	52
	<i>Communications and Awareness</i> .....	54
<b>CHAPTER 2</b>	<b>Recognizing and Capitalizing on Opportunity .....</b>	<b>61</b>
	Methods for Collecting Customer Data .....	61
	<i>Surveys</i> .....	62
	<i>Focus Groups</i> .....	71
	<i>Operational Feedback Systems</i> .....	72
	Cost of Poor Quality .....	75
	<i>Cost of Quality Examples</i> .....	78
	<i>Quality Cost Bases</i> .....	81
	Benchmarking .....	82
	<i>The Benchmarking Process</i> .....	82
	<i>Getting Started with Benchmarking</i> .....	83
	<i>Why Benchmarking Efforts Fail</i> .....	85
	<i>The Benefits of Benchmarking</i> .....	86

	<i>Some Dangers of Benchmarking</i> . . . . .	87
	Innovation . . . . .	87
	<i>Kano Model</i> . . . . .	88
	<i>Quality Function Deployment</i> . . . . .	89
	<i>Translating Customer Demands</i> . . . . .	93
	<i>Creative Destruction</i> . . . . .	101
	Strategic Planning . . . . .	106
	<i>Organizational Vision</i> . . . . .	107
	<i>Strategy Development</i> . . . . .	109
	<i>Strategic Styles</i> . . . . .	110
	<i>Possibilities-Based Strategic Decisions</i> . . . . .	111
	Strategic Development Using Constraint Theory . . . . .	113
	<i>The Systems Approach</i> . . . . .	114
	<i>Basic Constraint Management Principles and Concepts</i> . . . . .	117
	<i>Tools of Constraint Management</i> . . . . .	126
	<i>Constraint Management Measurements</i> . . . . .	138
	<i>Summary and Conclusion</i> . . . . .	143
<b>CHAPTER 3</b>	<b>Data-Driven Management</b> . . . . .	<b>145</b>
	Attributes of Good Metrics . . . . .	145
	<i>Measuring Causes and Effects</i> . . . . .	147
	The Balanced Scorecard . . . . .	149
	<i>Translating the Vision</i> . . . . .	151
	<i>Communicating and Linking</i> . . . . .	159
	<i>Business Planning</i> . . . . .	162
	<i>Feedback and Learning</i> . . . . .	166
<b>CHAPTER 4</b>	<b>Maximizing Resources</b> . . . . .	<b>177</b>
	Choosing the Right Projects . . . . .	177
	<i>Types of Projects</i> . . . . .	178
	<i>Analyzing Project Candidates</i> . . . . .	179
	<i>Using Pareto Analysis to Identify Six Sigma Project Candidates</i> . . . . .	187
	<i>Throughput-Based Project Selection</i> . . . . .	189
	Ongoing Management Support . . . . .	195
	<i>Internal Roadblocks</i> . . . . .	196
	<i>External Roadblocks</i> . . . . .	197
	<i>Individual Barriers to Change</i> . . . . .	197

*Ineffective Management Support Strategies* . . . . . 198  
*Effective Management Support Strategies* . . . . . 199  
*Cross-Functional Collaboration* . . . . . 200  
Tracking Six Sigma Project Results . . . . . 201  
    *Financial Results Validation* . . . . . 204  
    *Team Performance Evaluation* . . . . . 204  
    *Team Recognition and Reward* . . . . . 205  
    *Lessons-Learned Capture and Replication* . . . . . 207

**PART II Six Sigma Tools and Techniques**

**CHAPTER 5 Project Management Using DMAIC and DMADV . . . . . 211**

DMAIC and DMADV Deployment Models . . . . . 211  
    *Project Scheduling* . . . . . 216  
    *Project Reporting* . . . . . 228  
    *Project Budgets* . . . . . 230  
    *Project Records* . . . . . 231  
Six Sigma Teams . . . . . 232  
    *Team Membership* . . . . . 233  
    *Team Dynamics Management, Including Conflict Resolution* . . . 233  
    *Stages in Group Development* . . . . . 234  
    *Member Roles and Responsibilities* . . . . . 236  
    *Management’s Role* . . . . . 238  
    *Facilitation Techniques* . . . . . 238

**CHAPTER 6 The Define Phase . . . . . 243**

Project Charters . . . . . 243  
Project Decomposition . . . . . 246  
    *Work Breakdown Structures* . . . . . 246  
    *Pareto Analysis* . . . . . 247  
Deliverables . . . . . 248  
    *Critical to Quality Metrics* . . . . . 250  
    *Critical to Schedule Metrics* . . . . . 257  
    *Critical to Cost Metrics* . . . . . 259  
Top-Level Process Definition . . . . . 265  
    *Process Maps* . . . . . 266  
Assembling the Team . . . . . 267

<b>CHAPTER 7</b>	<b>The Measure Phase</b> .....	<b>269</b>
	Process Definition .....	269
	<i>Flowcharts</i> .....	270
	<i>SIPOC</i> .....	271
	Metric Definition .....	275
	<i>Measurement Scales</i> .....	276
	<i>Discrete and Continuous Data</i> .....	278
	Process Baseline Estimates .....	278
	<i>Enumerative and Analytic Studies</i> .....	280
	<i>Principles of Statistical Process Control</i> .....	283
	<i>Estimating Process Baselines Using Process Capability Analysis</i> ..	289
<b>CHAPTER 8</b>	<b>Process Behavior Charts</b> .....	<b>291</b>
	Distributions .....	291
	<i>Methods of Enumeration</i> .....	291
	<i>Frequency and Cumulative Distributions</i> .....	293
	<i>Sampling Distributions</i> .....	294
	<i>Binomial Distribution</i> .....	295
	<i>Poisson Distribution</i> .....	297
	<i>Hypergeometric Distribution</i> .....	298
	<i>Normal Distribution</i> .....	299
	<i>Lognormal Distribution</i> .....	306
	<i>Exponential Distribution</i> .....	307
	<i>Weibull Distribution</i> .....	309
	Control Charts for Variables Data .....	310
	<i>Averages and Ranges Control Charts</i> .....	310
	<i>Averages and Standard Deviation (Sigma) Control Charts</i> .....	314
	<i>Control Charts for Individual Measurements (X Charts)</i> .....	317
	Control Charts for Attributes Data .....	323
	<i>Control Charts for Proportion (p Charts)</i> .....	323
	<i>Control Charts for Count of Items (np Charts)</i> .....	327
	<i>Control Charts for Average Occurrences-Per-Unit (u Charts)</i> ...	329
	<i>Control Charts for Counts of Occurrences-Per-Unit (c Charts)</i> ..	332
	Control Chart Selection.....	336
	<i>Rational Subgroup Sampling</i> .....	336
	Control Chart Interpretation .....	341
	<i>Run Tests</i> .....	347

	Short-Run Statistical Process Control Techniques . . . . .	348
	<i>Variables Data</i> . . . . .	350
	<i>Attribute SPC for Small and Short Runs</i> . . . . .	361
	<i>Summary of Short-Run SPC</i> . . . . .	368
	SPC Techniques for Automated Manufacturing . . . . .	369
	<i>Problems with Traditional SPC Techniques</i> . . . . .	369
	<i>Special and Common Cause Charts</i> . . . . .	370
	<i>EWMA Common Cause Charts</i> . . . . .	371
	<i>EWMA Control Charts Versus Individuals Charts</i> . . . . .	378
	Process Capability Indices . . . . .	380
	<i>Example of Non-Normal Capability Analysis Using Minitab</i> . . . . .	385
<b>CHAPTER 9</b>	<b>Measurement Systems Evaluation . . . . .</b>	<b>391</b>
	Definitions . . . . .	391
	<i>Measurement System Discrimination</i> . . . . .	395
	<i>Stability</i> . . . . .	395
	<i>Bias</i> . . . . .	396
	<i>Repeatability</i> . . . . .	397
	<i>Reproducibility</i> . . . . .	400
	<i>Part-to-Part Variation</i> . . . . .	403
	<i>Summary Reporting</i> . . . . .	403
	<i>Gage R&amp;R Analysis Using Minitab</i> . . . . .	404
	<i>Linearity</i> . . . . .	407
	<i>Linearity Analysis Using Minitab</i> . . . . .	409
	Attribute Measurement Error Analysis . . . . .	410
	<i>Operational Definitions</i> . . . . .	412
	<i>How to Conduct Attribute Inspection Studies</i> . . . . .	413
	<i>Minitab Attribute Gage R&amp;R Example</i> . . . . .	417
<b>CHAPTER 10</b>	<b>Analyze Phase . . . . .</b>	<b>423</b>
	Value Stream Analysis . . . . .	423
	<i>Value Stream Mapping</i> . . . . .	427
	<i>Spaghetti Charts</i> . . . . .	433
	Analyzing the Sources of Variation . . . . .	434
	<i>Cause and Effect Diagrams</i> . . . . .	435
	<i>Boxplots</i> . . . . .	437
	<i>Statistical Inference</i> . . . . .	439

<i>Chi-Square, Student's t, and f Distributions</i> . . . . .	440
<i>Point and Interval Estimation</i> . . . . .	444
<i>Hypothesis Testing</i> . . . . .	452
<i>Resampling (Bootstrapping)</i> . . . . .	459
Regression and Correlation Analysis . . . . .	460
<i>Linear Models</i> . . . . .	463
<i>Least-Squares Fit</i> . . . . .	466
<i>Correlation Analysis</i> . . . . .	470
Designed Experiments . . . . .	472
The Traditional Approach Versus	
Statistically Designed Experiments . . . . .	472
<i>Terminology</i> . . . . .	472
<i>Design Characteristics</i> . . . . .	474
<i>Types of Design</i> . . . . .	475
<i>One-Factor ANOVA</i> . . . . .	477
<i>Two-Way ANOVA with No Replicates</i> . . . . .	479
<i>Two-Way ANOVA with Replicates</i> . . . . .	480
<i>Full and Fractional Factorial</i> . . . . .	482
<i>Power and Sample Size</i> . . . . .	491
<i>Testing Common Assumptions</i> . . . . .	491
Analysis of Categorical Data . . . . .	499
<i>Making Comparisons Using Chi-Square Tests</i> . . . . .	499
<i>Logistic Regression</i> . . . . .	501
<i>Binary Logistic Regression</i> . . . . .	503
<i>Ordinal Logistic Regression</i> . . . . .	506
<i>Nominal Logistic Regression</i> . . . . .	510
Non-Parametric Methods . . . . .	513

**CHAPTER 11 The Improve/Design Phase . . . . .517**

Using Customer Demands to Make	
Design and Improvement Decisions . . . . .	517
<i>Pugh Concept Selection Method</i> . . . . .	517
Lean Techniques for Optimizing Flow . . . . .	518
<i>Unnecessary Process Steps</i> . . . . .	519
<i>Excessive Movement of Material or Personnel</i> . . . . .	519
<i>Bottleneck or Constraint</i> . . . . .	520
<i>Process Errors Requiring Rework</i> . . . . .	521
<i>Excess In-process Inventory</i> . . . . .	521

<i>Understanding Queues to Balance Processes</i> . . . . .	526
Using Empirical Model Building to Optimize . . . . .	529
<i>Phase 0: Getting Your Bearings</i> . . . . .	531
<i>Phase I: The Screening Experiment</i> . . . . .	532
<i>Phase II: Steepest Ascent (Descent)</i> . . . . .	536
<i>Phase III: The Factorial Experiment</i> . . . . .	538
<i>Phase IV: The Composite Design</i> . . . . .	540
<i>Phase V: Robust Product and Process Design</i> . . . . .	544
Data Mining, Artificial Neural Networks, and Virtual Process Mapping . . . . .	548
<i>Example of Neural Net Models</i> . . . . .	549
Optimization Using Simulation . . . . .	552
<i>Predicting CTQ Performance</i> . . . . .	552
<i>Simulation Tools</i> . . . . .	553
<i>Random Number Generators</i> . . . . .	557
<i>Model Development</i> . . . . .	560
<i>Virtual DOE Using Simulation Software</i> . . . . .	570
Risk Assessment Tools . . . . .	572
<i>Design Review</i> . . . . .	573
<i>Fault-Tree Analysis</i> . . . . .	574
<i>Safety Analysis</i> . . . . .	575
<i>Failure Mode and Effect Analysis</i> . . . . .	578
Defining New Performance Standards Using Statistical Tolerancing .	581
<i>Assumptions of Formula</i> . . . . .	585
<i>Tolerance Intervals</i> . . . . .	585
 <b>CHAPTER 12</b>	
<b>Control/Verify Phase</b> . . . . .	<b>587</b>
Validating the New Process or Product Design . . . . .	587
Business Process Control Planning . . . . .	588
<i>Maintaining Gains</i> . . . . .	588
<i>Tools and Techniques Useful for Control Planning</i> . . . . .	590
<i>Preparing the Process Control Plan</i> . . . . .	591
<i>Process Control Planning for Short and Small Runs</i> . . . . .	593
<i>Process Audits</i> . . . . .	596
<i>Selecting Process Control Elements</i> . . . . .	596
<i>Other Elements of the Process Control Plan</i> . . . . .	599
<i>Multivariate Control Charts</i> . . . . .	599
<i>Principal Component Analysis</i> . . . . .	608

<b>APPENDIX 1</b>	<b>Glossary of Basic Statistical Terms</b> .....	617
<b>APPENDIX 2</b>	<b>Area Under the Standard Normal Curve</b> .....	623
<b>APPENDIX 3</b>	<b>Critical Values of the <i>t</i>-Distribution</b> .....	627
<b>APPENDIX 4</b>	<b>Chi-Square Distribution</b> .....	629
<b>APPENDIX 5</b>	<b><i>F</i> Distribution (<math>\alpha = 1\%</math>)</b> .....	631
<b>APPENDIX 6</b>	<b><i>F</i> Distribution (<math>\alpha = 5\%</math>)</b> .....	633
<b>APPENDIX 7</b>	<b>Poisson Probability Sums</b> .....	635
<b>APPENDIX 8</b>	<b>Tolerance Interval Factors</b> .....	639
<b>APPENDIX 9</b>	<b>Control Chart Constants</b> .....	643
<b>APPENDIX 10</b>	<b>Control Chart Equations</b> .....	645
<b>APPENDIX 11</b>	<b>Table of <math>d_2^*</math> Values</b> .....	647
<b>APPENDIX 12</b>	<b>Factors for Short Run Control Charts for Individuals, <math>\bar{X}</math>, and <i>R</i> Charts</b> .....	649
<b>APPENDIX 13</b>	<b>Sample Customer Survey</b> .....	651
<b>APPENDIX 14</b>	<b>Process <math>\sigma</math> Levels and Equivalent PPM Quality Levels</b> .....	653
<b>APPENDIX 15</b>	<b>Black Belt Effectiveness Certification</b> .....	655
<b>APPENDIX 16</b>	<b>Green Belt Effectiveness Certification</b> .....	667
<b>APPENDIX 17</b>	<b>AHP Using Microsoft Excel</b> .....	679
	<b>Notes</b> .....	683
	<b>References</b> .....	685
	<b>Index</b> .....	693