Manufacturing Handbook of Best Practices
An Innovation, Productivity, and Quality Focus
The St. Lucie Press/APICS Series on Resource Management

Titles in the Series

Applying Manufacturing Execution Systems
by Michael McClellan

Back to Basics: Your Guide to Manufacturing Excellence
by Steven A. Melnyk and R.T. “Chris” Christensen

Enterprise Resources Planning and Beyond: Integrating Your Entire Organization
by Gary A. Langenwalter

ERP: Tools, Techniques, and Applications for Integrating the Supply Chain
by Carol A. Ptak with Eli Schragenheim

Integrated Learning for ERP Success: A Learning Requirements Planning Approach
by Karl M. Kapp, with William F. Latham and Hester N. Ford-Latham

Integral Logistics Management: Planning and Control of Comprehensive Business Processes
by Paul Schönsleben

Inventory Classification Innovation: Paving the Way for Electronic Commerce and Vendor Managed Inventory
by Russell G. Broeckelmann

Lean Manufacturing: Tools, Techniques, and How To Use Them
by William M. Feld

Macrologistics Management: A Catalyst for Organizational Change
by Martin Stein and Frank Voehl

Restructuring the Manufacturing Process: Applying the Matrix Method
by Gideon Halevi

Basics of Supply Chain Management
by Lawrence D. Fredendall and Ed Hill

Supply Chain Management: The Basics and Beyond
by William C. Copacino

Handbook of Supply Chain Management
by Jim Ayers

© 2002 by CRC Press LLC
# Table of Contents

**Chapter 1**  The Agile Enterprise ................................................................. 1  
1.1 Introduction .................................................................................................. 1  
1.2 Traditional Manufacturing ........................................................................... 2  
1.3 Evolution from Lean to Agile Enterprise .................................................... 3  
1.4 Agile Enterprise Foundation ....................................................................... 5  
1.4.1 Customer Focus ..................................................................................... 5  
1.4.2 Strategy Deployment .............................................................................. 6  
1.4.3 Focus on Work ....................................................................................... 7  
1.5 Agile Manufacturing .................................................................................... 8  
1.5.1 Definition ............................................................................................... 8  
1.5.2 Agile Manufacturing Challenges in the Automotive Industry ............... 8  
1.6 Agile Enterprise Guiding Principles ........................................................... 9  
1.6.1 Benefits of Being Agile ........................................................................ 9  
1.6.2 What’s New or Different? ..................................................................... 10  
1.7 Agile Enterprise Tools and Metrics ............................................................. 10  
1.7.1 Transaction Analyses .......................................................................... 10  
1.7.2 Activity/Cost Chains .......................................................................... 11  
1.7.3 Organization Maps ............................................................................. 11  
1.7.4 Key Characteristics (KCs) ................................................................... 11  
1.7.5 Contact Chains .................................................................................... 11  
1.8 Customer Orientation .................................................................................. 12  
1.9 Information System Design ......................................................................... 13  
1.10 Cooperation through Virtual Teams and Corporations ................................ 14  
1.11 Highly Educated and Trained Workforce ................................................ 15  
1.11.1 The Rise of the Knowledge Worker .................................................... 17  
1.12 Agile Enterprise and the Internet ............................................................... 17  
1.12.1 Supply Chain Challenges .................................................................... 18  
1.12.2 Growth and Value .......................................................................... 19  
1.12.3 Impact of the Internet on Various Aspects of Agility ......................... 19  
1.12.4 Customer Orientation — The Rise of CRM  
  (Customer Relationship Management) ....................................................... 20  
  1.12.4.1 What Will It Take to Keep the Customer in the Future? ............... 21  
  1.12.4.2 A Value Chain Proposition ............................................................. 21  
  1.12.4.2.1 Functional Requirements ........................................................... 22  
  1.12.4.2.2 Reaping Business Benefits from IT ...................................... 23  
  1.12.4.2.3 Setting the Stage for Success ..................................................... 24
5.2.5.3 Why IPPD Benefits the Customer.................................90
5.2.5.4 Why IPPD Benefits an Organization .................................91

5.3 Organizing an IPT..........................................................................................91
5.3.1 Initial Challenges — What Are We Doing (Goals)?
5.3.1.1 Goals ...................................................................................91
5.3.1.2 Why Change?......................................................................92
5.3.1.3 Roles ...................................................................................92
5.3.2 Core Members (Generalists) vs. Specialists (Bit Players).................92
5.3.3 Collocation and Communication Links.............................................93
5.3.4 Team Culture......................................................................................93
5.3.5 Picking the Right Team Leader .........................................................94

5.4 Building the Environment (Culture) for Successful IPPD....................94
5.4.1 Effective Change Management..........................................................94
5.4.1.1 Fear and Jealousy of Change (from the Functional
Manager's View)................................................................................95
5.4.1.2 Organizational Issues Created by Change .........................95

5.5 The Tools that an IPT Will Require ..............................................................96
5.5.1 Technical Tools ..................................................................................96
5.5.2 Communication and Decision-Making Tools....................................96

5.6 Probable Problem Areas, and Mitigations.....................................................96
5.6.1 Reduced Development Time = Less Time for Corrections
and Customer Review and Feedback ..................................................96
5.6.1.1 Customer Inputs.................................................................97
5.6.1.2 Specification Errors ..................................................................97
5.6.2 “Silo” and “Group-Think” Mentality .................................................97
5.6.3 Self-Sufficient vs. Too Large a Team ................................................97
5.6.4 Recruiting — Internal (Why Were They Chosen?) vs. External .......98
5.6.5 Retention and Career Paths Following Project Completion .............98
5.6.6 Costs Associated with IPTs ...............................................................99

5.7 Methodologies of Simultaneous Product and Process Development ......100
5.7.1 Concept and Prototyping .................................................................100
5.7.2 Design and Development.................................................................100
5.7.2.1 CAD Databases ........................................................................101
5.7.2.2 Codevelopment .........................................................................101
5.7.2.3 Tooling (Molds and Dies) .........................................................101
5.7.2.4 Passive Assurance in Production ..............................................102
5.7.3 Qualification .....................................................................................102
5.7.3.1 Tooling Qualification ...............................................................102
5.7.3.2 Design Verification First ...........................................................103
5.7.3.3 Assembly Qualification = Product Qualification ...................103
5.7.4 Conclusion........................................................................................104

5.8 Internet Sites ............................................................................................104
References.......................................................................................................104
Chapter 6  ISO 9001:2000 Initiatives ................................................................. 107
6.1 Introduction .............................................................................................. 107
6.2 The Basic Changes .................................................................................. 108
6.3 Quality Management System .................................................................. 110
  6.3.1 Quality Management System Audit Checklist Based on ISO 9001:2000 Clause 4 113
6.4 Management Responsibility ...................................................................... 113
  6.4.1 Management Responsibility Audit Checklist Based on ISO 9001:2000 Clause 5 115
6.5 Resource Management ............................................................................ 115
  6.5.1 Resources Management Audit Checklist Based on ISO 9001:2000 Clause 6 115
6.6 Product Realization .................................................................................. 115
  6.6.1 Product Realization Audit Checklist Based on ISO 9001:2000 Clause 7 119
6.7 Measurement, Analysis, and Improvement ............................................. 119
  6.7.1 Measurement Analysis and Improvement Audit Checklist Based on ISO 9001:2000 Clause 8 121
6.8 Disclaimer ................................................................................................ 121
Appendices ..................................................................................................... 122

Chapter 7  ISO 14001 and Best Industrial Practices................................. 141
7.1 Introduction .............................................................................................. 141
7.2 Energy Use ............................................................................................... 142
  7.2.1 Lighting .............................................................................................. 142
    7.2.1.1 Recommendations and Guidelines ....................................... 142
  7.2.2 Ventilation ........................................................................................ 143
    7.2.2.1 Recommendations and Guidelines ....................................... 143
  7.2.3 Electrical Equipment and Machinery ................................................. 144
    7.2.3.1 Recommendations and Guidelines ....................................... 144
    7.2.3.1.1 Computers and Printers ............................................... 144
    7.2.3.1.2 Photocopy Machines .................................................... 144
    7.2.3.1.3 Stand-Alone Refrigerators and Freezers .................... 145
    7.2.3.1.4 Dishwashers .............................................................. 145
    7.2.3.1.5 Point-of-Use Water Heating ........................................ 145
  7.2.4 The Solar Option ................................................................................ 145
7.3 Other Environmental Impacts ................................................................. 145
  7.3.1 Use of Water ...................................................................................... 146
    7.3.1.1 Recommendations and Guidelines .................................... 146
    7.3.1.1.1 Inside Buildings ......................................................... 146
  7.3.2 Boilers ............................................................................................... 148
    7.3.2.1 Recommendations and Guidelines .................................... 148
    7.3.2.1.1 Optimizers .............................................................. 148

© 2002 by CRC Press LLC
7.3.3 Waste .......................... 148
  7.3.3.1 Recommendations and Guidelines ................. 148
  7.3.3.1.1 Permits ........................................ 148
  7.3.3.1.2 Waste Reduction Initiatives .............. 149
  7.3.3.1.3 Waste Water (See Also, Water Use) .... 149
  7.3.3.2 General .................................. 150

7.3.4 Recycling .............................. 150
  7.3.4.1 Recommendations ...................... 150

7.3.5 Ozone-Depleting Substances .............. 152
  7.3.5.1 Recommendations and Guidelines ........ 152
  7.3.5.1.1 Refrigeration and Air Conditioning ...... 153
  7.3.5.1.2 Dry Cleaning .............................. 153
  7.3.5.1.3 Fire Protection Systems .......... 154

7.3.6 Hazardous Substances .............. 154
  7.3.6.1 Recommendations and Guidelines .......... 154
  7.3.6.1.1 Acids .................................. 154
  7.3.6.1.2 Alkalis .................................. 154
  7.3.6.1.3 Bleach .................................... 154
  7.3.6.1.4 Solvents .................................. 155
  7.3.6.1.5 Phosphates ............................... 155

7.3.7 Stationery and Office Supplies .......... 156
  7.3.7.1 Recommendations and Guidelines .......... 157

7.3.8 Office Equipment — Fixtures and Fittings .......... 157
  7.3.8.1 Recommendations and Guidelines .......... 157

7.3.9 Transport .............................. 158
  7.3.9.1 Recommendations and Guidelines .......... 158
  7.3.9.1.1 Servicing .................................. 159
  7.3.9.1.2 Training and Driving Style .......... 159
  7.3.9.1.3 Vehicle Use .................................. 159

7.3.10 External Influences .............. 160
  7.3.10.1 Recommendations and Guidelines .......... 160

7.3.11 Miscellaneous .......................... 160
  7.3.11.1 Recommendations and Guidelines .......... 160

7.4 Environmental Management Initiatives .............. 160
  7.4.1 Energy Management Systems .......... 160
  7.4.1.1 Responsibility .............................. 160
  7.4.1.2 Energy Audit .................................. 161
  7.4.1.3 Action Plan .................................. 161
  7.4.1.4 Involve Employees .......................... 161
  7.4.1.5 Finance .................................. 162
  7.4.1.6 Energy Monitoring ...................... 162
  7.4.1.7 Yardsticks .................................. 162
  7.4.1.8 Consumption Targets .......................... 163

7.4.2 Access to Legislative Information .......... 163
  7.4.2.1 Recommendations and Guidelines .......... 163
Chapter 8  Lean Manufacturing ................................................................. 169
  8.1  Lean Manufacturing Concepts and Tools ........................................... 170
       8.1.1  Lean Objectives........................................................................ 171
       8.1.2  Define Value Principle .............................................................. 173
       8.1.3  Identify Value Stream ................................................................. 173
  8.2  Elimination of Waste Principle ......................................................... 174
       8.2.1  Definition of Waste .................................................................. 174
       8.2.2  Waste of Overproduction ......................................................... 174
       8.2.3  Waste of Inventory .................................................................. 174
       8.2.4  Waste of Correction .................................................................. 175
       8.2.5  Waste of Movement .................................................................. 176
       8.2.6  Waste of Motion ....................................................................... 176
       8.2.7  Waste of Waiting ..................................................................... 176
       8.2.8  Waste of Overprocessing ......................................................... 176
       8.2.9  Impact of Waste ....................................................................... 177
  8.3  Support the Workers’ Principle .......................................................... 177
  8.4  Pull System Strategy ......................................................................... 179
       8.4.1  Kanban Technique to Facilitate a Pull System Strategy .......... 179
       8.4.2  Level Scheduling (Heijunka) Technique .................................. 180
       8.4.3  Takt Time ................................................................................ 182
       8.4.4  Quick Changeover Technique ................................................... 182
       8.4.5  Small-Lot Production ................................................................. 183
  8.5  Quality Assurance Strategy ................................................................. 183
       8.5.1  Poka-Yoke Device (Mistake Proofing) ....................................... 184
       8.5.2  Visual Control and SS Techniques ............................................ 184
       8.5.3  Visual Controls ........................................................................ 185
       8.5.4  Preventive Maintenance Technique ......................................... 185
  8.6  Plant Layout and Work Assignment Strategy ..................................... 186
  8.7  Continuous Improvement (Kaizen) Strategy ...................................... 188
       8.7.1  Standardized Work Technique to Support Kaizen .................. 189
       8.7.2  Standard Cycle Time ................................................................. 189
       8.7.3  Standard Work Sequence .......................................................... 189
       8.7.4  Standard WIP ......................................................................... 190
  8.8  Decision-Making Strategy ................................................................. 190
  8.9  Supplier Partnering Strategy in Lean Manufacturing ....................... 190
       8.9.1  Small Supplier Network .............................................................. 191
       8.9.2  Short-Term Contract/Long-Term Commitment ....................... 191
       8.9.3  Supplier Assistance .................................................................. 191
10.4 Process Analysis and Improvement Network (PAIN).................................232
  10.4.1 Reasons for PAIN .................................................................232
  10.4.2 PAIN — Main Model............................................................232
  10.4.3 PAIN — Models A Through G .............................................233
  10.4.4 Phase 1 ..............................................................................238
  10.4.5 Phase 2 ..............................................................................238
  10.4.6 Phase 3 ..............................................................................238
  10.4.7 PAIN — Model G ...............................................................239

Appendix................................................................................................................241

Chapter 11 Quality Function Deployment (QFD)............................................245
  11.1 Introduction .............................................................................245
  11.2 Risk Identification .....................................................................249
  11.3 The Seven-Step Process ............................................................249
  11.4 Kano Model ............................................................................251
  11.5 Voice of the Customer Table .....................................................252
  11.6 House of Quality (HOQ) ............................................................254
  11.7 Four-Phase Approach ...............................................................256
  11.8 Matrix of Matrices Approach .....................................................257
  11.9 Recommendations ...................................................................257
    11.9.1 Software ...........................................................................257
    11.9.2 Books................................................................................257
    11.9.3 Web Sites .........................................................................258

Chapter 12 Manufacturing Controls Integration...........................................261
  12.1 The Basic Premise of Inventory ..................................................261
  12.2 Need for Inventory Identified by Definition ....................................262
  12.3 Manufacturing Is Really Just a Balancing Act ................................264
    12.3.1 The Balance ......................................................................264
  12.4 The Primary Controls for Inventory .............................................267
  12.5 The Tools for Inventory Control ................................................271
    12.5.1 The ABC Inventory System ................................................272
    12.5.2 Capacity Capability and the Effect on Inventory ....................279
    12.5.3 Production Constraints .......................................................280

Chapter 13 Robust Design ............................................................................285
  13.1 The Significance of Robust Design .............................................286
  13.2 Fundamental Principles of Robust Design — The Taguchi Method ......289
  13.3 The Robust Design Cycle ..........................................................290
    13.3.1 A Robust Design Example: An Experimental Design to Improve
            Golf Scores .............................................................................290
    13.3.1.1 Identify the Main Function ...............................................290
    13.3.1.2 Identify the Noise Factors ...............................................290

© 2002 by CRC Press LLC
13.3.1.3 Identify the Quality Characteristic to be Observed and the Objective Function to be Optimized \( \ldots \) 291
13.3.1.4 Identify the Control Factors and Alternative Levels \( \ldots \) 291
13.3.1.5 Design the Matrix Experiment and Define the Data Analysis Procedure \( \ldots \) 291
13.3.1.6 Conduct the Matrix Experiment \( \ldots \) 292
13.3.1.7 Analyze the Data to Determine the Optimum Levels of Control Factors \( \ldots \) 293

Chapter 14 Six Sigma Problem Solving \( \ldots \) 295
14.1 Product, Process, and Money \( \ldots \) 297
14.1.1 Defects per Unit (DPU) \( \ldots \) 297
14.1.2 Throughput Yield (\( Y_{TP} \)), \( K \), and \( R \) \( \ldots \) 297
14.1.3 An Example Calculation \( \ldots \) 299
14.1.4 Escaping Defects \( \ldots \) 300
14.1.5 Final Comments on Defects and Money \( \ldots \) 301
14.2 Basics of Problem Solving \( \ldots \) 301
14.2.1 Basic Problem Solving \( \ldots \) 301
14.2.2 Comparison of Methodologies \( \ldots \) 303
14.2.2.1 Six Sigma DMAIC \( \ldots \) 305
14.2.2.2 Ford 8D TOPS \( \ldots \) 305
14.2.2.3 Lean Manufacturing \( \ldots \) 305
14.3 Selecting Tools and Techniques \( \ldots \) 305
14.4 Managing for Effective Problem Solving \( \ldots \) 307
14.4.1 Balancing Patience and Urgency \( \ldots \) 307
14.4.2 Balancing Containment and Correction \( \ldots \) 310
14.4.3 Balancing “Hands On” vs. “Hands Off” \( \ldots \) 310
14.4.4 Balancing Flexibility and Rigor \( \ldots \) 311
14.4.5 Balancing Autonomy and Accountability \( \ldots \) 312
14.4.6 From Distrust to Win–Win \( \ldots \) 313
14.5 Contributors’ Roles and Timing \( \ldots \) 314
14.5.1 Upper Management \( \ldots \) 314
14.5.2 Champion and Coordinator \( \ldots \) 315
14.5.3 Middle Management \( \ldots \) 316
14.5.4 Experts \( \ldots \) 316
14.5.5 Team Members \( \ldots \) 316
14.5.6 Operators \( \ldots \) 316
14.6 Conclusion \( \ldots \) 317

Chapter 15 Statistical Process Control \( \ldots \) 319
15.1 Describing Data \( \ldots \) 319
15.1.1 Histograms \( \ldots \) 319
15.2 Overview of SPC \( \ldots \) 320
15.2.1 Control Chart Properties \( \ldots \) 321
15.2.2 General Interpretation of Control Charts ........................................323
15.2.3 Defining Control Limits.................................................................324
15.2.4 Benefits of Control Charts..............................................................324
15.3 Choosing a Control Chart.................................................................327
15.3.1 Attribute Control Charts ..............................................................327
15.3.2 Variables Control Charts ..............................................................329
15.3.3 Selecting the Subgroup Size ......................................................331
15.3.4 Run Tests ..................................................................................334
15.3.5 Short-Run Techniques ...............................................................335
15.4 Process Capability and Performance Indices ........................................336
15.4.1 Interpretation of Capability Indices.............................................338
15.5 Autocorrelation ............................................................................339
15.5.1 Detecting Autocorrelation ...........................................................340
15.5.2 Dealing with Autocorrelation......................................................343
References..........................................................................................344

Chapter 16 Supply Chain Management ..................................................345
16.1 Introduction .................................................................................345
16.2 Defining the Manufacturing Supply Chain ......................................346
16.3 Defining Supply Chain Management ..............................................348
16.4 Critical Issues in Supply Chain Management ....................................349
16.4.1 Supply Chain Integration ..........................................................350
   16.4.1.1 Information Technology ....................................................351
   16.4.1.2 Information Access ..........................................................351
   16.4.1.3 Centralized Information ...................................................352
   16.4.1.4 IT Development and Strategic Planning ..........................353
16.4.2 Strategic Partnering ..................................................................353
   16.4.2.1 Supplier Partnerships ........................................................354
   16.4.2.2 Logistics Partnerships .......................................................354
16.4.3 Logistics Configuration ............................................................355
   16.4.3.1 Data Gathering ................................................................356
   16.4.3.2 Estimating Costs .............................................................356
   16.4.3.3 Logistics Network Modeling ............................................358
16.5 Inventory Management ..................................................................360
   16.5.1 Forecasting Customer Demand ............................................360
   16.5.2 Inventory Ordering Policy .....................................................362
16.6 Synchronizing Supply to Demand ..................................................365
References..........................................................................................366

Chapter 17 Supply Chain Management — Applications .........................369
17.1 Optimum Reorder Case Study ......................................................369
17.2 Basic Partnering Case Study ..........................................................371
17.3 Advanced Partnering Case Study ..................................................375
17.4 SCM Improvement Case Study ......................................................378
Chapter 18  The Theory of Constraints .............................................................383

18.1 From Functional to Flow ...........................................................................383

18.1.1 The Value Chain .................................................................................384

18.1.2 The Constraint Approach to Analyzing Performance .......................385

18.1.3 Two Important Prerequisites .............................................................386

18.1.3.1 Define the System and Its Purpose (Goal) ......................................386

18.1.3.2 Determine How to Measure the System’s Purpose .......................387

18.2 Understanding Constraints .......................................................................388

18.2.1 Physical Constraints ..........................................................................388

18.2.2 Policy Constraints .............................................................................393

18.2.3 Paradigm Constraints ........................................................................394

18.2.4 A Hi-Tech Tale ..................................................................................395

18.3 Conclusion ...............................................................................................397

References .......................................................................................................397

Chapter 19  TRIZ ..........................................................................................399

19.1 What Is TRIZ? .......................................................................................399

19.2 The Origins of TRIZ .............................................................................399

19.2.1 Altshuller’s First Discovery ...............................................................400

19.2.2 Altshuller’s Second Discovery ...........................................................400

19.2.3 Altshuller’s Third Discovery ...............................................................400

19.2.4 Altshuller’s Levels of Inventiveness ................................................401

19.2.4.1 Level 1: Parametric Solution .....................................................401

19.2.4.2 Level 2: Significant Improvement in the Technology Paradigm ....401

19.2.4.3 Level 3: Invention within the Paradigm .......................................401

19.2.4.4 Level 4: Invention outside the Paradigm .....................................402

19.2.4.5 Level 5: True Discovery ..............................................................402

19.3 Basic Foundational Principles ...............................................................402

19.3.1 Ideality .............................................................................................402

19.3.2 Contradictions ................................................................................404

19.3.2.1 Technical Contradictions .........................................................404

19.3.2.2 Physical Contradictions .............................................................404

19.3.3 Resources ........................................................................................405

19.4 A Scientific Approach ..........................................................................405

19.4.1 How TRIZ Works .............................................................................407

19.4.2 Five Requirements for a Solution to be Inventive ............................409

19.5 Classical and Modern TRIZ Tools ..........................................................410

19.5.1 Classical TRIZ – Knowledge-Based Tools ......................................410

19.5.1.1 The Contradiction Matrix .........................................................410

19.5.1.2 Physical Contradictions .............................................................412

19.5.1.2.1 Formulating and Solving Physical Contradictions ...............413

19.5.1.2.2 An Example ........................................................................413
19.5.1.3 The Laws of Systems Evolution ................................. 413
19.5.2 Analytical Tools ............................................................... 415
  19.5.2.1 Sufield ................................................................. 416
  19.5.2.2 Algorithm for Inventive Problem Solving (ARIZ) .... 418
    19.5.2.2.1 The Steps in ARIZ .......................................... 419
    19.5.2.2.2 Problem Analysis ........................................... 420
    19.5.2.2.3 Resource Analysis .......................................... 422
    19.5.2.2.4 Model of Ideal Solution ................................. 423
19.6 Caveat ............................................................................. 424
19.7 Conclusion ....................................................................... 425
References ............................................................................. 425
Preface

By Jack B. ReVelle

Sometimes it seems as though there is no end to the number of new or nearly new manufacturing methods that are now available. The primary objective for bringing together this book is for it to become your single-source reference to what’s currently happening in modern manufacturing.

Whether your goal is to improve organizational responsiveness, product quality, production scheduling, or sensitivity to customer expectations, or to reduce process cycle time, cost of quality, or variation in products or processes, there is a methodology waiting to be discovered and introduced to enhance your operations.

In an effort to facilitate your use of this book, it has been organized in two ways: alphabetically, to ease the location of a specific topic; and by application, to indicate primary usage. No matter how the topics are enumerated or organized, there is seemingly no end to the scope of tools and techniques available to the well-informed manufacturing manager. The topics addressed in this book have been classified and then subclassified according to their major applications in Table 1.

The next few pages are dedicated to briefly describing each of these topics.

- An agile enterprise is adept at rapidly reorganizing its people, management, physical facilities, and operating philosophy to be able to produce highly customized products and services that satisfy a new customer or a new market.
- Design for manufacture and assembly (DFMA) and design for six sigma (DFSS) are complementary approaches to achieve a superior product line that maximizes quality while minimizing cost and cycle time in a manufacturing environment. DFMA stresses the achievement of the simplest design configuration. DFSS applies statistical analysis to achieve nearly defect-free products.
- Design of experiments (DOE) is the statistical superstructure upon which DFMA and DFSS are based. By analyzing the results of a predetermined series of trial runs, the optimal levels or settings for each critical parameter or factor are established.
- Integrated product and process development (IPPD) is a cross-functional, team-oriented approach to maximize concurrent development of both a product design and the means to produce the design.
- ISO 9000:2000 is the most recent version of the international standard for quality management systems (QMS). Originally approved in 1987 and revised in 1994, this is the most recent version of ISO 9000. Because of substantial changes, even persons familiar with earlier versions of this standard need additional training.
- ISO 14001 is the international standard for environmental management systems (EMS) and their integration into overall management structures.
• **Lean manufacturing** is an integrated collection of tools and techniques, traceable back to the Toyota production system, that focuses on the elimination of waste from the production process.

• **Manufacturing controls integration** brings together a collection of related systems such as enterprise resource planning (ERP) and manufacturing resource planning (MRP) to manage their internal operations and establish the demands of their supply chains.

• **Measurement systems analysis (MSA)** is the examination and understanding of the entire measurement process as well as its impact on the data it generates. The process includes procedures, gauges, software, personnel, and documentation.

• **Process analysis** is the mapping, input–output analysis, and detailed examination of a process including each of its sequential steps.

• **Quality function deployment (QFD)** is a matrix-based approach to acquisition and deployment of the “voice of the customer” throughout an organization to ensure that customer expectations, demands, and desires are thoroughly integrated into products and services. The initial QFD matrix is widely known as the House of Quality (HOQ).

• **Robust design** of a product or a process is the logical search for its optimal design (the levels or settings for each controllable parameter or factor) when considering the negative effect of the most critical uncontrollable/noise factors.

• **Six sigma** is a financially focused, highly structured approach to advancing the objectives of continuous improvement. The first of two chapters addresses the benefits resulting from the application of Six Sigma quality, while the second chapter focuses on the Six Sigma problem-solving methodology.

• **Statistical quality/process control (SQC/SPC)** was initially developed in the 1920s, but was substantially enhanced in the 1970s and 1980s by W. Edwards Deming and Joseph Juran and in the 1990s through the use of personal computers. This chapter emphasizes when and how to use SQC/SPC to improve products and processes as well as how this collection of tools differs from other statistical techniques.

• **Supply chain management (SCM)** is the control of the network used to deliver products and services from raw materials to end consumers through an engineered flow of information, physical distribution, and cash. The first of two chapters addresses the basics of SCM, while the second chapter focuses on SCM applications.

• The concepts known as the **theory of constraints (TOC)** and the **critical chain** were developed by Eli Goldratt. They represent a major expansion of the existing methodology known as critical path planning or the activity network diagram.

• **TRIZ** (a Russian acronym also known as the **theory of innovative problem solving (TIPS)**) is a highly integrated collection of facts regarding physical, chemical, electrical, and biological principles that are used to predict where future breakthroughs are likely to occur and what they are likely to be.
Our contributing authors are all seasoned manufacturing veterans who have a particular interest in and extensive understanding of the topics about which they have written. In many cases the editor has worked directly with these authors at one point or another in their careers, so he can attest to their knowledge and willingness to share this knowledge with those who want to learn more about their profession. However, the idea to create this book, the choice of topics, and the selection of contributing authors are all mine and so, as editor, I accept full responsibility for any shortcomings you may find.

At this point it should be evident that this book is intended to provide information for both novice and experienced manufacturing managers. If a particular topic is of special interest to you for purposes of review or to initiate your understanding of its “fit” within the broad spectrum of tools and techniques that are a regular part of today’s manufacturing venue, you will have immediate access to the basics as well as a bridge to more advanced information regarding that topic.

Remember, this is a handbook, not a textbook. Although you may wish to read the entire book from front to back, it is not necessary to do so. Simply search out the topic(s) of interest to you and begin your journey into the future of manufacturing.

### TABLE 1
**Topical Classification by Major Usage**

<table>
<thead>
<tr>
<th>Topic</th>
<th>Design</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agile Enterprises</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Design for Manufacture &amp; Assembly/Design for Six Sigma (DFMA/DFSS)</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Design of Experiments (DOE)</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Integrated Product and Process Development (IPPD)</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>ISO 9000:2000</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>ISO 14000</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Lean Manufacturing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manufacturing Controls Integration</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Measurement Systems Analysis (MSA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process Analysis</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Quality Function Deployment (QFD)</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Robust Design</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Six Sigma Benefits Resulting from Six Sigma Quality</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Six Sigma Problem Solving</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Statistical Quality/Process Control (SQC/SPC)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply Chain Management Basics</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Supply Chain Management Applications</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Theory of Constraints/Critical Chain</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>TRIZ/Theory of Innovative Problem Solving (TIPS)</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

© 2002 by CRC Press LLC
Acknowledgments

The team of authors, editor, and publisher that helped us to convert the original concept for a highly focused manufacturing handbook into this final product deserves public recognition. My thanks are extended to all the contributing authors who produced their respective chapters. Special thanks and appreciation are due to Drew Gierman, our publisher at St. Lucie Press, who pushed and pulled us to ensure that this handbook would eventually become a reality. Maria Muto of Muto Management Associates, our Phoenix-based editor, deserves more than thanks and appreciation: she has earned our enduring respect for her tenacity and professionalism. Without her intervention and involvement, we would still be running the race trying to bring everything together for you, our readers. And of course, her check is in the mail.
Dr. Jack B. ReVelle, The Wizard of Odds, provides his advice and assistance to his clients located throughout North America. In this capacity, he helps his clients to better understand and continuously improve their processes through the use of a broad range of Six Sigma, Total Quality Management, and continuous improvement (Kaizen) tools and techniques. These include process mapping, cycle time management, quality function deployment, statistical quality control, the seven management and planning tools, design of experiments, strategic planning (policy deployment), and integrated product and process development. In May 2001, Dr. ReVelle completed instructing “An Introduction to Six Sigma,” a Web-based graduate course on behalf of California State University, Dominguez Hills.

Previously, he was Director of the Center for Process Improvement for GenCorp Aerojet in Azusa and Sacramento, CA, where he provided technical leadership for the Operational Excellence program. This included support for all the Six Sigma, Lean/Agile Enterprise, Supply Chain Management, and High Performance Workplace activities. Prior to this, Dr. ReVelle was the leader of Continuous Improvement for Raytheon (formerly Hughes) Missile Systems Company in Tucson, AZ. During this period, he led the Hughes teams that won the 1994 Arizona Pioneer Award for Quality and the 1997 Arizona Governor’s Award for Quality. He also established the Hughes team responsible for obtaining ISO 9001 registration in 1996. On behalf of Hughes, Dr. ReVelle worked with the Joint Arizona Consortium-Manufacturing and Engineering Education for Tomorrow (JACME²T) as the leader of the Quality Curriculum Development Group and as the lead TQM trainer.

Dr. ReVelle’s previous assignments with Hughes Electronics were at the corporate offices as Manager, Statistical and Process Improvement Methods, and as Manager, Employee Opinion Research and Training Program Development. Prior to joining Hughes, he was the Founding Dean of the School of Business and Management at Chapman University in Orange, CA.

Currently, Dr. ReVelle is a member of the Board of Directors, Arizona Governor’s Award for Quality (1999–2000). Previously, he was a member of the Board of Examiners for the Malcolm Baldrige National Quality Award (1990 and 1993), a judge for the Arizona Governor’s Award for Quality (1994–1996), a member of the Awards Council for the California Governor’s Award for Quality (1998–1999), and a judge for the RIT — USA Today Quality Cup (1994–2001).


Dr. ReVelle is a fellow of the American Society for Quality, the Institute of Industrial Engineers, and the Institute for the Advancement of Engineering. He is listed in Who’s Who in Science and Engineering, Who’s Who in America, Who’s Who in the World, and as an outstanding educator in The International Who’s Who in Quality.

Dr. ReVelle is a recipient of the Distinguished Economics Development Programs Award from the Society of Manufacturing Engineers 1990, the Taguchi Recognition Award from the American Supplier Institute 1991, the Akao Prize from the QFD Institute 1999, and the Lifetime Achievement Award from The National Graduate School of Quality Management 1999. He is one of only two persons ever to receive both the Taguchi Recognition Award (for his successful application of Robust Design) and the Akao Prize (for his outstanding contribution to the advancement of quality function deployment).

Dr. ReVelle’s award-winning articles have been published in QUALITY PROGRESS, INDUSTRIAL ENGINEERING, INDUSTRIAL MANAGEMENT, and PROFESSIONAL SAFETY magazines. During 1994 and 1995, Dr. ReVelle created and hosted a series of monthly satellite telecasts, “Continuous Improvement Television” (CITV), for the National Technological University.

Dr. ReVelle received his B.S. in chemical engineering from Purdue University and both his M.S. and Ph.D. in industrial engineering and management from Oklahoma State University. Prior to receiving his Ph.D., he served 12 years in the U.S. Air Force. During that time, he was promoted to the rank of major and was awarded the Bronze Star Medal while stationed in the Republic of Vietnam as well as the Joint Services Commendation Medal for his work in quality assurance with the Nuclear Defense Agency.

Dr. ReVelle was a Senior Vice President and Treasurer of the Institute of Industrial Engineers (IIE), Director of the Aerospace and Defense Division of the IIE, a Co-Chair of the Total Quality Management (TQM) Committee of the American Society for Quality (ASQ), and a member of the Board of Directors of the Association for Quality and Participation (AQP).

Other professional memberships include the American Statistical Association (ASA) and the American Society of Safety Engineers (ASSE). Dr. ReVelle’s national honor society memberships include Sigma Tau (all engineering), Alpha Pi Mu (industrial engineering), Alpha Iota Delta (decision sciences), and Beta Gamma Sigma (business administration).
Contributors

Jonathon L. Andell
Andell Associates
Phoenix, AZ

Douglas Burke
General Electric
Gilbert, AZ

Adi Choudri
GenCorp Aerojet
Folsom, CA

R.T. "Chris" Christensen
University of Wisconsin
Madison, WI

Charles A. Cox
Compass Organization, Inc.
Gilbert, AZ

Syed Imtiaz Haider
Gulf Pharmaceutical Industries
United Arab Emirates

John W. Hidahl
GenCorp Aerojet
Rancho Cordova, CA

Robert Hughes
Ethicon
Cincinnati, OH

Paul A. Keller
Quality America/Quality Publishing
Tucson, AZ

Edward A. Peterson
GenCorp Aerojet
Auburn, CA

Jack B. ReVelle
ReVelle Solutions, LLC
Tustin, CA

Lisa J. Scheinkopf
Chesapeake Consulting, Inc.
Tempe, AZ

Steven F. Ungvari
Consultant
Brighton, MI
Dedication

This handbook is dedicated to

- Bren, my wife of 33 years and the love of my life. No significant decision can or should be made without her counsel.
- Karen, our daughter who has become a lovely young lady and an exceptional commercial artist.
- Manufacturing vice presidents, directors, managers, engineers, specialists, and technicians around the world. This is your book; let it help you focus on innovation, productivity, and quality in manufacturing.
About APICS

APICS, The Educational Society for Resource Management, is an international, not-for-profit organization offering a full range of programs and materials focusing on individual and organizational education, standards of excellence, and integrated resource management topics. These resources, developed under the direction of integrated resource management experts, are available at local, regional, and national levels. Since 1957, hundreds of thousands of professionals have relied on APICS as a source for educational products and services.

- **APICS Certification Programs**—APICS offers two internationally recognized certification programs, Certified in Production and Inventory Management (CPIM) and Certified in Integrated Resource Management (CIRM), known around the world as standards of professional competence in business and manufacturing.

- **APICS Educational Materials Catalog**—This catalog contains books, courseware, proceedings, reprints, training materials, and videos developed by industry experts and available to members at a discount.

- **APICS—The Performance Advantage**—This monthly, four-color magazine addresses the educational and resource management needs of manufacturing professionals.

- **APICS Business Outlook Index**—Designed to take economic analysis a step beyond current surveys, the index is a monthly manufacturing-based survey report based on confidential production, sales, and inventory data from APICS-related companies.

- **Chapters**—APICS’ more than 270 chapters provide leadership, learning, and networking opportunities at the local level.

- **Educational Opportunities**—Held around the country, APICS’ International Conference and Exhibition, workshops, and symposia offer you numerous opportunities to learn from your peers and management experts.

- **Employment Referral Program**—A cost-effective way to reach a targeted network of resource management professionals, this program pairs qualified job candidates with interested companies.

- **SIGs**—These member groups develop specialized educational programs and resources for seven specific industry and interest areas.
- **Web Site**—The APICS Web site at [http://www.apics.org](http://www.apics.org) enables you to explore the wide range of information available on APICS’ membership, certification, and educational offerings.
- **Member Services**—Members enjoy a dedicated inquiry service, insurance, a retirement plan, and more.

For more information on APICS programs, services, or membership, call APICS Customer Service at (800) 444-2742 or (703) 354-8851 or visit [http://www.apics.org](http://www.apics.org) on the World Wide Web.