CONTENTS

Preface xxiii

Acknowledgments xxv

1 Fundamentals of Cost Estimating 1

1.1 Cost Estimating Fundamentals, 4
1.2 Organizing for Estimating, 5
1.3 Developing Ground Rules and Assumptions, 6
1.3.1 The Work Breakdown Structure, 6
1.3.2 Work Element Numbering System, 8
1.3.3 Development of the Structure, 8
1.3.4 Designations of Work Element Levels, 8
1.3.5 Treatment of Alternative, Parallel, or Recurring/ Nonrecurring Costs, 12
1.3.6 More About Work Element Coding Conventions, 13
1.3.7 Work Breakdown Structure Dictionaries, 13
1.4 Scheduling, 13
1.4.1 Precedence/Successor Relationships and Dates, 14
1.4.2 Techniques Utilized in Schedule Planning, 14
1.5 The Retrieval and Use of Historical Cost Data, 16
1.6 Cost Estimating Relationships, 18
1.6.1 Removing and/or Accounting for the Effects of Inflation, 18
1.6.2 Removing the Effects of Labor Rate Fluctuations, 19
1.6.3 Adjusting Historical Data to Account for Past Inefficiencies, 21
1.7 Develop and Use Production Learning Curves, 22
1.8 Identification of Skill Categories, Skill Levels, and Labor Rates, 22

1.8.1 Skill Categories, 23
1.8.2 Skill Levels, 23
1.8.3 The Dynamic Skill Mix, 23
1.8.4 Static and Dynamic Skill Mix Examples, 24
1.9 Developing Labor and Material Estimates, 30
1.9.1 Methods Time Measurement (MTM), 30
1.9.2 Industrial, Shop, or Office Standards, 31
1.9.3 Staffing and Shoploading Estimating, 32
1.9.4 Material Estimating, 32
1.10 Develop Overhead and Administrative Cost Estimates, 33
1.10.1 Direct Costs: Definition, 33
1.10.2 Indirect Costs: Definition, 33
1.10.3 Other Costs: Definition, 34
1.11 Applying Inflation and Escalation (Cost Growth) Factors, 35
1.11.1 Dealing with Inflation, 35
1.11.2 Dealing with Escalation, 36
1.12 Pricing or Computing the Estimated Cost, 37
1.13 Analyzing, Adjusting, and Supporting the Estimate, 38
1.14 Publishing and Presenting the Cost Estimate, 39
References, 40

2 Activity-Based Costing and Traditional Cost Allocation Structures 41

2.1 Cost Classifications and Concepts, 41
2.1.1 Accounting Structures and Systems, 41
2.1.2 Patterns in Cost Behavior, 44
2.1.3 Traceability of Costs, 49
2.2 Activity-Based Costing (ABC), 50
2.2.1 Planning for ABC, 51
2.2.2 Product Costing, 52
2.2.3 Developing Cost Drivers, 53
2.2.4 Typical ABC Applications, 54
2.2.5 ABC in Manufacturing Organizations, 55
2.2.6 ABC in Service Organizations, 56
2.2.7 ABC in R&D Operations, 58
2.2.8 Cost Management and Strategy, 58
2.3 The Nature of Product Costing, 59
2.3.1 Product Cost Flows, 60
2.3.2 Job Order Costing, 61
2.3.3 Process Costing, 64
2.4 Indirect Cost Allocation, 67
2.4.1 Allocation to Jobs, 68
2.4.2 Allocation of Service Department Overhead, 72
2.4.3 Allocation in Process Costing Systems, 74
2.5 Cost Control Utilizing Standards, 75

2.5.1 Material Standards, 75
2.5.2 Labor Standards, 76
2.5.3 Flexible Budgeting, 78
2.6 Analyzing Performance by Cost, 79
2.6.1 Variance Analysis, 79
2.6.2 Breakeven Analysis, 82
2.6.3 Differential Analysis, 85
2.6.4 Profit Relationship of Segments, 88
2.6.5 Profit of the Company, 90
References, 93

3 Statistical Techniques in Cost Estimation 95

3.1 Introduction, 95
3.1.1 Historical Data Collection, 95
3.1.2 Statistical Inference, 96
3.1.3 Parametric Versus Nonparametric, 96
3.2 Basic Concepts Regarding Statistical Tests, 97
3.2.1 Statement of Hypotheses, 97
3.2.2 Choice of Statistical Test, 98
3.2.3 Level of Significance, 99
3.2.4 The Sampling Distribution, 101
3.2.5 The Region of Rejection, 101
3.2.6 The Statistical Decision, 102
3.3 Parametric Statistical Tests, 102
3.3.1 The Treatment of Outliers, 103
3.3.2 Large-Sample Goodness-of-Fit Testing, 106
3.3.2.1 Graphic Methods, 106
3.3.2.2 Chi-Squared Test, 108
3.3.3 Transformations, 109
3.3.4 Predictive Methods, 111
3.3.4.1 Linear Regression, 112
3.3.4.2 Sampling and Regression Analysis, 117
3.3.4.3 Multiple Regression, 118
3.3.4.4 Selection of Independent Variables, 122
3.4 Nonparametric Statistical Tests, 126
3.4.1 Kruskal-Wallis *H* Test, 126
3.4.2 Kolmogorov-Smirnov One-Sample Statistic, 128
3.5 Concluding Remarks, 130
References, 130

4 Discounted Cash Flow Analysis 131

4.1 Introduction, 131
4.1.1 The Time Value of Money Concept and When It Applies, 131

4.1.2 Cash Flows, 132
4.2 Structuring the Discounted Cash Flow Analysis, 136
4.2.1 Multiple Levels of Investment, 136
4.2.2 Exclusion of Common Cash Flows and Sunk Costs, 136
4.2.3 Equal Capabilities Between Alternatives, 137
4.2.4 Equal Economic Lifetimes, 137
4.2.5 Income Tax Considerations, 138
4.2.6 Disregard Payment Schedules Due to Financing Arrangements, 139
4.2.7 Uncertainties and Risk, 139
4.3 Decision Criteria, 140
4.3.1 Present Value, 140
4.3.2 Equivalent Annual Amount, 143
4.3.3 Assumption of an Infinite Horizon, 145
4.3.4 Internal Rate of Return, 146
4.3.5 Example of the Present-Value Method, 148
4.4 Selection from Multiple Alternatives, 152
4.5 The Relationship Between Interest and Inflation, 157
4.6 Choosing a Discount Rate, 164
4.7 Concluding Remarks, 166
References, 166

5 Learning Curves and Progress Functions **169**

5.1 Introduction, 169
5.1.1 Objectives/Purpose, 169
5.1.2 Problem Statement, 170
5.2 Applied Learning Curve Theory, 173
5.2.1 Assumptions, 173
5.2.2 Constraints, 174
5.2.3 Approaches, 174
5.2.3.1 Wright System, 174
5.2.3.2 Crawford System, 176
5.3 Preliminary Considerations, 177
5.3.1 Theoretical First Unit (TFU) Cost, 177
5.3.2 Learning Curve Slope Ranges, 178
5.4 Analytical Techniques, 180
5.4.1 Mathematical Relations, 180
5.4.2 Solution Procedures, 182
5.4.2.1 Graphical Solutions, 182
5.4.2.2 Algebraic Solutions Using Established Equations, 184
5.4.2.3 Tabular Solutions, 186
5.4.2.4 Composite Learning Curve, 186

5.4.2.5 Computer Solution of Learning Curve Problems, 187
5.5 Effects of Design Changes on the Learning Curve, 188
5.6 Factors Affecting Learning Curve Slope, 189
5.7 Other Information on Learning Curves, 189
5.7.1 Learning Losses Due to Production Interruptions, 189
5.7.2 Learning in Small Lots, 190
5.7.3 Learning Curve/Complexity Relationships, 190
5.7.4 Incentives During Learning, 190
5.7.5 Misapplications of the Learning Curve Concept, 191
5.7.6 Learning in Manual Operations, 191
5.7.7 Learning Curves from Standard Time Data, 191
5.7.8 Learning in Mechanical Assembly Tasks, 191
5.8 Concluding Remarks, 192
References, 192

6 Detailed Cost Estimating **193**

6.1 The Anatomy of a Detailed Estimate, 193
6.1.1 Time, Skills, and Labor-Hours Required to Prepare an Estimate, 196
6.2 Discussion of Types of Costs, 197
6.2.1 Initial Acquisition Costs, 197
6.2.2 Fixed and Variable Costs, 198
6.2.3 Recurring and Nonrecurring Costs, 198
6.2.4 Direct and Indirect Costs, 198
6.3 Collecting the Ingredients of the Estimate, 198
6.3.1 Labor-Hours, 198
6.3.2 Materials and Subcontracts, 200
6.3.3 Labor Rates and Factors, 200
6.3.4 Indirect Costs, Burden, and Overhead, 201
6.3.5 General and Administrative Costs, 201
6.3.6 Fee, Profit, or Earnings, 201
6.3.7 Assembly of the Ingredients, 201
6.4 The First Questions to Ask (and Why), 202
6.4.1 What Is It?, 202
6.4.2 What Does It Look Like?, 203
6.4.3 When Is It to Be Available?, 203
6.4.4 Who Will Do It?, 203
6.4.5 Where Will It Be Done?, 203
6.5 The Estimate Skeleton: The Work Breakdown Structure, 204
6.6 The Hierarchical Relationship of a Detailed Work Breakdown Structure, 204
6.7 Functional Elements Described, 206

6.8 Physical Elements Described, 206
6.9 Treatment of Recurring and Nonrecurring Activities, 208
6.10 Work Breakdown Structure Interrelationships, 208
6.10.1 Skill Matrix in a Work Breakdown Structure, 209
6.10.2 Organizational Relationships to a Work Breakdown Structure, 210
6.11 Methods Used within the Detailed Estimating Process, 210
6.11.1 Detailed Resource Estimating, 210
6.11.2 Direct Estimating, 210
6.11.3 Estimating by Analogy (Rules of Thumb), 211
6.11.4 Firm Quotes, 211
6.11.5 Handbook Estimating, 211
6.11.6 The Learning Curve, 212
6.11.7 Labor-Loading Methods, 215
6.11.8 Statistical and Parametric Estimating as Inputs to Detailed Estimating, 216
6.12 Developing a Schedule, 217
6.13 Techniques Used in Schedule Planning, 217
6.14 Estimating Engineering Activities, 218
6.14.1 Engineering Skill Levels, 218
6.14.2 Design, 218
6.14.3 Analysis, 218
6.14.4 Drafting, 218
6.15 Manufacturing/Production Engineering, 219
6.15.1 Engineering Documentation, 221
6.16 Estimating Manufacturing/Production and Assembly Activities, 222
6.17 Manufacturing Activities, 222
6.18 In-Process Inspection, 224
6.19 Testing, 224
6.20 Computer Software Cost Estimating, 226
6.21 Labor Allowances, 227
6.21.1 Variance from Measured Labor-Hours, 227
6.21.2 Personal, Fatigue, and Delay (PFD) Time, 227
6.21.3 Tooling and Equipment Maintenance, 228
6.21.4 Normal Rework and Repair, 228
6.21.5 Engineering Change Allowance, 228
6.21.6 Engineering Prototype Allowance, 228
6.21.7 Design Growth Allowance, 229
6.21.8 Cost Growth Allowance, 229
6.22 Estimating Supervision, Direct Management, and Other Direct Charges, 229
6.23 The Use of "Factors" in Detailed Estimating, 230
6.24 Concluding Remarks, 231

7 Parametric Estimating **233**

7.1 Introduction, 233
7.1.1 An Overview of Parametric Estimating, 233
7.1.2 Origins of Parametric Estimating, 235
7.1.3 Applicability of the Parametric Method, 236
7.2 Database Development, 237
7.2.1 Data Collection, Organization, and Normalization, 237
7.2.2 Bookkeeping Normalizations, 239
7.3 Model Building, 241
7.3.1 Common CER Equation Forms, 241
7.3.2 Choosing the Right Equation Form for the CER, 250
7.3.3 Measures of Goodness of Fit, 252
7.3.4 Multiple Regression, 254
7.4 Model Application, 255
7.4.1 CER Stratification, 257
7.4.2 Cost Adjustments and Complexity Factors, 259
7.4.3 Number of Developmental Units, 259
7.4.4 Design Inheritance, 259
7.4.5 Design Complexity, 260
7.4.6 Production Rate Effects, 260
7.5 Trends and Directions, 262
7.5.1 New Applications and Broader Scopes, 262
7.5.2 Parametrics and Risk Analysis, 262
7.6 Concluding Remarks, 264
References, 265

8 Risk Analysis for Cost/Schedule/Technical Performance **267**

8.1 Risk Analysis, 267
8.2 Aspects of Risk Analysis, 268
8.2.1 Probability Theory and Expert Opinion, 269
8.2.2 Methods for Quantifying Expert Opinion, 270
8.2.2.1 The Modified Churchman-Ackoff Method, 271
8.2.2.2 The Normalized Geometric Mean Vector Method, 271
8.2.2.3 Gamble Method, 272
8.2.2.4 Diagrammatic Method, 272
8.2.2.5 The Delphi Technique, 272
8.3 Risk Analysis Techniques, 272
8.3.1 Network Analysis, 273
8.3.1.1 Network Analysis Technique, 279
8.3.1.2 Critical Path Method (CPM), 280
8.3.1.3 Program Evaluation and Review Technique (PERT), 282

8.3.1.4 ARTEMIS Probabilistic Analysis of Network (PAN), 283
8.3.1.5 Risk Information System and Network Evaluation Technique (RISNET), 287
8.3.1.6 Venture Evaluation and Review Technique (VERT), 292
8.3.2 Decision Risk Analysis Method, 300
8.3.3 Cost Estimating Risk Analysis Technique, 305
8.3.3.1 Stochastic Aggregation Model (SAM), 305
8.3.3.2 Example Case: Project X, 308
8.3.3.2.1 SAM Input Form for Project X, 308
8.3.3.2.2 SAM Output for Project X, 309
8.3.3.3 SAM Technical Notes, 309
8.3.3.3.1 How SAM Handles CER Risk, 310
8.3.3.3.2 Interpretation of SAM Output, 310
8.3.4 Risk Factor Method, 311
8.4 Application of Risk Analysis Technique, 312
References, 314

9 Design to Cost **317**

9.1 Introduction, 317
9.2 The Product Design Process, 318
9.3 Cost Estimating Models, 325
9.4 Decision-Making for Design, 328
9.4.1 Optimization Methods, 328
9.4.2 Single Design Variable, 329
9.4.3 Multiple Design Variables, 330
9.4.4 Geometric Programming for Design, 333
9.4.5 Goal Programming for Design, 349
9.5 Concluding Remarks, 352
References, 352

10 Construction Cost Estimating **353**

10.1 Introduction, 353
10.1.1 Overview, 353
10.1.2 Consideration of Construction Type, 354
10.1.2.1 Building Construction, 355
10.1.2.2 Heavy Construction, 355
10.1.3 Consideration of Contract Form, 355
10.1.3.1 Cost-Plus Contracts, 355
10.1.3.2 Lump-Sum Contracts, 356
10.1.3.3 Unit-Price Contracts, 356
10.1.4 Degrees of Cost Estimating, 357
10.1.5 Bidding Strategy, 358

10.2 Preliminary Cost Estimating, 358
10.2.1 Overview, 358
10.2.2 Preliminary Cost Estimating for Building Construction, 358
10.2.2.1 Area and Capacity Estimates, 359
10.2.2.2 Systems Estimates, 362
10.2.2.3 Comparable Facility Estimates, 362
10.2.2.4 Time Estimates, 364
10.2.3 Preliminary Cost Estimating for Heavy Construction, 364
10.2.3.1 Estimating Highway Construction, 365
10.3 Detailed Cost Estimating, 367
10.3.1 Overview, 367
10.3.2 Building Construction, 368
10.3.2.1 Quantity Takeoffs, 368
10.3.2.2 Labor Rates, 369
10.3.2.3 Equipment Rates, 371
10.3.2.4 Subcontracts, 373
10.3.2.5 Indirect Costs, 373
10.3.3 Heavy Construction, 374
10.3.3.1 List of Pay Items, 374
10.3.3.2 Unit Prices, 375
10.3.3.3 Distribution of Indirect Costs, 375
10.3.3.4 Unbalanced Bids, 375
10.3.4 Cash Flow Analysis, 376
10.4 Time Schedules in Cost Estimating, 380
10.4.1 Overview, 380
10.4.2 CPM Schedules, 383
10.4.2.1 Arrow Diagramming, 383
10.4.2.2 Precedence Diagramming, 384
10.4.2.3 CPM Calculations, 386
10.4.2.4 Least-Cost Scheduling, 390
10.4.2.5 Payment Progressing, 395
10.4.2.6 Resource Leveling, 395
10.4.3 Pert Schedules, 396
10.4.4 Monte Carlo Simulation Schedules, 401
10.5 Concluding Remarks, 403
References, 405

11 Cost Estimating in Manufacturing 407

11.1 Introduction, 407
11.2 Labor Costing, 409
11.2.1 Engineering and Design, 409
11.2.2 Standard Time Data, 413
11.2.2.1 Direct-Time Study, 414
11.2.2.2 Predetermined Systems, 419

11.2.3 Labor Rate Schedules, 426
11.2.4 Indirect Labor, 427
11.3 Materials Costing, 427
11.3.1 Bill of Material, 427
11.3.2 Master Production Schedule, 429
11.3.3 Inventory/Order Costs and Policy, 429
11.4 Equipment and Tooling Cost Estimating, 436
11.4.1 Cost Models, 437
11.4.2 Standard Data Tables, 439
11.5 Quality Control, Reliability, and Test Estimating, 440
11.5.1 Inspection, 441
11.5.2 Analysis, 441
11.5.3 Scrap and Rework, 441
11.6 Other Costs, 442
References, 442

12 Cost Implications of Systems/Concurrent Engineering 445

12.1 Introduction, 445
12.2 Systems Engineering Approach to Design, 447
12.3 Design Practice, 452
12.4 Case Study Results, 455
12.5 Concluding Remarks, 458
References, 458

13 Aspects Affecting Cost Estimation in Government Procurement 459

13.1 Federal Government Philosophies and Policies, 459
13.1.1 Governmental Perspective, 459
13.1.2 General Statutory Requirements, 460
13.1.3 Broad Policies, 461
13.2 Procurement Planning Requirements, 462
13.2.1 Agency Acquisition Plans, 463
13.2.2 Annual Budget Cycle, 463
13.2.3 Multiyear Procurements, 463
13.3 Cost Estimation in Government Contracts, 465
13.3.1 Firm-Fixed-Price Contracts, 466
13.3.2 Fixed-Price Contracts with Economic Price Adjustment, 466
13.3.3 Fixed-Price Incentive Contracts, 467
13.3.4 Fixed-Ceiling-Price Contracts with Retroactive Price Redetermination, 468
13.3.5 Fixed-Price Contracts with Prospective Price Redetermination, 469
13.3.6 Firm-Fixed Price, Level-of-Effort Term Contracts, 469
13.3.7 Cost-Sharing Contracts, 470

13.3.8 Cost-Plus-Incentive-Fee Contracts, 470
13.3.9 Cost-Plus-Award-Fee Contracts, 471
13.3.10 Cost-Plus-Fixed-Fee Contracts, 472
13.3.11 Indefinite-Delivery Contracts, 472
13.3.12 Time-and-Materials, Labor-Hour, and Letter Contracts, 474
13.3.13 Federal Supply Schedule Contracting, 475
13.3.14 Facilities Contracts, 475
13.3.15 Construction and Architect-Engineer Contracts, 475
13.3.16 Contracts with Educational Institutions, 476
13.3.17 Contracts with State and Local Governments, 476
13.4 Cost Accounting Standards and Principles, 477
13.4.1 Applicability of Government Standards, 477
13.4.2 Special Cost Terms, 477
13.4.3 Standards, 478
13.4.4 Cost Principles, 479
13.5 Cost Grouping and Structures, 480
13.5.1 Five-Year Defense Plan, 480
13.5.2 DOD Program Management, 480
13.5.3 Contracting, 482
13.6 Separate Cost Principles, 483
13.6.1 Compensation for Personal Services, 483
13.6.2 Special Contracts and Grants, 484
13.7 Constraints Outside the Cost Estimate, 484
13.7.1 Limitation-of-Costs Clause, 484
13.7.2 Practices and Decision Precedents, 484
13.8 Other Considerations in Cost Estimating for Contracts with the Federal Government, 485
References, 486

14 Computer-Aided Cost Estimating 489

14.1 Introduction, 489
14.2 State-of-the-Art Cost Estimating Tools, 489
14.2.1 Simple User Interfaces, 490
14.2.2 Flexibility, 490
14.2.3 Automation of Common Cost Estimating Tasks, 490
14.2.4 Integrated Sets of Generic Tools, 491
14.2.5 Cost Estimating Shells and Vertical Market Systems, 491
14.3 Automated Cost Estimation, 492
14.3.1 Automated Cost Estimating Integrated Tools (ACEIT) Description, 492
14.3.2 Work Breakdown Structure (WBS) Definition, 493
14.3.3 Equations, Analogies, Factors, and More, 497
14.3.3.1 Methodology Specification Using Spreadsheets, 498

14.3.3.2 Methodologies Specified Using ACEIT, 500
14.3.4 Learning Curve Adjustments, 501
14.3.4.1 Discontinuous Learning Curves, 503
14.3.4.2 Rate-Adjusted Learning Curves, 503
14.3.4.3 Shared Learning Curves, 504
14.3.5 G&A, Fee, Overhead, Fiscal-Year, and Dollar Unit Adjustment, 505
14.3.6 Time Phasing the Estimate, 506
14.3.7 "What-if" (Sensitivity) Analysis, 509
14.3.8 Documentation, 510
14.4 Database Software, 514
14.4.1 Relational Databases, 516
14.4.2 Typical Database Software Packages, 516
14.4.3 Automated Cost Database, 516
14.4.3.1 Database Administrator, 517
14.4.3.2 Database Entry, 517
14.4.3.3 Search and Retrieval, 518
14.5 Statistical Packages, 518
14.6 Risk Analysis Tools, 521
14.7 Pricing Tools, 525
14.8 Specialized Cost Estimating Tools, 526
14.8.1 Black-Box Estimator (BBEST) Models, 526
14.8.2 PRICE Models, 526
14.9 Hardware Devices, 528
14.10 Concluding Remarks, 530
14.10.1 Define the Problem to Be Estimated, 530
14.10.2 Create a Test Case, 531
14.10.3 Identify Candidate Software/Hardware and Test It, 531
References, 531

15 The Software Acquisition Process **533**

15.1 Overview, 533
15.1.1 The Life Cycle, 534
15.1.2 The Acquisition Contract, 534
15.1.3 Monitoring and Inspection, 536
15.1.4 Software Indicators, 537
15.2 Model Request for Proposal (RFP), 537
15.2.1 System Specification, 539
15.2.2 Instructions to Bidders, 539
15.2.3 Statement of Work (SOW), 540
15.2.4 Contract Data Requirements List (CDRL), 542
15.2.5 Experience, 542
15.3 Software Development Status Indicators, 543
15.3.1 Requirements Stability, 544

15.3.2 Software Development Manpower, 548
15.3.3 Software Development Progress, 548
15.3.4 Computer Resource Utilization, 552
15.3.5 Schedule Risk Analysis, 553
15.3.6 Trouble Report Resolution, 554
15.3.7 Software Product Delivery, 556
15.3.8 Software Supportability, 557
15.4 Supportability Assessment, 559
15.5 Concluding Remarks, 563
References, 564

16 Software Development Effort Estimating 565

16.1 Introduction, 565
16.2 Why So Challenging?, 565
16.3 Estimation Factors, 566
16.3.1 Personnel Characteristics, 566
16.3.2 Product Characteristics, 567
16.3.3 Development Environment and Process Maturity, 568
16.4 Methods of Estimation, 569
16.4.1 Analogy Estimation, 569
16.4.2 Parametric Estimation, 570
16.4.3 Detailed Estimation, 573
16.4.3.1 Software Development Phases, 576
16.4.3.1.1 Software Requirements Analysis, 576
16.4.3.1.2 Product Design, 576
16.4.3.1.3 Detailed Design, 577
16.4.3.1.4 Software Code and Unit Test, 577
16.4.3.1.5 Software Integration and Functional Test, 577
16.4.3.2 Factors Affecting Detailed Software Cost Estimates, 577
16.4.3.3 Establishing Skill Categories, Skill Levels, and Labor Rates, 579
16.4.3.4 Estimating, Pricing, and Publishing the Estimate, 580
16.5 Increasing the Accuracy of Software Cost Estimates, 583
16.5.1 Standardize the Development Process, 583
16.5.2 Establish Metrics Database, 584
16.5.3 Standardize the Estimation Process, 585
16.6 Case Study: Software Effort Estimates for the BEST EFFORT System, 587
16.6.1 End Product Requirements, 587
16.6.2 BEST EFFORT Parametric Effort Estimation, 589

16.6.3 BEST EFFORT Detailed Effort Estimation, 592
16.6.4 Results Summary, 595
16.7 Concluding Remarks, 596
References, 597

17 Software Life Cycle Cost Estimation 599

17.1 Introduction, 599
17.1.1 Support Activity, 599
17.1.2 Independent Verification and Validation, 600
17.1.3 Maintenance, 601
17.1.4 Description of Historical Projects, 601
17.2 Support Activities Estimation, 601
17.2.1 Determining Support Items, 602
17.2.2 Software Project Management, 603
17.2.3 Project Manager Technical Assistance, 604
17.2.4 Project Plan and Standards Preparation, 605
17.2.5 Schedule Preparation and Updating, 606
17.2.6 Administration Support, 607
17.2.7 Software Development Library, 608
17.2.8 Documentation Generation, Library, and Documentation Processing, 609
17.2.9 Configuration Management, 611
17.2.10 Software Quality Assurance, 612
17.2.11 Software Development Environment, 614
17.2.12 Facilities, 616
17.2.13 Software Development Supplies, 617
17.2.14 Formal Training and Help Desk, 618
17.2.15 User Operations Training and Installation Support, 619
17.2.16 Budget Reserves, 620
17.3 Independent Verification and Validation, 621
17.3.1 IV&V Activities, 621
17.3.1.1 Determine the Program Risks and Constraints, 622
17.3.1.2 Tailor the IV&V Program, 623
17.3.1.3 Execute the IV&V Program, 623
17.3.1.4 Measure the IV&V Results/Impacts, 624
17.3.1.5 Focus Future IV&V Efforts, 624
17.3.2 How Much for IV&V?, 624
17.4 Software Maintenance Estimation, 626
17.4.1 Sustaining Engineering and Scope Changes, 626
17.4.2 Variations in Software Maintenance Activities, 627
17.4.3 Major Maintenance Cost Drivers, 628
17.4.4 Methodology for Estimating Software Maintenance, 629
References, 630

18 Artificial Intelligence in Cost Estimating **633**

18.1 Introduction, 633
18.2 Knowledge-Based Cost Estimation Paradigm, 636
18.3 Formal Models, 639
18.4 A Frame-Based System, 640
18.4.1 Building Work Element Structures, 641
18.4.2 Skill Category and Skill Mix Determination, 641
18.4.3 Scheduling and Resource Adjustments, 642
18.4.4 Cost Growth and Contingency Estimation, 642
18.4.5 Parametric Estimating, 643
18.4.6 Cost Factor Development and Use, 643
18.4.7 Make-or-Buy Criteria and Determination, 644
18.4.8 Determining Mix and Magnitude of Independent Research and Development, 644
18.4.9 Profit and Profitability Determination and Planning, 645
18.4.10 Purchasing Decision Making (Source Evaluation and Selection), 645
18.5 Concluding Remarks, 646
References, 646

19 Cost Estimating as a Profession **647**

19.1 Introduction, 647
19.2 What Is Cost Estimating?, 648
19.3 The Cost Estimating Discipline, 649
19.4 The Changing Role of the Cost Estimator, 651
19.5 Training and Education, 651
19.5.1 American Association of Cost Engineers, 652
19.5.2 American Society of Professional Estimators, 652
19.5.3 Institute for Management Accountants, 653
19.5.4 International Society of Parametric Analysts, 654
19.5.5 National Contract Management Association, 654
19.5.6 Society of American Value Engineers, 655
19.5.7 Society of Cost Estimating and Analysis, 655
19.6 The Changing Cost Estimating Environment, 655
References, 656

Dictionary of Estimating Terms **657**

Index **711**