

A faint, light-colored circuit diagram is overlaid on the entire cover. It features several triangular op-amp symbols, resistors, and various interconnecting lines and arrows, suggesting a complex electronic or control system.

# MANAGING BUSINESS PROCESS FLOWS

## Principles of Operations Management

Second Edition

**Ravi Anupindi**  
**Sunil Chopra**  
**Sudhakar D. Deshmukh**  
**Jan A. Van Mieghem**  
**Eitan Zemel**

iGrafx  
**PROCESS** 2003

*Visualize Your Way to a Better Business™*



# Contents

Preface xi

About iGrafx® Process™ xiv

## **PART I: PROCESS MANAGEMENT AND STRATEGY 1**

### **CHAPTER 1 Products, Processes, and Performance 2**

Introduction 2

1.1 The Process View of Organizations 3

1.2 Performance Measures 6

1.2.1 *The Importance of Measurement: Management by Fact* 6

1.2.2 *Types of Measures: Financial, External, and Internal* 6

1.3 Products and Product Attributes 9

1.4 Processes and Process Competencies 12

1.4.1 *Process Competencies* 12

1.4.2 *Process Architectures: Job Shop versus Flow Shop* 13

1.5 Process Design, Planning, Control, and Improvement 15

1.6 The Plan of the Book 16

Summary 16

Key Terms 17

Discussion Questions 17

Selected Bibliography 17

### **CHAPTER 2 Operations Strategy and Management 18**

Introduction 18

2.1 Strategic Positioning and Operational Effectiveness 19

2.2 The Strategy Hierarchy 20

2.3 Strategic Fit 22

2.4 Focused Operations 24

2.5 Matching Products and Processes 26

2.6 The Operations Frontier and Trade-Offs 28

2.7 The Evolution of Strategy and Operations Management 32

Summary 35

Key Terms 35

Discussion Questions 35

Selected Bibliography 36

**PART II: PROCESS FLOW MEASUREMENT 39**

**CHAPTER 3 Process Flow Measures 40**

Introduction	40
3.1 The Essence of Process Flow	41
3.2 Three Key Process Measures	42
3.3 Flow Time, Flow Rate, and Inventory Dynamics	44
3.4 Throughput in a Stable Process	49
3.5 Little's Law: Relating Average Flow Time, Throughput, and Average Inventory	50
3.5.1 <i>Material Flow</i>	51
3.5.2 <i>Customer Flow</i>	51
3.5.3 <i>Job Flow</i>	52
3.5.4 <i>Cash Flow</i>	52
3.5.5 <i>Cash Flow (Accounts Receivable)</i>	52
3.5.6 <i>Service Flow (Financing Applications at Auto-Moto)</i>	53
3.6 Analyzing Financial Flows through Financial Statements	57
3.6.1 <i>Assessing Financial Flow Performance</i>	58
3.6.2 <i>Cash-to-Cash Cycle Performance</i>	61
3.6.3 <i>Targeting Improvement with Detailed Financial Flow Analysis</i>	62
3.7 Inventory Turns (Turnover Ratio)	64
3.8 Using Operational Measures to Improve Financial Measures: What Do We Mean by "an Improvement"?	65
Summary	67
Key Equations and Symbols	68
Key Terms	68
Discussion Questions	68
Exercises	68
Modeling Exercise	71
Selected Bibliography	73

**CHAPTER 4 Flow-Time Analysis 74**

Introduction	74
4.1 The Process Flowchart	76
4.2 Flow-Time Measurement	78
4.3 Theoretical Flow Time	80
4.3.1 <i>Activity Time and Critical Paths</i>	80
4.3.2 <i>Computing Flow Time</i>	82
4.3.3 <i>Value-Adding and Non-Value-Adding Activities</i>	84
4.3.4 <i>Extensions: Rework, Visits, and Work Content</i>	84
4.3.5 <i>Flow-Time Efficiency</i>	86
4.4 Levers for Managing Theoretical Flow Time	88
4.4.1 <i>Eliminate: Reducing the Work Content of Critical Activities</i>	89
4.4.2 <i>Work in Parallel: Moving Work Off the Critical Path</i>	90
4.4.3 <i>Select: Modifying the Product Mix</i>	91

Summary	92
Key Equations and Symbols	93
Key Terms	93
Discussion Questions	93
Exercises	94
Modeling Exercise	96
Selected Bibliography	98
Appendix: The Critical Path Method	99

## **CHAPTER 5 Flow Rate and Capacity Analysis 101**

Introduction	101
5.1 Resources and Resource Pools	102
5.2 Flow Rate Measurement	104
5.2.1 Theoretical Capacity	104
5.2.2 Computing Theoretical Capacity	105
5.2.3 Extensions: Other Factors Affecting Theoretical Capacity	106
5.2.4 Throughput and Capacity Utilization	107
5.3 Effect of Product Mix on Theoretical Capacity and Profitability of a Process	110
5.3.1 Unit Load for Product Mix	110
5.3.2 Theoretical Capacity for Product Mix	110
5.3.3 Optimizing Profitability	114
5.4 Other Factors Affecting Process Capacity	115
5.4.1 Net Availability	116
5.4.2 Setups	116
5.4.3 Effective Capacity of a Process	118
5.5 Levers for Managing Throughput	119
5.5.1 Comparisons	119
5.5.2 Improving Theoretical Capacity	120
5.5.3 Other Improvements	123
5.5.4 Internal and External Bottlenecks	123
5.5.5 The Improvement Spiral	124
Summary	124
Key Equations and Symbols	125
Key Terms	125
Discussion Problems	126
Exercises	126
Modeling Exercise	128
Selected Bibliography	130
Appendix: Optimizing Product Mix with Linear Programming	131

## **CHAPTER 6 Inventory Analysis 132**

Introduction	132
6.1 Inventory Classification	134
6.2 Inventory Benefits	137

6.2.1	<i>Economies of Scale</i>	137	
6.2.2	<i>Production and Capacity Smoothing</i>	138	
6.2.3	<i>Stockout Protection</i>	138	
6.2.4	<i>Price Speculation</i>	139	
6.3	Inventory Costs	139	
6.4	Inventory Dynamics of Batch Purchasing	141	
6.5	Economies of Scale and Optimal Cycle Inventory	144	
6.6	Effect of Lead Times on Ordering Decisions	150	
6.7	Price Discounts: Forward Buying	152	
6.8	Levers for Managing Inventories	155	
	Summary	156	
	Key Equations and Symbols	157	
	Key Terms	157	
	Discussion Questions	157	
	Exercises	157	
	Modeling Exercise	160	
	Selected Bibliography	162	
	Appendix: Derivation of EOQ Formula and Forward-Buying Quantity	163	
<b>PART III: PROCESS FLOW VARIABILITY 165</b>			
<b>CHAPTER 7 Managing Flow Variability: Safety Inventory 166</b>			
	Introduction	166	
7.1	Demand Forecasts and Forecast Errors	168	
7.2	Safety Inventory and Service Level	169	
7.2.1	<i>Service Level Measures</i>	170	
7.2.2	<i>Continuous Review, Reorder Point System</i>	171	
7.2.3	<i>Service Level Given Safety Inventory</i>	173	
7.2.4	<i>Safety Inventory Given Service Level</i>	175	
7.3	Optimal Service Level: The Newsvendor Problem	177	
7.4	Lead Time Demand Variability	183	
7.4.1	<i>Fixed Replenishment Lead Time</i>	184	
7.4.2	<i>Variability in Replenishment Lead Time</i>	185	
7.5	Pooling Efficiency through Aggregation	187	
7.5.1	<i>Physical Centralization</i>	187	
7.5.2	<i>Principle of Aggregation and Pooling Inventory</i>	191	
7.6	Shortening the Forecast Horizon through Postponement	192	
7.7	Levers for Reducing Safety Inventory	193	
	Summary	194	
	Key Equations and Symbols	194	
	Key Terms	195	
	Discussion Questions	195	
	Exercises	195	
	Modeling Exercise	197	

Selected Bibliography	200
Appendix: Calculating Service Level for a Given Safety Inventory	201

## **CHAPTER 8 Managing Flow Variability: Safety Capacity 202**

Introduction	202
8.1 Service Process and Its Performance	204
8.1.1 <i>Service Processes</i>	204
8.1.2 <i>Service Process Attributes</i>	206
8.1.3 <i>Service Process Performance</i>	207
8.1.4 <i>Relationships between Performance Measures</i>	210
8.2 Effect of Variability on Process Performance	211
8.3 Drivers of Process Performance	214
8.3.1 <i>The Queue Length Formula</i>	215
8.3.2 <i>The Exponential Model</i>	217
8.4 Performance Improvement Levers	219
8.4.1 <i>Variability Reduction Levers</i>	219
8.4.2 <i>Capacity Utilization Levers</i>	220
8.4.3 <i>Synchronization of Capacity with Demand</i>	221
8.5 Effect of Pooling Capacity	222
8.6 Effect of Blocking and Abandonment	224
8.7 Capacity Investment Decisions	226
8.7.1 <i>The Economics of Buffer Capacity</i>	227
8.7.2 <i>The Economics of Processing Capacity</i>	228
8.8 Variability in Process Performance	229
8.9 Managing Customer Perceptions and Expectations	232
Summary	233
Key Equations and Symbols	233
Key Terms	234
Discussion Questions	234
Exercises	235
Modeling Exercise	238
Selected Bibliography	240
Appendix: The Exponential Model with Finite Buffer Capacity	241

## **CHAPTER 9 Managing Flow Variability: Process Control and Capability 242**

Introduction	242
9.1 Performance Variability	244
9.2 Analysis of Variability	246
9.2.1 <i>Check Sheets</i>	246
9.2.2 <i>Pareto Charts</i>	247
9.2.3 <i>Histograms</i>	248
9.2.4 <i>Run Charts</i>	249
9.2.5 <i>Multi-Vari Charts</i>	250
9.3 Process Control	252
9.3.1 <i>The Feedback Control Principle</i>	252
9.3.2 <i>Types and Causes of Variability</i>	253

9.3.3	<i>Control Limit Policy</i>	255
9.3.4	<i>Control Charts</i>	256
9.3.5	<i>Cause–Effect Diagrams</i>	263
9.3.6	<i>Scatter Plots</i>	264
9.4	<b>Process Capability</b>	265
9.4.1	<i>Fraction of Output within Specifications</i>	266
9.4.2	<i>Process Capability Ratios (<math>C_{pk}</math> and <math>C_p</math>)</i>	266
9.4.3	<i>Six-Sigma Capability</i>	268
9.4.4	<i>Capability and Control</i>	270
9.5	<b>Process Capability Improvement</b>	270
9.5.1	<i>Mean Shift</i>	270
9.5.2	<i>Variability Reduction</i>	270
9.5.3	<i>Effect of Process Improvement on Process Control</i>	272
9.6	<b>Product and Process Design</b>	273
9.6.1	<i>Design for Processing</i>	273
9.6.2	<i>Robust Design</i>	274
	<b>Summary</b>	274
	<b>Key Equations and Symbols</b>	275
	<b>Key Terms</b>	276
	<b>Discussion Questions</b>	276
	<b>Exercises</b>	276
	<b>Selected Bibliography</b>	278

## **PART IV: PROCESS INTEGRATION 281**

### **CHAPTER 10 Lean Operations: Process Synchronization and Improvement 282**

	<b>Introduction</b>	282
10.1	<b>Processing Networks</b>	283
10.2	<b>The Process Ideal: Synchronization and Efficiency</b>	284
10.3	<b>Waste and Its Sources</b>	285
10.4	<b>Improving Flows in a Plant: Basic Principles of Lean Operations</b>	289
10.4.1	<i>Improving Process Architecture: Cellular Layouts</i>	290
10.4.2	<i>Improving Information and Material Flow: Demand Pull</i>	291
10.4.3	<i>Improving Process Flexibility: Batch-Size Reduction</i>	294
10.4.4	<i>Quality at Source: Defect Prevention and Early Detection</i>	295
10.4.5	<i>Reducing Processing Variability: Standardization of Work, Maintenance, and Safety Capacity</i>	296
10.4.6	<i>Visibility of Performance</i>	297
10.4.7	<i>Managing Human Resources: Employee Involvement</i>	297
10.4.8	<i>Supplier Management: Partnerships</i>	298
10.5	<b>Improving Flows in a Supply Chain</b>	299
10.5.1	<i>Lack of Synchronization: The Bullwhip Effect</i>	300
10.5.2	<i>Causes of the Bullwhip Effect</i>	301
10.5.3	<i>Leverage to Counteract the Bullwhip Effect</i>	303

10.6 The Improvement Process	306
10.6.1 Process Stabilization: Standardizing and Controlling the Process	306
10.6.2 Continuous Improvement: Management by Sight and Stress	306
10.6.3 Business Process Reengineering: Process Innovation	307
10.6.4 Benchmarking: Heeding the Voices of the Best	308
10.6.5 Managing Change	309
Summary	309
Key Terms	310
Discussion Questions	311
Selected Bibliography	311
<b>Appendix I MBPF Checklist</b>	<b>313</b>
Process Flow Measures	313
Levers for Managing Theoretical Flow Time	313
Levers for Managing Throughput	313
Levers for Reducing Waiting Time	314
Levers for Controlling Process Variability	314
Levers for Managing Flows in Processing Networks	314
<b>Appendix II Background Material in Probability and Statistics</b>	<b>316</b>
Random Variables, Mean, Variance, and Covariance	316
Random Variable	316
Mean	316
Variance	316
Covariance and Coefficient of Correlation	317
Some Probability Distributions	317
The Poisson Probability Distribution	317
The Exponential Probability Distribution	318
The Normal Probability Distribution	318
<b>Appendix III iGrafx® FlowCharter™ Quick Reference Guide</b>	<b>320</b>
<b>Appendix IV iGrafx® Process Simulation Quick Reference Guide</b>	<b>323</b>
Five-Step Process to Simulation Analysis	323
Step 3: Build a Process Model	323
Create a Process Diagram (Map or Flowchart)	323
Describe the Behavior of Each Shape/Activity	324
Describe the Process Environment in the Scenario	326
Execute Simulation and Analyze Results in the Report	327
<b>Glossary</b>	<b>329</b>
<b>Index</b>	<b>336</b>