

# Operations Management Theory and Practice

## SECONDEDI





## B. Mahadevan

## PEARSON

BOUT THE AUTHOR

adevan is a professor of operations management at the Indian Institute of Manageangalore, where he has been teaching since 1992. He is also Dean (administration) nstitute. Professor Mahadevan has more than 18 years of wide-ranging experience ning, research, consulting, and academic administration at IIM Bangalore and other l institutions such as IIT Delhi and XLRI, Jamshedpur. He was earlier Chief Editor IMB Management Review, the premier Indian journal for management educators, ants and practitioners.

ofessor Mahadevan received his M.Tech. and Ph.D. from the Industrial Engineering magement Division of IIT Madras. He holds a bachelor's degree in engineering (pron engineering) from the College of Engineering, Guindy, Madras.

ofessor Mahadevan was earlier the EADS-SMI Chair Professor for Sourcing and Management at IIM Bangalore. He was a visiting scholar at the Tuck School of Busi-Dartmouth, New Hampshire, in 1999-2000. He was also a retainer consultant to e Consulting LLP, USA, in 2001–2002. Professor Mahadevan is on the board of s of some NGOs providing valuable community and social service. ofessor Mahadevan is a member of the editorial board of the Production and Oper-Management Journal and the International Journal of Business Excellence. He served editorial board of Six Sigma and Competitive Advantage. Besides being on the advioards of several business schools and management journals in India, Professor levan has published several of his research findings in leading international journals s the California Management Review, the European Journal of Operational Research, oduction and Operations Management Journal, the International Journal of Production ch, the International Journal of Technology Management and the Asian Journal of tions Management. He is a lifetime member of the Society of Operations Manageand a member of the Production and Operations Management Society. rofessor Mahadevan has been recognized for his excellence in teaching both at IIM lore and outside. He has been consistently rated among the top five professors in IIM lore's teaching and executive education programmes. He was also conferred the Best Teacher Award by the Association of Indian Management Schools in 2005. part from Operations Management: Theory and Practice, Professor Mahadevan is also uthor of The New Manufacturing Architecture, and has developed software that sses issues in restructuring manufacturing systems for competitive advantage. His ch interests include supply chain management issues in e-markets and e-auction. rofessor Mahadevan's other interests include researching the possibility of using nt Indian wisdom to address contemporary concerns. He is active in inculcating these among his students and the youth through various forums and public lectures. Pro-Mahadevan was also a member of the Central Sanskrit Board, an advisory body to linistry of Human Resource Development, Department of Education, on all Sanskrit y issues in the country.





BRIEF CONTENTS

About the Author iv Preface XVII

### UNDERSTANDING OPERATIONS 2 PART

- **Operations Management: Trends and Issues** 2
- 2 Operations Strategy 26

## PART II DESIGNING OPERATIONS 56

- 3 Process and Capacity Analysis 56
- 4 Design of Manufacturing Processes 102
- 5 Design of Service Systems 150
- 6 The Product Development Process 180
- Project Management 208
- 8 Total Quality Management 242

## PART III OPERATIONS AND THE VALUE CHAIN 276

- 9 Supply Chain Management 276
- Facilities Location 304 10
- Sourcing and Supply Management 332
- 12 Inventory Planning and Control 362

## PART IV PLANNING AND CONTROL OF OPERATIONS 394

- 13 Demand Forecasting 394
- 14 Aggregate Production Planning 428
- 15 Resources Planning 474
- 16 Scheduling of Operations 508
- 17 Lean Management 536
- 18 Six-Sigma Quality Control 576
- 19 Maintenance Management 608

Index 643

OP 10 A state of the state o



	CONTENTS
	About the Author iv 2 Preface xvii
	PART I UNDERSTANDING OPERATIONS 2
	1 Operations Management: Trends and Issues 2
	IDEAS AT WORK 1.1: OPERATIONS MANAGEMENT AT MTR FOODS,
	BANGALORE 3 1.1 Introduction to Operations Management 4
	1.2 Manufacturing Trends in India       5         1.3 Services as a Part of Operations
	Management       7         Intangibility       9         Heterogeneity       9         Simultaneous production and consumption       9
	Perishability 9 IDEAS AT WORK 1.2: OPERATIONS
	MANAGEMENT IN SERVICE SYSTEMS 10 1.4 Operations as a Key Functional
	Area 11 1.5 Operations Management: A Systems
	Perspective 14 1.6 Operations Management
Demund Foreuring foreuring units	Functions     16       Design versus operational control
	issues 16 Long-term versus short-term issues 17
	1.7 Challenges in Operations Management 18
	Competitive pressure due to economic reforms 18
	Growing customer expectations 19 Technological developments 20
	Environmental issues 20
	1.8 Current Priorities for Operations Management 21
	IDEAS AT WORK 1.3: CHALLENGES FACED BY THE WHITE GOODS INDUSTRY 22
	Summary 23 Review Questions 23 Net-Wise Exercises 23 Notes 24
	Suggested Readings 25

<b>Operations Strategy</b> 26
IDEAS AT WORK 2.1: AIR DECCAN: INDIA'S FIRST LOW-COST AIRLINE 27
2.1 The Relevance of Operations Strategy 29
2.2 The Strategy-formulation Process 30
Step 1: Understand the competitive market dynamics 31
Step 2: Identify order-qualifying and order- winning attributes 31
IDEAS AT WORK 2.2: ORDER-WINNING AND ORDER-QUALIFYING ATTRIBUTES 32
Step 3: Identify strategic options for
sustaining competitive advantage 33
Step 4: Devise the overall corporate strategy 33
Step 5: Arrive at the operations
strategy 33
2.3 Measures for Operational Excellence 34
2.4 Options for Strategic Decisions in
Operations 36
Product portfolio 36 Process design 37
Process design 37 Supply chain 38
Technology 39
Capacity 40
2.5 Break-even Analysis 40
2.6 The Cost Versus Flexibility Trade-off in Operations Strategy 42
2.7 World-class Manufacturing
Practices 42
Toyota's journey as a world-class manufacturer 43
Principles of world-class
manufacturing 44
Challenges in WCM 46
2.8 Emerging Trends and Implications for Operations 46
Globalization of the Indian economy 46
The outsourcing wave 48
Collaborative commerce through the Internet 49
Summary 51
Review Questions 52
Problems 52
Net-Wise Exercises 53
Case: Ginger Hotels 53
Notes 54
Suggested Readings 54

1.11085

CONTENTS	
SNING OPERATIONS 56	Supplement 3A: SimulationModelling94Summary99
<ul> <li>Process and Capacity Analysis 56</li> <li>IDEAS AT WORK 3.1: CAPACITY EXPANSION PLANS 57</li> <li>3.1 Process as a Unit of Measurement in Operations 57</li> <li>3.2 Process Flow-charting 58</li> <li>3.3 Planning Premises and Process Implications 59</li> <li>Make to stock (MTS) 59</li> <li>Make to order (MTO) 60</li> <li>Assemble to order (ATO) 60</li> <li>3.4 Analysing Processes 61</li> <li>3.5 Process Redesign Using Business</li> </ul>	<ul> <li>Review Questions 99</li> <li>Problems 100</li> <li>Suggested Readings 100</li> <li>4 Design of Manufacturing</li> <li>Processes 102</li> <li>IDEAS AT WORK 4.1: PROCESS DESIGN AT MILLITEC MACHINERY 103</li> <li>4.1 Determinants of Process Characteristics in Operations 103</li> <li>Volume 104</li> <li>Variety 104</li> <li>Flow 104</li> <li>4.2 Types of Processes and Operations Systems 105</li> </ul>
Process Re-engineering (BPR)65Value-added (VA) activities70Non-value-added (NVA) activities70Necessary but non-value-added (NNVA)activities703.6 Defining Capacity70	Continuous flow systems 105 Intermittent flow 108 IDEAS AT WORK 4.2: THE POLYESTER FILAMENT YARN PLANT AT RELIANCE INDUSTRIES LIMITED 109 Jumbled flow systems 111 IDEAS AT WORK 4.3: PROCESS REDESIGN FOR
<ul> <li>3.7 Measures of Capacity 72</li> <li>3.8 The Time Horizon in Capacity Planning 74</li> <li>IDEAS AT WORK 3.2: NINE SOURCES OF WASTE 75</li> </ul>	IMPROVING FLOW1124.3 The Process-Product Matrix1144.4 Layout Planning1154.5 Implications of Layout Planning116
<b>3.9 The Capacity Planning Framework</b> 76Estimating the total requirement76Estimating labour and machine requirements77Computing capacity availability78Process mapping and capacity analysis30	<ul> <li>4.6 Types of Layouts 116         <ul> <li>Process layout 116</li> <li>Product layout 117</li> <li>Group technology layout 119</li> <li>Fixed position layout 120</li> </ul> </li> <li>IDEAS AT WORK 4.4: LAYOUT REDESIGN RESULTS IN NUMEROUS BENEFITS 121</li> </ul>
3.10 Alternatives for Capacity Augmentation 82 Waste elimination 83 Multi-skilling of the workforce 83 Subcontracting/outsourcing 84	<ul> <li>4.7 Performance Measures for Layout Design 121</li> <li>IDEAS AT WORK 4.5: WORKPLACE ORGANIZATION AT THERMAX 122</li> <li>4.8 Design of Process Layouts 123</li> </ul>
<b>3.11 Decision Tree for Capacity</b> Planning 85Summary87Review Questions88Problems89Mini Project90Case: Vasudhri Tooling Limited90Notes93Suggested Readings93	The qualitative approach to layout design 124 The quantitative approach to layout design 125 Software packages for layout design 126 <b>4.9 Design of Product Layouts</b> 127 <b>4.10 Alternative Approaches to Layout</b> Design 128 Design of group technology layouts 131

	IDEAS AT WORK 4.6: LINE BALANCING AT MICO 131	
	Rank order clustering (ROC) 132	
	One worker–multiple machine layouts 134	6
	4.11 Technology Issues in Process Design 135	
	Flexible manufacturing systems 135 Automated material-handling systems 137	
	4.12 Complexity in Operations Management 139	
	Summary 140	
	Review Questions 141	
	Problems 142	
	Net-Wise Exercises 143	
	Mini Projects 143	
	Case: Aerospace India Limited 144	
	Notes 147	
	Suggested Readings 148	
	ouggeotea neadingo	
	5 Design of Service Systems 150	
	IDEAS AT WORK 5.1: DESIGN OF LUXURY SERVICES 151	
	5.1 Design of Service Systems: Characteristic Aspects 151	
	5.2 Customer Contact in Service Systems 152	
	5.3 Complexity and Divergence in Service Systems 154	
	5.4 Service Positioning 156	
	IDEAS AT WORK 5.2: BLUE GINGER: THE VIETNAMESE RESTAURANT AT TAJ WEST END, BANGALORE 158	
	5.5 Service Blueprinting 159	
	5.6 Capacity Planning in Services Using Queueing Analysis 160	
	The basic structure of a queueing system 161	
	5.7 Other Aspects of Addressing Capacity Issues in Services 169	
	5.8 Service Quality 171	
	IDEAS AT WORK 5.3: IMPROVING SERVICE QUALITY THROUGH BETTER COMMUNICATION: THE CASE OF ARAVIND EYE HOSPITALS 173	
	Summary 173	
N.	Review Questions 174	
	Problems 175	7
	Net-Wise Exercises 176	
	Mini Projects 177	
	Case: Waiting Times at Post Offices 177	

.

	CONTENTS	1	IX
Notes 179			
Suggested Readings	179		
The Product Dev Process 180	elopmen		
IDEAS AT WORK 6.1 100,000 PEOPLES' C		: THE INR	
6.1 India's Role in R Development	esearch and	d	
6.2 Product Develop Competitive Ad	oment: The		
6.3 The Product Dev Process 184	velopment		
DEAS AT WORK 6.2 NEW-PRODUCT DEV INDIA 184	ELOPMENT P	ROCESS IN	
Stages in the product process 186	striit to		
The stage-gate appr representation of the process 187			
6.4 Organization for Development			
6.5 Tools for Efficient Development	190		
Understanding custo	omer needs	190	
IDEAS AT WORK 6.3 KNOW WHAT THE C Quality function dep Value engineering	USTOMER W.		
Design for manufact Tools for mass custo	-	195 196	
IDEAS AT WORK 6.4 EXERCISE: OPPORTU CUTTING 198			
6.6 Performance Mea Development Pro			
6.7 Management Acc Product Develop			
6.8 Software Product	t Developm	ent 202	2
Summary 203			
Review Questions	203		
Net-Wise Exercises	204		
Case: The New-produ	ict Develop	ment	
Process at Energex	204		
<b>Notes</b> 205			
Suggested Readings	206		
Project Managem	nent 2	08	
IDEAS AT WORK 7.1: SATELLITE TRACKING STATION 209			

## CONTENTS

6 second f Dunio st	Commi
1 Characteristics of Project Organizations 210	IDEAS ORGA
2 The Phases of Project Management 212	Employ Addres
3 A Framework for Project	8.5 Qua
Management	Histog
Work breakdown structure 214 215	Pareto
Organization breakdown structure	Cause
Cost hreakdown suuciuio	diagra
.4 Tools and Techniques for Project	CEDA
Management 217 Developing a network representation of a	Poka v
project 201	ENH
IDEAS AT WORK 7.2: THE CHAINSA-GURGAON PIPELINE PROJECT 218	A PI Quali
Analysis of project networks 210	Quali
7 5 Addressing Time and Resource	8.6 Qu
Constraints 224	Qual
Resource levelling 224	Qual
Time-cost trade-offs in projects 226 7.6 Handling Uncertainty in Project	IDE TO
Completion 200	8.7 D
Simulation of project networks	S
IDEAS AT WORK 7.3: CRITICAL CHAIN: APPLICATION OF THE THEORY OF CONSTRAINTS	Summ
TO PROJECT MANAGEMENT 234	Revie
Summary 234	Proble
Review Questions 235	Net-V
Problems 235	Mini
Proplems 238	Case
Mini Projects 238 Case: Distribution Transformer Company	Limit
	Note
Limited (Dict)	Sugg
Notes 240	Jugg
Suggested Readings 241	
Total Quality Management 242	Contraction of the
IDEAS AT WORK 8.1: POKA YOKE FOR DEFECT	ODEDAT
PREVENTION	OPERAT
8.1 The Quality Revolution 244	CHAIN
8.2 Quality Gurus 245 William Edwards Deming 245	9 Sup
Joseph M. Juran 246	
Philip B. Crosby 246	
Karou Ishikawa 247	9.1
Shigeo Shingo 247	T
Genichi Taguchi 248 248	r i
8 3 Definitions of Quarty	1
Conformance to specifications	
Fulfilling customer needo	9.2
Fitness for use 249 8.4 Total Quality Management 251	

## Commitment of top management 251 AS AT WORK 8.2: QUALITY POLICY AT SOME ANIZATIONS 253 ANIZATIONSoyee involvement253essing training requirements254Lality Management Tools255 grams 266 diagrams and effect (fishbone) 267 ams 268 C 259 yoke EAS AT WORK 8.3: MATRIX DIAGRAM FOR HANCING THE COMPETITIVENESS OF PRODUCT 261 lity function deployment 262 lity costing 262 263 Quality Certifications and Awards ality awards 284 Vality certifications 265 DEAS AT WORK 8.4: SRF'S TOM JOURNEY OWARDS THE DEMING PRIZE 266 **Design of Quality Assurance** Systems 268 2.69 mary w Questions 270 lems 271 Wise Exercises · Projects 272 S.Z. (Complements), S.Z. se: Bangalore Garment Exports 272 ted

1.1

λ.

otes 274 gested Readings 274

## TIONS AND THE VALUE

276

## upply Chain Management 276

IDEAS AT WORK 9.1: MOTHER DAIRY: A CASE FOR SUPPLY CHAIN MANAGEMENT? 277

**1 What Is a Supply Chain?** 277 The need for efficient supply chain management 279

Information and material flows in the supply chain 280

chain2802.2 Supply Chain Components2817.2 Supply Chain Supply chain281

÷.

	The in-house supply chain 282 The outbound supply chain 283	
	IDEAS AT WORK 9.2: SUPPLY CHAIN MANAGEMENT SOLUTION FOR INDIAN OIL CORPORATION LIMITED 286	
	<b>9.3 Supply Chain Management: A Process Orientation</b> 287	
	9.4 Supply Chain Structure 288	
	9.5 The Bullwhip Effect 290	
	<b>9.6 Measures of Supply Chain</b> <b>Performance</b> 291	
	Post-process indices 291 Process indices 293	
	IDEAS AT WORK 9.3: THE SUPPLY CHAIN OPERATIONS REFERENCE (SCOR) MODEL 294	11
	<b>9.7 Design of Supply Chains</b> 296 Designing efficient supply chains 297 Designing responsive supply chains 297	
	9.8 Third-party Logistics in Web-based Firms 298	
	<b>9.9 The Role of Information Technology in Supply Chain Management</b> 298	
	IDEAS AT WORK 9.4: SUPPLY CHAIN MANAGEMENT SOLUTION FROM i2 299	
	Summary 300	
	Review Questions 301	
	Net-Wise Exercises 301	
	Mini Projects 302	
	Notes 302	
	Suggested Readings 302	
10	Facilities Location 304	
	IDEAS AT WORK 10.1: LI & FUNG: GLOBAL OPERATIONS 305	
	<b>10.1 Globalization of Operations</b> 307	
	Regulatory issues 307	
	Factor advantages 308 Expanding markets in developing	
	countries 308	
	<b>10.2 Factors Affecting Location</b> <b>Decisions</b> 310	
	Market-related issues 310	
	Cost-related issues 311	
	Regulatory and policy issues 311	
	Other issues 312	
	10.3 Location Planning Methods       312         Location factor rating       312	
	IDEAS AT WORK 10.2: SPECIAL ECONOMIC ZONES: A POLICY ANGLE TO LOCATION PLANNING 313	
	The centre-of-gravity method315The load-distance method316The transportation model318	

CONTENTS

<b>10.4 Other Issues in Location Planning</b> 321
Summary 322
Review Questions 322
Problems 323
Net-Wise Exercises 324
Mini Project 325
Case: Indcoserve—An Industrial Cooperative
of Tea Factories in the
Nilgiris 325
Notes 331
Suggested Readings 331
Sourcing and Supply Management 332
IDEAS AT WORK 11.1: THE ROLE OF THE
WEB IN SOURCING AND SUPPLY MANAGEMENT 333
11.1 The Importance of Sourcing and
Supply Management 334 Quality management issues 334
Changing cost structure 334
Quick-response requirements 334
Creating a lean organization 334
The importance of new-product development 335
11.2 Strategic Sourcing 336
11.3 The Procurement Process 338
11.4 Approaches to Supply Management 340
IDEAS AT WORK 11.2: HIDDEN COSTS OF TRADITIONAL SUPPLY MANAGEMENT PRACTICES 342
IDEAS AT WORK 11.3: TRUSTING SUPPLIERS? 343
<b>11.5 Developing Reliable Vendors</b> 344
Supplier development 344
Supplier certification programmes 345
IDEAS AT WORK 11.4: THE CLUSTER APPROACH TO SUPPLIER DEVELOPMENT 345
Vendor rating 346
11.6 Measures for Sourcing and Supply Chain Management 348
Basic measures for supplier performance 348
Measures for long-term partnerships 349
IDEAS AT WORK 11.5: TOTAL COST OF OWNERSHIP IN AN AUTO-COMPONENT MANUFACTURING UNIT 349
11.7 The Make-or-buy Decision 350
<b>11.8 Business Process Outsourcing</b> 350 Cost 350
Core versus non-core activities 351
Management of capacity expansion 351

### CONTENTS

361 Strategic restructuring 9 E-procurement 351 Collaborative market mechanisms 352 Quasi-market mechanisms 353 353 Neutral market mechanisms 355 mmary 355 view Questions 355 et-Wise Exercise ase: Bharat Controls Limited 356 ysore otes 359 uggested Readings 360 ventory Planning and 362 ontrol TIDEAS AT WORK 12.1: INVENTORY MANAGEMENT IN A CONSUMER PRODUCTS COMPANY 2.1 Inventory Planning for Independent **Demand Items** 364 Continuous demand 364 Uncertainty of demand 364 2.2 Types of Inventory 364 Seasonal inventory 364 Decoupling inventory 365 365 Cyclic inventory 366 Pipeline inventory 366 Safety stock 11.4 40000 367 12.3 Inventory Costs Inventory-carrying cost 367 Cost of ordering 368 369 Cost of shortages 12.4 Inventory Control for Deterministic Demand Items 370 Problems in the EOQ model 12.5 Handling Uncertainty in Demand 12.6 Inventory Control Systems 374 The continuous review (Q) system 375 The periodic review (P) system 376 Issues in the P and Q systems of inventory control 377 **12.7 Selective Control of Inventory** ABC classification 379 Other classification schemes for selective control 381 IDEAS AT WORK 12.2: THE INVENTORY CONTROL SYSTEM OF A PETROCHEMICAL 382 MANUFACTURER 12.8 Inventory Planning for Single-period Demand 382

12.9 Other Issues in Inventory Planning and Control 384

Summary Review Qu Problems Mini Projec Case: MMI Notes Suggested Readings

## PART

## OPERATIONS

13

372

379

384	
lestions	385
386	
cts 388	
IL Limited	388
392	
d Readings	393

## PLANNING AND CONTROL OF

394

### 394 Demand Forecasting

IDEAS AT WORK 13.1: THE ROLE OF FORECASTING IN A PETROCHEMICAL-MANUFACTURING COMPANY 39S 13.1 Forecasting as a Planning Tool 395 13.2 Why Do We Forecast? -396 13.3 Forecasting Time Horizon 397 Short-term forecasting Medium-term forecasting Long-term forecasting 13.4 Design of Forecasting Systems 398 13.5 Developing the Forecasting - 399 Logic 400 13.6 Sources of Data 400 Sales-force estimates Point of sales (POS) data systems 401 Forecasts from supply chain partners 2}() { Trade/industry association journals 101 B2B portals/marketplaces 4()) Economic surveys and indicators 401 Subjective knowledge 402

## 13.7 Models for Forecasting 402

13.8 Extrapolative Methods Using Time Series 402

IDEAS AT WORK 13.2: THE ROLE OF THE WORLD WIDE WEB IN FORECASTING 403 Moving averages 404 The exponential smoothening

method 405

Extracting the components of time series 406

Estimating the trend using linear regression 408 Extracting the seasonal component

13.9 Causal Methods of Forecasting 411 Econometric models 412

410

13.10 Accuracy of Forecasts 413

IDEAS AT WORK 13.3: FACTORS AFFECTING FERTILIZER USE IN PUNJAB 413

Forecast error (FE)414Mean absolute deviation (MAD)414Mean absolute percentage error(MAPE)414Mean squared error (MSE)414Tracking signal (TS)41513.11 Using the Forecasting System417Getting started417Focus forecasting419Incorporating external information419Forecasting systems: Stability versus419	<ul> <li>IDEAS AT WORK 14.2: USE OF SPREADSHEETS FOR AGGREGATE PRODUCTION PLANNING 452</li> <li>The linear programming model for APP 453</li> <li>The linear decision rule (LDR) 466</li> <li>14.10 Master Production Scheduling 456</li> <li>Summary 459</li> <li>Review Questions 459</li> <li>Problems 460</li> <li>Case: New Age Electronics</li> <li>Limited 462</li> </ul>
Summary 421 Review Questions 421	Notes 464 Suggested Readings 464
Problems 422 Net-Wise Exercises 425 Mini Project 425 Case: ABS Caterers 425 Note 426 Suggested Readings 426	Supplement 14A: Linear ProgrammingProgramming465Summary472Review Questions472Problems472Suggested Readings473
14 Aggregate Production	
Planning 428 IDEAS AT WORK 14.1: PRODUCTION PLANNING	<ul> <li>15 Resources Planning 474</li> <li>IDEAS AT WORK 15.1: ERP IMPLEMENTATION AT HPCL 475</li> </ul>
AT CTUNC. 429 14.1 Planning Hierarchies in Operations 430 14.2 Aggregate Production Planning 432 14.3 The Need for Aggregate Production Planning 433 14.4 A Framework for Aggregate Production Planning 434 14.5 Alternatives for Managing Demand 434 Reservation of capacity 434 Influencing demand 434 14.6 Alternatives for Managing Supply 435 Inventory-based alternatives 435 Capacity adjustment alternatives 435	<ul> <li>15.1 Dependent Demand Attributes 476</li> <li>15.2 Planning a Framework: The Basic Building Blocks 477</li> <li>Multiple levels in products 477</li> <li>Multiple levels in products 477</li> <li>Product structure 478</li> <li>The bill of materials (BOM) 481</li> <li>Time phasing the requirement 481</li> <li>Determining the lot size 486</li> <li>Incorporating lead-time information 487</li> <li>Establishing the planning premises 488</li> <li>15.3 MRP Logic 489</li> <li>15.4 Using the MRP System 494</li> <li>Updating MRP schedules 494</li> <li>Safety stock and safety lead time 495</li> <li>15.5 Capacity Requirements Planning</li> </ul>
14.7 Basic Strategies for Aggregate Production Planning438Level strategy438Chase strategy439Mixed strategy440	(CRP)49615.6Distribution Requirement Planning (DRP)49815.7Manufacturing Resources Planning (MRP II)
14.8 Aggregate Production Planning Methods 450	15.8 Enterprise Resource Planning (ERP) 500
Heuristic methods for APP 450 Optimal methods for APP 451	<b>15.9 Resources Planning in Services</b> 501 IDEAS AT WORK 15.2: RAMCO ONDEMAND
14.9 Operations Research Tools for Production Planning 451 Aggregate production planning using the transportation model 451	ERP502Summary503Review Questions503

### CONTENTS

blems 504
t-Wise Exercises 506
ni Projects 507
tes 507
ggested Readings 507
heduling of Operations 508
IDEAS AT WORK 16.1: PREACTOR APS: SOFTWARE FOR SCHEDULING OPERATIONS 509
5.1 The Need for Scheduling 510
5.2 Scheduling: Alternative Terms 511 Planning-related terms 511 Technological constraints-related
torms
Administration-related to the
6.3 The Loading of Machines
6.4 The Scheauing Concert
Scheduling rules 515
Performance cincina
6.5 Scheduling of Flow Shops
Johnson's rule 519 521
16.6 Scheduling of Job Shops
16.7 Input Output 16.8 Operational Control Issues in Mass 16.8 Production Systems 524
Machine redeployment 525 525
Altering operator anocations
A dissection material leeu lacos
16.9 Operations Planning and Control Based on the Theory of Constraints 525
Measures of performance 526 The analogy of marching soldiers 526
The analogy of marching solution
The unally manufacturing 527
Synchronous manufacturing
Synchronous manufacturing 527 Constraints in a manufacturing system 528
Synchronous manufacturing OZ Constraints in a manufacturing system 528 The drum-buffer-rope (DBR)
Synchronous manufacturing 527 Constraints in a manufacturing system 528 The drum-buffer-rope (DBR) methodology 50
Synchronous manufacturing 527 Constraints in a manufacturing system 528 The drum-buffer-rope (DBR) methodology 50 Summary 531
Synchronous manufacturing 022 Constraints in a manufacturing system 528 The drum-buffer-rope (DBR) methodology 00 Summary 531 Review Questions 531
Synchronous manufacturing024Constraints in a manufacturing528System528The drum-buffer-rope (DBR)methodology50Summary531Review Questions531Problems532
Synchronous manufacturing027Constraints in a manufacturing528System528The drum-buffer-rope (DBR)methodology0Summary531Review Questions531Problems532Mini Projects533
Synchronous manufacturing 527 Constraints in a manufacturing system 528 The drum-buffer-rope (DBR) methodology 500 Summary 531 Review Questions 531 Problems 532 Mini Projects 533 Notes 534
Synchronous manufacturing 027 Constraints in a manufacturing system 528 The drum-buffer-rope (DBR) methodology 500 Summary 531 Review Questions 531 Problems 532 Mini Projects 533 Notes 534 Suggested Readings 534
Synchronous manufacturing927Constraints in a manufacturing528System528The drum-buffer-rope (DBR)methodology500Summary531Review Questions531Problems532Mini Projects533Notes534Suggested Readings534Lean Management536
Synchronous manufacturing 92.7 Constraints in a manufacturing system 528 The drum-buffer-rope (DBR) methodology 530 Summary 531 Review Questions 531 Problems 532 Mini Projects 533 Notes 534 Suggested Readings 534 Lean Management 536 DEAS AT WORK 17.1: LUCAS TVS: THE JIT GRAND PRIX WINNER 537
Synchronous manufacturing 027 Constraints in a manufacturing system 528 The drum-buffer-rope (DBR) methodology 530 Summary 531 Review Questions 531 Problems 532 Mini Projects 533 Notes 534 Suggested Readings 534 Lean Management 536 DEAS AT WORK 17.1: LUCAS TVS: THE JIT GRAND PRIX WINNER 537
Synchronous manufacturing 044 Constraints in a manufacturing system 528 The drum-buffer-rope (DBR) methodology 530 Summary 531 Review Questions 531 Problems 532 Mini Projects 533 Notes 534 Suggested Readings 534 Lean Management 536 DEAS AT WORK 17.1: LUCAS TVS: THE JIT GRAND PRIX WINNER 537
Synchronous manufacturing 047 Constraints in a manufacturing system 528 The drum-buffer-rope (DBR) methodology 530 Summary 531 Review Questions 531 Problems 532 Mini Projects 533 Notes 534 Suggested Readings 534 Lean Management 536 DEAS AT WORK 17.1: LUCAS TVS: THE JIT GRAND PRIX WINNER 537

17.4 Creating a Lean Enterprise 540 17.5 Waste Elimination as the Core Logic of JIT 542 17.6 Elements of JIT Manufacturing 544 Changes in the manufacturing architecture 544 Lot-size reduction 546 Set-up time reduction through SMED 546Kanban as a control tool 548 IDEAS AT WORK 17.2: SET-UP TIME REDUCTION IN BRAKES INDIA 549 17.7 Production Planning and Control 550 in JIT Push and pull scheduling 550 The kanban system 551 Design of kanban quantities 564 17.8 Improvement Options in Operations 556 557 Radical improvement Continuous improvement 557 IDEAS AT WORK 17.3: TOWARDS ZERO NON-VALUE-ADDED ACTIVITIES 558 17.9 The Continuous Improvement Process 558 17.10 Tools for Continuous Improvement 560 17.11 Organization for Continuous Improvement 561 Task force for continuous with adT 2.Mb. improvement 561 562 Quality circles Project-based small group improvement activities (SGIA) 562 Visual control aids for improvement 562 17.12 Organizational Challenges in Lean Management 563 IDEAS AT WORK 17.4: VISUAL CONTROL FOR CONTINUOUS PROCESS IMPROVEMENT 564 JIT implementation issues 565 Cultural and human issues 566 Summary 568 Review Questions 568 Problems 569 Mini Projects 569 Case: Bharat Auto Components Limited 14.6 ASSERTATION COOP 570 (BACL) 573 Notes Suggested Readings 574 18 Six-Sigma Quality Control 576 IDEAS AT WORK 18.1: QUALITY CONTROL AT INDIAN FOOD SPECIALTIES LIMITED 577

18.1 The Six-Sigma Approach to Quality Control and Management 577

£.

<b>18.2 Defects Per Million Opportunities</b> (DPMO) 578
18.3 Six-Sigma Methodology (DMAIC) 579
IDEAS AT WORK 18.2: DEFECT OPPORTUNITIES: THE CASE OF FIXED DEPOSITS 581
<b>18.4 Organization for Six-Sigma</b> Quality 581
18.5 Variations in Processes 582
Common causes 583
Assignable causes 584
18.6 Process Control Fundamentals 585
18.7 Setting Up a Process Control System 585
Step 1: Choose the characteristic for process control 586
Step 2: Choose the measurement method 586
Step 3: Choose an appropriate sampling procedure 587
Step 4: Choose the type of control chart 588
Step 5: Compute the control limits 588
Step 6: Plot the data and analyse it 593
<b>18.8 Process Improvements in the</b> Long Run 596
Process capability 597
Potential capability 598
Actual capability 598
18.9 Six Sigma and Process Capability 600
18.10 Acceptance Sampling 600
Single sampling plan 601 AQL and LTPD 601
Summary 604
Review Questions 604
Problems 605
Net-Wise Exercises 606
Mini Project 606
Notes 607
Suggested Readings 607
Maintenance Management 608
IDEAS AT WORK 19.1: TPM EXCELLENCE AWARD FOR TVS MOTORS 609
10.1 The Need for Maintenance

 19.1 The Need for Maintenance

 Management
 610

 Maintenance versus APP
 610

 Maintenance versus scheduling
 610

 Maintenance versus quality control
 610

19

XV

19.2 Equipment Life Cycle 612
19.3 Measures of Maintenance
Performance 613
Equipment breakdowns 613
Mean time between failures (MTBF) 613
Mean time to repair (MTTR)
Availability 614
19.4 Requirements for Effective
Maintenance Management 616 Catalogues of equipment 616
Maintenance policy/manual 636
Troubleshooting mechanisms
Fault-tree analysis 618
Maintenance information systems 618
IDEAS AT WORK 19.2: TROUBLESHOOTING
MECHANISMS FOR EFFECTIVE
MAINTENANCE 619
<b>19.5 Maintenance Alternatives</b> 619
Inspection (routine) 620
Preventive maintenance (PM) 620
Predictive maintenance (condition monitoring) 620
Breakdown maintenance (BD) 621
Planned shutdowns/major overhauls 621
Equipment replacement 621
19.6 Decision Tools for Maintenance
Management 623
Optimal preventive maintenance
policy 623 Group replacement policies 626
Equipment replacement decisions 626
<b>19.7 Spare-parts Management</b> 627
Types of spares 628
Inventory planning for spare parts 529
<b>19.8 Total Productive Maintenance</b> 631
Overall equipment effectiveness 634
TPM methodology 633
TPM implementation 634
Summary 635
Review Questions 636
Problems 636
Net-Wise Exercises 638
Case: Braking Systems Incorporated 638
Notes 640
Suggested Readings 641

Index

643

### AND REAL PROPERTY AND ADDRESS OF TAXABLE PROPERTY.

the second of the second of the second The second line of the second s THE REPORT OF A DESCRIPTION OF A DESCRIP CONTRACTOR AND ADDRESS OF CONTRACTOR AND ADDRESS ADDRE

WATSTATUL LOSS 1 OF 11 THE DOORSHERE DOORSHERE

he are made the set of the set THE PART OF THE

AND STATE VIEW DATES

## SUGESTED READINGS water-term

- AL D. Dowler, "Add "Derrock deeper without an index." Add, "Antipute and the second s Second sec [4] M. M. M. Marthall, "Internet all Control of Additional and the second se
  - all sold at the second summaries the part of the second the state of the second second second second the second se
- Ull betren balances and an and we share which any how have
- SADE THE REPORT IN THE REPORT OF A LERGE The Arthough States of the States of t were historie and the second of the second o
- ALVERT AT A CONTRACT OF A DESCRIPTION AND AND A DESCRIPTION AND A WILDARDER' TOTAL OF THE SOUTH STRUCTURES AND INCOMENTS. Same and UNTRAL Pressents Theresets Mandel Production Distances in Table 14

assembly postponement, 297-298 assignable causes, 584–585 assignment method, 512 ATO, see assemble to order automated guided vehicle system, 138-139 automated material handling system, 137-139 automated storage and retrieval system, 138 autonomous maintenance, 634-635 availability, 614 average resource utilization, 128 B2B marketplaces, 401 back office, 160 back ordering, 435 backlog, 436 bathtub curve phenomenon, 612-613 benchmarking, 191, 269, 559 beta distribution, 230

3PL, see third-party logistics 5s, 560-561

SUBJECT INDEX

n ABC classification of inventories, 379-380, 630 acceptable quality level, 603 acceptance number, 601 acceptance sampling, 600-603 accuracy, 597 activity duration, 230 activity on arc, 219 activity on node, 219 actual capability, 598 aggregate production planning, 17, 75, 432, 610 alternatives for managing demand, 434-435 alternatives for managing supply, 435-438 basic strategies for, 438-440 chase strategy, 439-440 framework for, 434 heuristic methods for, 450-451 level strategy, 438-439 linear decision rule, 456 linear programming model for, 453-456 and master production scheduling, 456-458 mixed strategy, 440 need for, 433 optimal methods for, 451 use of spreadsheets for, 452-453 using the transportation model, 451 AGV system, see automated guided vehicle system andon lights, 45 AOA, see activity on arc AON, see activity on node APP, see aggregate production planning AQL, see acceptable quality level arrival parameters, in an operating system, 163 AS/RS, see automated storage and retrieval system assemble to order, 60-61

bill of materials, 145, 240, 335, 477, 481 single-level, 481 indented, 481 modular, 481 bill of resources, 501 block diagonalized structure, 132 BOM, see bill of materials BOR, see bill of resources bottleneck resource, 528 bottleneck, 62 BPO, see business process outsourcing BPR, see business process re-engineering breakdown maintenance, 621 break-even analysis, 40-41 break-even point, 41, 52 break-even sales, 41 bullwhip effect, 290-291 bundling efforts, 338 Bureau of Indian Standards, 265 business process outsourcing, 48-49, 333, 350-351 business process re-engineering, 65-70 business processes, 48 buyer-centric marketplace, 353

c charts, 593 calling population, in an operating system, 161-163 capability maturity model, 267 capability maturity model integration, 267 capability maturity model, 267 capacity defined, 40 effectiveness of, 73 input measures of, 72 output measures of, 73 capacity availability, computation of, 78-80 capacity choices, in service system, 153-154 capacity constrained resource, 528 capacity expansion, 57, 72, 80, 351 capacity of the machine, 70-71 capacity planning, 17, 74–77, 85, 110, 114, 431-432, 435, 457 cost-based method, 85 decision tree for, 85 framework, 76-81 operational performance based methods, 85 in services, using queueing analysis, 160-170 in the short run, 75 time horizon in, 74-76 capacity requirements (labour and machine), 77 capacity requirements planning, 17, 496-498, 510 capacity reservation, 170, 434 capacity utilization, 42, 73, 163, 370

- capital budgeting exercises, 74
- capital spares, 384, 628

cause and effect diagram, 255, 257-258 CBS, see cost breakdown structure CCPM, see critical chain project management CCR, see capacity constrained resource CEDAC, 255, 258-259 cellular manufacturing, 120 cellular manufacturing system, 121, 131, 565 chance variations, 583, 585 channel management, 287 chase strategy, 439–440 Chelliah Committee Report, 18, 46 Chinese manufacturers, 47 choice of locations, 306 cluster, 345 CMM, see capability maturity model CMMI, see capability maturity model integration collaborative commerce, 49-51 collaborative mechanisms, 352-353 common causes, 583-584 competitive advantage of a location, 309 in product development process, 182-184 competitive marketing dynamics, 31 competitive priorities, 43 competitor analysis, 191-192 complexity degree of, 154, 156 in location planning, 309 in operations management, 139-140 in a service system, 154–156 concept generation stage, in product development cycle, 185-186 concurrent engineering, 189 condition monitoring, 620 constant WIP, 523-524 constraints, in a manufacturing system, 528-529 consumer goods, 38 consumer products company, 363 consumer's risk, 603 continuous flow systems, 105-108 continuous improvement process, 259, 558-560 continuous improvement, of operations, 556-558 organization for, 561-563 steps, 559-560 task force, 561 tools for, 560-561 visual control, 562-565 continuous review system, 375-376 continuous streamlined flow, 37 contribution margin, 41 control charts, 588 CONWIP, see constant WIP core operations layer, 13 corporate strategy, 28-31, 33, 36 cost breakdown structure, 216-217 strength with the state of

### SUBJECT INDEX

342, 368-369 , 369–370 capability pability path method atio nit time, 227 iect management, 226 oject management, 234 thod, 222 5-516 233 ty requirements planning mer relationship management act, 9, 12, 152-154 , 13–14 ionship management systems, anufacturing system, 113-114 , 484 127-128 ry, 365 ology, see drum-buffer-rope ology ing operations, 83 ing patterns, 289–290 ventory, 365 illion opportunities, 578-579 are-analyse-improve-control ology, 579–580 quality, 248–251 nmonality, 197 emand, 476-477 emand item, 476-477 sembly, 196 vironment, 196 calization, 196 anufacturability, 195–196 ocesses, 103 , in product development cycle, 186 sign for assembly sign for environment sign for localization esign for manufacturability nufacturing systems, 110 , 139, 285, 512 ess, 197 inventories, 476 network, 284–285 requirement planning, 277, degree of, 155-156 e define-measure-analyseove-control methodology, 579-580 amic programming e defects per million opportunities istribution requirement planning

drum-buffer-rope methodology, 530-531 dynamic programming, 451, 627

earliest due date, 515 early start time, for activity, 222-223 econometric models, 412-413 economic order quantity, 370, 486 economies of scale, 40, 71, 336, 338, 376 EDD, see earliest due date efficient supply chain, 38-39, 279-280, 297 EFQM, see European Foundation for Quality Management electronic data interchange, 66, 290 electronic markets, 50, 333, 339-340, 352-354 employee involvement, 45, 253-254 in quality assurance, 253-254, 268 empowerment methods, 254 enabling processes, 49 "end-of-the-period" syndrome, 526 engineering change notice, 199 enterprise resource planning, 66, 297-298, 475, 500-501 EOQ, see economic order quantity e-procurement, 333, 351-354 EPZ, see export processing zone model equipment life cycle, 612-613 equipment replacement decision, 621-622, 626-627 ERP software, 501 ERP, see enterprise resource planning ES, see early start time for activity European Foundation for Quality Management, Excel solver, 467, 471 expansion flexibility, 137 expected activity duration, 230 expediting, 111, 414, 512 explosion, 478 exponential distribution, 164 export processing zone model, 313

failure rate, 612 fast-moving consumer goods, 287 fault-tree analysis, 618 FCFS, see first-come-first-served FDI, see foreign direct investment FE, see forecast error finance function, 12 first-come-first-served, 516 fishbone diagram, 247, 255, 257-258 fixed costs, 40 fixed deposits, 581 fixed order interval system, 376 fixed order quantity method, 375, 378, 485-486 fixed position layout, 120 flexibility, 42 flexible manufacturing cell, 136 flexible manufacturing system, 135-137 flow balancing, notion of, 110 flow patterns, in manufacturing systems

continuous flow system, 105-108 intermittent flow systems, 108-111 jumbled flow systems, 111-114 flow shop, 107, 514, 519-521 flow time, 516 flow, role in an operations system, 104-105 FMCG, see fast-moving consumer goods FMS, see flexible manufacturing system focus forecasting, 419 focus groups, 190 FOQ, see fixed order quantity forecast error, 414 forecasting time horizon, 397-398 long-term forecasting, 398 short-term forecasting, 397-398 medium-term forecasting, 398 forecasting, 16 accuracy of forecasts, 413-415 causal methods of, 402, 411-413 design of system for, 398-399 econometric models, 412-413 exponential smoothening method, 405-406 extrapolative methods using time series, 402-410 focus, 419 forecast error, 414 of future demand, 408 logic, 399-400 long-term, 398 medium-term, 398 method of least squares, 408-409 methods of moving averages, 404-405 models for, 402 need for, 396-397 in a petrochemical-manufacturing company, 395 as a planning tool, 395–396 in public policy decisions, 396 role of the World Wide Web in, 403 seasonal component, 410 short-term, 397-398 sources of data, 400-402 systems, 420 using a system for, 417-420 forecasts, accuracy of, 413-414 foreign direct investment, 307 forward auction, 352-353 front office, 160 FSN classification, 381 full-fare airline, 156 functional product, 38, 296-297 functional relationships, 412

Gantt charts, 520-523 gates, in new-product development project, GDP, 4, 7, 350 GDP, manufacturing and services contribution,

general purpose simulation system, 98 GHX, see Global Healthcare Exchange Global Healthcare Exchange, 50 global sourcing, 336, 351

## globalization, of the Indian economy, 46-48 Golden Quadrilateral Project, 285, 321 good scheduling practices, 113 GPSS, see general purpose simulation system green manufacturing practices, 22 Greenpeace, 22 group replacement policies, 622, 626 group technology, 112 group technology layout, 119-120 design of, 131

GT, see group technology

### H

heterogeneity, 9, 171 heuristic methods, 450-451 histograms, 256-257 horizontal carousel, 138 "house of quality"stage, 192–193, 262 human resources management function, 12

IIP, see index of industrial production IMVP, see International Motor Vehicles Programme inbound buffer, 552 inbound supply chain, 281-282 incremental model, of software development process, 202 incurred cost, of the product, 200 independent demand, 364 in-depth interviews, 190 index of industrial production, 5-6 in-house supply chain, 282-283 innovation, 182 innovation layer, 13 innovative product, 38, 296 insurance spares, 628-630 intangibility, 9, 171 intermittent flow systems, 108-111 intermittent or batch flow, 37 International Motor Vehicles Programme, 244 International Organization for Standardization, 265 inventory control systems, 374-378 petrochemical manufacturer, 382 inventory planning cost of overstocking, 382 cost of understocking, 383 for deterministic demand items, 370-372 "how much" and "when" questions in, 367 for independent demand items, 364 issues, 384 for a single-period demand, 382-383 inventory, 363 inventory carrying cost, 367-368 inventory, types of 364-367 cyclic inventory, 365 decoupling inventory, 365 pipeline inventory, 366 safety stock, 366-367 seasonal inventory, 364-365 inventory-carrying cost, 367-368

ISO, see International Organization for Standardization ISO 9000 system, 267

Japanese manufacturing firms, 244, 322, 341, 538 JIT, see just in time job shop, 113–114, 514–515 Johnson's rule, 519 jumbled flow, 37 jumbled flow systems, 111-114 Juran's trilogy, 246 just in time, 60 core logic of, 542-544 elements of, 544-548 implementation issues, 565-566 philosophy, 43, 322, 541 production planning and control, 550-555 purchasing, 338, 340 systems, 44, 114

kaizen, 120, 267, 560-561 kanban, 45-46, 537-538, 548 conveyance kanban (C-kanban), 552 production kanban (P-kanban), 552 kanban cards, 45 late finish time for activity, 223 layout design fundamental measure for, 121 good, 121–122 GT, 131–132 one worker-multiple machine, 134-135 performance measures, 121-123 qualitative approach to, 124-125 quantitative approach to, 125-126 software for, 126-127 one worker-multiple machine, 134-135 layout planning, in manufacturing and service organizations, 115 implications, 116 layout, types of, 116-120 process layout, 116-117 product layout, 117-119 group technology layout, 119-120 fixed position layout, 120 LCL, see lower control limit LDR, see linear decision rule lead time, 61, 374-375, 487 lean management. See also just in time development of, 540-542 need for, 538-539 organizational challenges, 563-567 philosophy, 539-540 lean organization, 334–335 learning curve effect, 71 level strategy, 438-439 LFL, see lot-for-lot life-cycle costing, 200 line balancing, 127, 131, 524 line of interaction, 160

### SUBJECT INDEX

645

line of visibility, 160 linear decision rule, 456 linear programming, 318, 451, 467 model for APP, 453-456 linear regression, 408-409 linear sequential model, of software development process, 202 line-balancing technique, 524 Little's formula, 165 loading, 511-512 loading of machines, 512 location decisions, 306 in developing countries, 308-310 factor advantages, 308 factors affecting, 310-312 globalization of, 307-310 location planning, 306 issues in, 321-322 location planning method, 312-321 centre-of-gravity method, 315-316 load-distance method, 316-317 location factor rating method, 312 transportation model, 318-319 location of facilities, 154 logistics management, 285-286 longest processing time, 515 loss function, 248 lot sizing, 485 lot tolerance percent defective, 603 lot-for-lot rules, 485 lot-for-lot, 485 lot-size reduction, 546 low level coding, 479 low-cost country sourcing, 336 lower control limit, 585 lower specification limit, 585 LP, see linear programming LSL, see lower specification limit LTPD, see lot tolerance percent defective luxury services, design of, 151

M

machine flexibility, 137 machine-component incident matrix, 131 MAD, see mean absolute deviation mainstream activities, 210 maintainability improvement, 614, 633-634 maintenance consumables, 628 maintenance information system, 618 maintenance management alternatives available for, 619-622 decision tools for, 623-627 effectiveness of, 616-618 measures of performance, 613-615 vs APP, 610 vs quality control, 610-612 vs scheduling, 610 maintenance prevention, 614, 633-634 make or buy decision, 350 make span, 516–517 make to order, 60 make to stock system, 59-60 management accounting, 200-201 The second s

### SUBJECT INDEX

roach, 201 ing, 200 201 rchitecture, 537, 544 irm, 4 oostponement, 297-298 esources planning, 499-500 rends, in India, 5-7 ector, 7 of the white goods industry, n absolute percentage error rs, analogy of, 526-527 , 190–191 tion, 12 ibution, 163–164 tion, 196–199 n, 107 n system, 107, 525 ion schedule, 456-458, 488-489, ng system, 136 ements planning, 476 ng of, 494–496 , 261 deviation, 414 percentage error, 414 error, 414-415 ween failures, 613-614 epair, 614 rformance, for manufacturing chine-component incident ine assembly, 44 , 440 ine assembly, 44 n, 195–196, 297 tors, for outsourcing, 48 er production scheduling rial requirements planning anufacturing resources planning 9-490 s, updating, 494–495 495 n, 495 squared error an time between failures to order ee make to stock system ean time to repair ing, 340 of the workforce, 83-84

ppliers, 344 non-value-added activities, 70,

ation process, 338 Vational Environmental Plan,

esentation of a project, 217-219

NNVA activities, see necessary but non-valueadded activities no-frills airline, 156 non-peak hour, 61, 170, 364, 434 non-value-added analysis, 66, 69, 560 NVA analysis, see non-value-added analysis OBS, see organization breakdown structure

OC curve, see operating characteristics curve OEE, see overall equipment effectiveness one-size-fits-all sourcing strategy, 336 on-time delivery index, 294-295 on-time delivery index percentage, 295 operating characteristics curve, 602 operating inventory, 476 operating system, basic inputs in an, 14 operation functions, in an organization, 11-14 operation research tools, for production planning, 451-456 operational control, nature and degree of, 154 operational excellence, measures for, 34-36 operational planning tools, 256 operational processes, 49 operations control, 15, 17 operations management complexity, 139-140 current priorities for, 21-22 challenges in, 18-21 design vs operational control issues, 16-17 developments in the area of, 30 emerging trends for, 46-51 long-term vs short-term issues, 17-18 role of operations in an organization, 11-14 services as a part of, 7-11 a systems perspective, 14-16 operations planning, 15 operations scheduling, 511 operations strategy cost vs flexibility trade-off, 42 options for strategic decisions in operations, 36-40 relevance, 29-30 strategy formulation process, 30-34 operations support layer, 13 operations systems, 4 designing of, 151 operations-strategy exercise, 35 order acceptance, 339 order placement, 339 order receipt, 339 order up to level, 376-377 order walkthrough, 67 order winners, 30 order-qualifying attributes, 31-33 order-winning attributes, 31-33 organization breakdown structure, 215-216 OT, see overtime OTD, see on-time delivery index outbound buffer, 552 outbound supply chain, 283-287 outsourcing, 48-49 outsourcing wave, 48 overall corporate strategy, 33

overall equipment effectiveness, 614, 631-633 overtime, 437 CONTRACTOR OF A DESCRIPTION OF A DESCRIP o charts, 592 P systems, of inventory control, 377-378 packaging postponement, 297-298 papermaking, 106 parameter design, 248 pareto diagram, 256-257 PDCA cycle, 245, 579 peak hour, 61, 105, 170 perceptual maps, 191 performance efficiency, of the equipment, 632 performance metrics, 165-166 periodic order quantity method, 486-487 periodic review system, 376-377 perishability, 9-11 PERT, see programme evaluation and review technique physical development of product, in product development cycle, 186 pipeline inventory, 366 planned shutdown, 621 planning framework, aspects of bill of materials, 481 component level planning, 488-489 determination of lot size, 485-486 lead-time information, 487 multiple levels of relationships, 477-478 product structure, 478-481 time requirement of items, 481-484 PM cycle, 623-626 point of sales data systems, 401 Poisson distribution, 164, 166 poka yoke, 45, 243, 248, 259-261 POQ, see periodic order quantity POS, see point of sales data systems postponement, types of, 297-298 potential capability, 598 precision, 597 predictive maintenance, 620 preventive maintenance, 620 proactive mode of capacity build-up, 72 probability of acceptance, 601 problem cards, 258 process analysis, 57-59 process flow charting, 58-59 process batch, 528 process capability, 597 process control fundamentals, 585 and scope for improvements, 596-599 setting up of, 585-596 process design, 15, 37, 58, 103, 105, 107, 135-139 process divergence, 155 process flexibility, 137 process indices, 293-296 process industries, 83, 106-107 process layout, 116-117 layout planning, 115-116 process layouts, design of, 123-127 qualitative approach to layout design, 124-125

quantitative approach to layout design, 125-126 process mapping, 67-69, 80, 159, 549, 560 process or a functional layout, 116–117 process ownership, 253 process redesigning, 112–113 processing, defined, 14 process-product matrix, 114-115 procurement notices, 511 procurement process, 338-340 producer's risk, 603 product development, 180-207 key to competitive advantage, 182 management accounting tools for, 200 organization for, 188 process, 184-187 software product development, 202 stage-gate approach, 187 tools for, 190 product development process, 183 management accounting for, 200-201 product development cycle, 185, 187 product development funnel, 187 performance measures for, 199-200 software, 202 stages in, 185-187 product flexibility, 137 product layout, 117-119 design of, 127–128 product platform, 197 product portfolio, 36-37 product profile, 38 production flow analysis, 132 production orders, 511 production planning in a hierarchical fashion, 430–432 programme evaluation and review technique, 230 project management, 210 framework for, 214–217 phases of, 212–214 THE TOTAL NAME time and resource constraints, 224-227 tools and techniques for, 217-223 and uncertainties, 230-231, 233 project networks analysis of, 219-223 simulation, 233 project organizations, characteristics of, 210-212 prototyping model, of software development process, 202 pull-based scheduling system, 60, 550-551 push scheduling, 550-551

Q systems, of inventory control, 377-378 QC circles, see quality control circles QFD, see quality function deployment QS9000 quality standards, 47, 267 quality assurance system, 251, 268-269, 346, 543, 577, 582 quality certifications and awards, 263 – 268 quality circles, 562

quality control circles, 247

quality costing, 247, 262-263 quality function deployment, 192-194, 262 quality gurus, 245-248 quality improvement, 245-246 quality in a service set-up, 171–173 gaps in, 172–173 quality management tools, 255-263 quality policy, 252-253 quality revolution, 244-245 quality, definitions, 248–250 quasi-market mechanism, 353 queue parameters, in an operating system, IN ANY CONTRACTOR THREE THREE 163 queueing system, basic structure of a, 160-169 queueing theory, 161 arrival rate, 163 service rate, 164 quick-response system, 334

radical improvements, of operations, 557 RAD, see rapid application development model, of software development process RAN, see random order random number generator, 94-95, 450, 516 random order, 516 rank order clustering, 132-133 rapid application development model, of software development process, 202 rapid capacity expansion, 351 reactive mode of capacity build-up, 72 relationship management, 287 reliable vendors, development of, 344-347 re-order point, 630 request for proposals, 49, 339 request for quotations, 49, 339 requirements analysis, of software development process, 202 research and development, in India, 181–182 resource availability, 80 resource levelling, 224 resources planning, in services, 501 responsive supply chain, 38-39, 42, 297-298 reverse auction, 20, 339-340, 352-354 reverse engineering, of a product, 191 RFP, see request for proposals RFQ, see request for quotation rotable spares, 628-629 route planning, 286 routine inspection, 611, 620, 622 routing flexibility, 137

safety lead time, 496 safety stock, 366-367, 374, 378, 495 sales-force estimates, 400-401 sampling plan, 601 satellite tracking and telemetry systems, 209-210 scheduling, 610 administration-related terms, 512

routing, defined, 511-512

## SUBJECT INDEX

context, 513-518

defined, 511 of flow shops, 514, 519-521 input-output control, 523-524 of job shops, 514, 521 need for, 510-511 and operational control issues, 524-525 of operations, 511 performance criteria, 516-518 push and pull, 550-551 rules, 515-516 technological constraints-terms, 511-512 SCM, see supply chain management SCOR model, see supply chain operations reference model search methods, 450-451 seasonal inventory, 364-365 seasonality, 407 seasonality index, 410-411 selective bottleneck scheduling, 509 selective control of inventories, 379-381 ABC classification, 379-380 FSN classification, 381 VED classification, 381 XYZ classification, 381 semi-automatic machines, 134 sequencing, 512 service blueprinting, 159-160 service levels, concept of, 372-374 service organization, 4 service parameters, in an operating system, service positioning, 156-159 service sector, 7-8 service system capacity choices in, 153-154 complexity in a, 154–156 customer contact, 156 degree of customization, 156 design of, 151–152 luxury services, 151 quality factor, 171-173 service-product spectrum, 8 SERVQUAL model, in service quality, 171, 173 set-up time reduction, 75, 541, 546–547 SEZ, see special economic zones shop configuration, 514 shortest processing time, 515 simplicity, 45-46 simulation, 94, 126, 233 application of, 99 computer software for, 98 of project networks, 233 RAND function, 95 strategic planning of a simulation experiment, 98 simultaneity, 171 single sampling plan, 601 single sourcing, 340–343 single-minute exchange of die, 546–547 single-period demand, 382-383 six sigma, 577, 600 and process capability, 600 methodology, 579

647

### SUBJECT INDEX

ol fundamentals, 585 processes, 582 y, 577 for, 581-582 provement, 254, 257, 562 e-minute exchange of die pment process nodel of, 202 model, 202 , 126–127 ntial model, 202 model, 202 ication programme, 267 tion development model, 202 s analysis, 202 202 del, 202 ges for layout design, 125-126 -126 25-126 ct development, 202 258 apply management, aspects of 340-344 bach to supply development, , 336–338 334-336 y" decision, 350 18-349 t process, 338-340 lors, development of, 344-347 nagement, 627-631 ical process control ic zones, 20, 306, 313 f software development process, iners, 554 1, 337 ess control, 249, 582 hase committees, 340 ons, 28 , 28 ires, of a product development 99-200 ing exercise, 28–29 ng, 336–338 lation process, 30-34 g process, 28 w, 107 , 84-85 cation programme, 346 mance, measures for, 348-349 of, 281–282 p effect, 291 96-298 1 - 282

information and material flows in, 280-281 in-house, 282–283 lead time, 296 outbound, 283-287 performance measures, 291-296 structure, 288-290 supply chain management information technology, 298-299 need for, 279-280 principles, 279 supply chain operations reference model, 294 supply chain partners, 401 supply-demand mismatch, 437-439 sustainability, 16 synchronous manufacturing, 527-529 system availability, 80 system structure, in an operating system, 163 systems design, 248 TAKT time, 60, 524–525 target costing, 201 TCO, see total cost of ownership technological forecasting, 411, 413 technology options for manufacturing processes, 39 theory of constraints philosophy, 509, 525-531 third-party logistics, 281, 284, 288, 290, 298 throughput time, 61–62 Tier-2 suppliers, 282 time series, 402 components of, 406-408 time-cost trade-offs, in projects, 226-227 TOC, see theory of constraints philosophy tolerance design, 248 total cost of ownership, 338, 349 total productive maintenance, 45, 631-635 total quality management, 43-44, 251-254 Toyota production system, 259 TPM, see total productive maintenance TPN, see trading partner network TQM, see total quality management tracking signal, 415 trade/industry association journals, 401 trade-off obstacles, 42-43

UCL, see upper control limit uncertainty of demand, 364, 372-374

trading partner network, 352

transportation model, 318-319, 451, 453

manufacturing, in India, 5-7

troubleshooting mechanisms, 617, 619

transformation process, 5

trial-and-error method, 450

two-bin system, 375, 377, 554

trustworthiness, 343

type I error, 603

type II error, 603

TS, see tracking signal

transfer batch, 528

trends, 407

utilization of a resource, 528

VA activities, see value-added activities value engineering, 194, 287, 297, 348 value stream, 336, 541 value stream mapping, 67 value-added activities, 70, 558 value-added tax, 307 variance of the activity duration, 230 variations in processes, 582-585 variety reduction, 196, 198, 384 variety, role in an operations system, 104-105 VAT, see value-added tax VED classification, 381, 630 vendor rating system, 346-347 vendor selection, 339 vertical carousel, 138 visual control aids, 562-563 voice of the customer, 579, 585 voice of the process, 579, 585 volume flexibility, 137 volume, role in an operations system, 104-105 volume-variety-flow, 116

waiting line models, 161-163, 165, 169 wandering bottleneck, 65 waste elimination approach, 83 waste, in operations and start-up, 74-75 waterfall model, of software development process, 202 WBS, see work breakdown structure WCM, see world-class manufacturing Web EDI, 352 Web-based e-commerce, 298 weighted moving average, 404-405 weighted points plan, 347 WIP, see work-in-process inventory; work-inprogress inventory work breakdown structure, 214-215 work-in-process inventory, 61 work-in-progress inventory, 165 World Trade Organization, 22 world-class manufacturing, 42-46 WTO, see World Trade Organization

 $\overline{X}$  and R charts, 588-590 X-category suppliers, 344 XYZ classification, 381

zero-defect performance, notion of, 247 zero-inventory system, 44

## NAME AND COMPANY INDEX

ABB India, 59, 307 ACC, see Associated Cement Corporation Airbus, 306, 539 Akao, Yoji, 262 Aravind Eye Care, Madurai, 157, 173 Ariba, 352 ASEAN, see Association of Southeast Asian Nations Ashok Leyland, 379 Asian Paints, 39, 283 Associated Cement Corporation, 57 Association of Southeast Asian Nations, 308 Audco India Limited, 127

Bajaj Auto Limited, 127, 184 Bangalore Metro Rail Corporation Limited, 212 Benetton, 297 Bharat Electronics Ltd, 192 Bharat Heavy Electricals Limited, 37, 59, 104, 111, 116, 120, 211 Bharat Petroleum Corporation Limited, 72 BHEL, see Bharat Heavy Electricals Limited BIL, see Brakes India Limited Blue Ginger restaurant, 158 BMRCL, see Bangalore Metro Rail Corporation Limited Boeing, 181, 306, 539 Bosch Limited, 279, 337 BPCL, see Bharat Petroleum Corporation Limited BPL, 435 ~ Wockhardt Hospitals, Bangalore, 160

Café Coffee Day, 31, 156 Canon, 73 Centre for Science and Environment, 419 CGL, see Crompton Greaves Limited CII, see Confederation of Indian Industry Coca-Cola, 419 Confederation of Indian Industry, 182 Crompton Greaves Limited, 431, 476, 635 Crosby, Philip B., 246–247, 263 CSE, see Centre for Science and Environment CTI Inc., 429

Brakes India Limited, 243, 549

dabbawala network, Mumbai, 278 DaimlerChrysler Research Centre, Bangalore, 181 Defence Research & Development

Organisation, 209

Dell Computers, 37, 181, 297

Deming, William Edwards, 245-246

DRDO, see Defence Research & Development Organisation

Essel Propack, 306 EXIM Bank, see Export-Import Bank of India Export-Import Bank of India, 265

## F

Ford Motor Company, 306, 350

## T)

GE Healthcare, 253 General Motors, United States, 34, 538 Ginger Hotels, 157 GKN Driveline India, 181

HAL, see Hindustan Aeronautics Limited, Μ Bangalore Mahindra & Mahindra, 184 Harley Davidson, 243-244, 538 Maiyas, 158 HCL AXON, 299 Marico, 635 Hero Honda Motors, 37, 253 Maruti Suzuki India Limited, 17, 322 Hewlett-Packard, 197, 306 Maruti Udyog Limited, 496, 524 Hindalco, 631, 635 Massachusetts Institute of Technology, 335 Hindustan Aeronautics Limited, Bangalore, 120 Mass Rapid Transit System, 212-213 Hindustan Copper, 15, 46 Mico, see Motor Industries Co. Ltd Hindustan Motors, 104, 261 Microsoft, 181 Hindustan Petroleum Corporation Limited, 475 Milltec Machinery Private Limited, Bangalore, Honeywell, 286 HPCL, see Hindustan Petroleum Corporation Mother Dairy, 277 Motor Industries Co. Ltd, 131 Limited Hyundai, 476 Motorola, 600 MTR Foods, Bangalore, 3–4 MUL, see Maruti Udyog Limited Murjani Group, 151

i2, 299–300, 352 IBM, 335 ICICI Bank, 157 IIT Madras, see Indian Institute of Technology Madras Indian Aluminum Company Limited, 18 Indian Food Specialties Limited, 577 Indian Institute of Technology Madras, 182 Indian Oil Corporation, 286 Indian Railways, 298 Indian Space Research Organisation, 120, 182, 209, 210, 402 IndiGo, 36 IOCL, see Indian Oil Corporation Ishikawa, Karou, 247 ISRO, see Indian Space Research Organisation

JD Edwards, 501 Jet Airways, 36, 154, 156, 419 Juran, Joseph M., 246

Karnataka State Police Housing Corporation, 333 KSPHC, see Karnataka State Police Housing Corporation

Kingfisher Airlines, 419 Kingfisher Red, 27-28

L&T, see Larsen and Toubro Lakshmi Machine Works, 29 Larsen and Toubro, 104, 111, 635 Lenovo, 37 LG Electronics, 298, 364 LIC, see Life Insurance Corporation of India Life Insurance Corporation of India, 159 Li & Fung, 305 LMW, see Lakshmi Machine Works Lucas-TVS, Chennai, 49, 188, 279, 299, 524, 537

National Centre for Biological Sciences, 182

## 0

Oracle, 352, 501

PeopleSoft, 501 Preactor APS, 509

Quantum, 335

Ramco, 502 Ramco Systems, 501 Rane Group, 181, 194 Reliance Industries Limited, 40, 107, 109–110, 119, 582 Reliance Life Sciences, 182 Royal Enfield, 184

SAARC, see South Asian Association for **Regional Cooperation** 

### NAME AND COMPANY INDEX

352, 501 ana Bhavan, Chennai, 57–58 en, 253 zo, Shigeo, 247–248, 259 Ericsson, 181 h Asian Association for Regional Cooperation, 308 Jet, 15, 154, 419 266-267 aram Finance Limited, 278 ki Motors Limited, 116



Taguchi, Genichi, 248 Taj West End, Bangalore, 158 Tanishq, 38, 296 Tata Cummins, 631 Tata Motors, 30, 31, 104, 117, 139 Tata Nano, 181, 184, 192 Thermax, 122 Titan Industries Limited, 104 Titan, 61 Toyota, 34, 306, 322

The set of the second second by the set of the second second

The second state where the second state where the second state where the second state of t

[30] James 1980 U. URARDARIO Z. INT. ORDER, and Application 1998 [1997].

South Manager of Annual Annual Street foodured and complexity of the second s 

Sec. If you have been and the second se ALL STELL SK. STRUCTURE SK. 15-4, 15-6, 11N

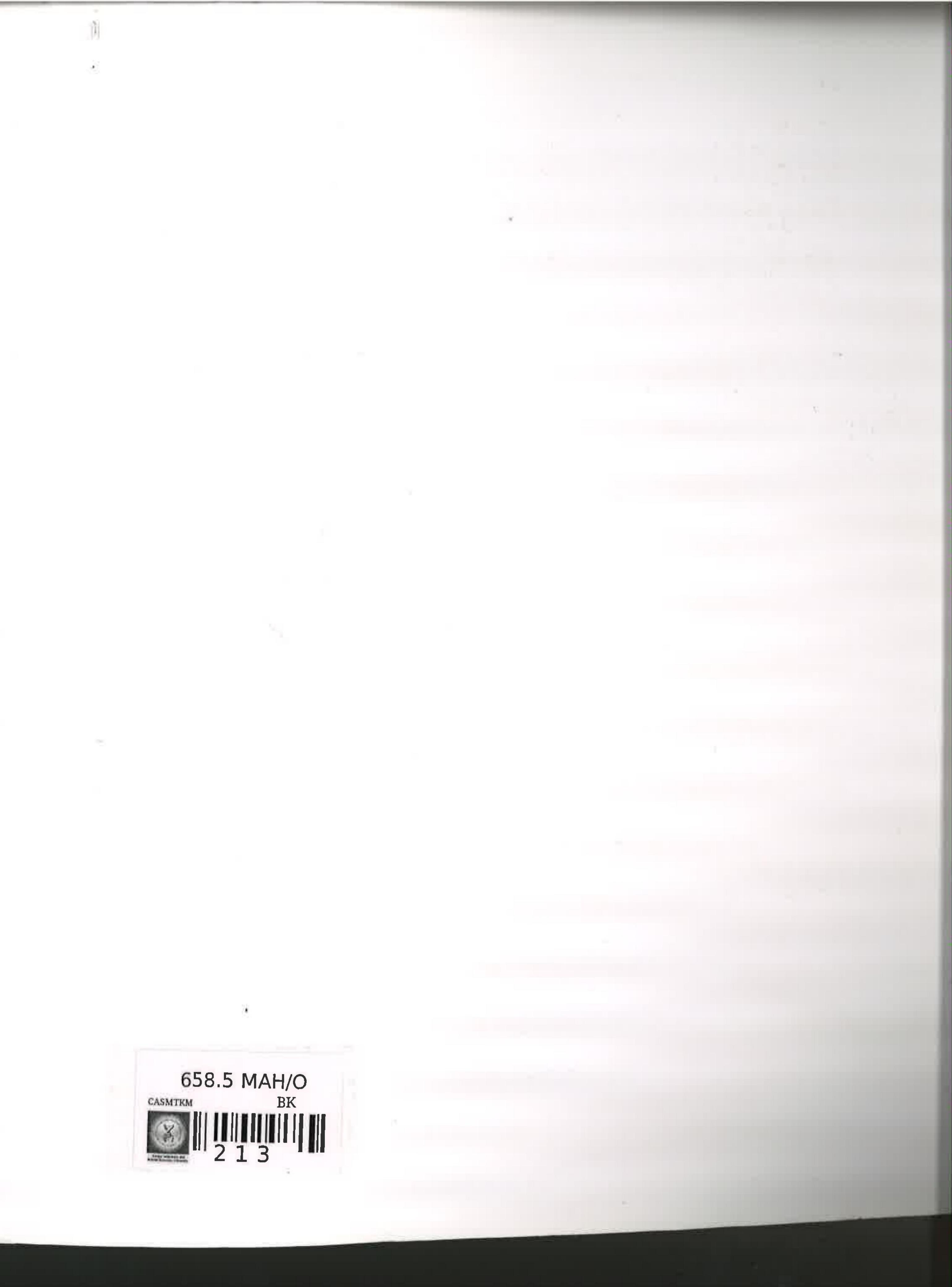
Annual weeks and the start a finance in the starts

The second is such that the

THE PRODUCTION A TIME IN THIS THE LAR 6 AND

Toyota Kirloskar Auto Parts, Bangalore, 73 Triveni Engineering, 29 TVS Group, 245 TVS Motor Company Limited, 184, 333, 609

Valgen Business Solutions, 501 Videocon, 184, 364, 435 Vikram Cements Ltd., 609, 631





# Operations Management Theory and Practice

## B. Mahadevan

The most fascinating and unique aspect of this book continues to be the emphasis on applications in the Indian context. In addition, the newly introduced Mini Projects will provide a self-learning platform.

BODHIBRATA NAG, INDIAN INSTITUTE OF MANAGEMENT CALCUTTA

I am impressed by how a complex topic like process and capacity analysis has been treated in such a simple and lucid manner. As an educator, I find the organization very learner-friendly and the variety of in-text and end-of-chapter inputs very rich. I especially liked "Supplement 3A: Simulation". It is an eyeopener for those who think this topic is a hard nut to crack. SUNIL SHARMA, FACULTY OF MANAGEMENT STUDIES, DELHI

The book comes across as a worthy treatise on operations management, the Indian way. Of much relevance and impact are the sections on the Tata Nano, Mother Dairy, Ginger Hotels and India's role in R&D.

SURAJ P. SOOD, S. P. JAIN INSTITUTE OF MANAGEMENT AND RESEARCH, MUMBAI

## **New to This Edition**

- **Reorganized chapters** with all related topics grouped together
- Two new chapters on process and capacity analysis (Chapter 3) and the design of service systems (Chapter 5)
- Revised and updated coverage of topics such as the design of manufacturing processes, lean management, and six sigma
- New! Fourteen end-of-chapter cases that discuss the issues faced by organizations in operations management
- New! Mini Projects and Net-Wise Exercises that provide a wide range of application-oriented problems to students
- New! Chapter supplements for complex topics such as simulation and linear programming, with a number of figures, screenshots, solved examples, and problems
- New! CD-ROM with videos provided with the book

Online resources available at www.pearsonad.co.m/bmahadevan





## SECOND EDITION

