

CONTENTS

Preface xv

1 INTRODUCTION 1

- 1.1 Importance and objectives of inventory control 1
- 1.2 Overview and purpose of the book 2
- 1.3 Framework 5
- References 5

2 FORECASTING 7

- 2.1 Objectives and approaches 7
- 2.2 Demand models 8
 - 2.2.1 Constant model 9
 - 2.2.2 Trend model 9
 - 2.2.3 Trend-seasonal model 10
 - 2.2.4 Choosing demand model 10
- 2.3 Moving average 11
- 2.4 Exponential smoothing 12
 - 2.4.1 Updating procedure 12
 - 2.4.2 Comparing exponential smoothing to a moving average 13
 - 2.4.3 Practical considerations and an example 14
- 2.5 Exponential smoothing with trend 16
 - 2.5.1 Updating procedure 16
 - 2.5.2 Practical considerations and an example 17
- 2.6 Winters' trend-seasonal method 18
 - 2.6.1 Updating procedure 18
 - 2.6.2 Practical considerations and an example 20
- 2.7 Using regression analysis 21
 - 2.7.1 Forecasting demand for a trend model 21
 - 2.7.2 Practical considerations and an example 23
 - 2.7.3 Forecasts based on other factors 24
 - 2.7.4 More general regression models 25
- 2.8 Sporadic demand 26

- 2.9 Box-Jenkins techniques 27**
- 2.10 Forecast errors 29**
 - 2.10.1 *Common error measures 29*
 - 2.10.2 *Updating MAD or σ^2 30*
 - 2.10.3 *Determining the standard deviation as a function of demand 32*
 - 2.10.4 *Forecast errors for other time periods 32*
 - 2.10.5 *Sales data instead of demand data 34*
- 2.11 Monitoring forecasts 34**
 - 2.11.1 *Checking demand 35*
 - 2.11.2 *Checking that the forecast represents the mean 35*
- 2.12 Manual forecasts 36**
- References 37**
- Problems 38**

3 COSTS AND CONCEPTS 43

- 3.1 Considered costs and other assumptions 44**
 - 3.1.1 *Holding costs 44*
 - 3.1.2 *Ordering or setup costs 44*
 - 3.1.3 *Shortage costs or service constraints 45*
 - 3.1.4 *Other costs and assumptions 45*
- 3.2 Different ordering systems 46**
 - 3.2.1 *Inventory position 46*
 - 3.2.2 *Continuous or periodic review 47*
 - 3.2.3 *Different ordering policies 48*
 - 3.2.3.1 *(R, Q) policy 48*
 - 3.2.3.2 *(s, S) policy 49*
- References 50**

4 SINGLE-ECHELON SYSTEMS: DETERMINISTIC LOT SIZING 51

- 4.1 The classical economic order quantity model 52**
 - 4.1.1 *Optimal order quantity 52*
 - 4.1.2 *Sensitivity analysis 54*
 - 4.1.3 *Reorder point 54*
- 4.2 Finite production rate 55**
- 4.3 Quantity discounts 56**
- 4.4 Backorders allowed 59**
- 4.5 Time-varying demand 61**
- 4.6 The Wagner-Whitin algorithm 63**

- 4.7 The Silver-Meal heuristic 66**
- 4.8 A heuristic that balances holding and ordering costs 68**
- 4.9 Exact or approximate solution 70**
- References 70**
- Problems 72**

5 SINGLE-ECHELON SYSTEMS: REORDER POINTS 77

- 5.1 Discrete stochastic demand 77**
 - 5.1.1 Compound Poisson demand 77*
 - 5.1.2 Logarithmic compounding distribution 80*
 - 5.1.3 Geometric compounding distribution 82*
 - 5.1.4 Smooth demand 83*
 - 5.1.5 Fitting discrete demand distributions in practice 85*
- 5.2 Continuous stochastic demand 85**
 - 5.2.1 Normally distributed demand 85*
 - 5.2.2 Gamma distributed demand 86*
- 5.3 Continuous review (R, Q) policy - inventory level distribution 88**
 - 5.3.1 Distribution of the inventory position 88*
 - 5.3.2 An important relationship 90*
 - 5.3.3 Compound Poisson demand 90*
 - 5.3.4 Normally distributed demand 91*
- 5.4 Service levels 94**
- 5.5 Shortage costs 95**
- 5.6 Determining the safety stock for given S_1 96**
- 5.7 Fill rate and ready rate constraints 97**
 - 5.7.1 Compound Poisson demand 97*
 - 5.7.2 Normally distributed demand 98*
- 5.8 Fill rate - a different approach 99**
- 5.9 Shortage cost per unit and time unit 101**
 - 5.9.1 Compound Poisson demand 101*
 - 5.9.2 Normally distributed demand 103*
- 5.10 Shortage cost per unit 106**
- 5.11 Continuous review (s, S) policy 107**
- 5.12 Periodic review - fill rate 109**
 - 5.12.1 Basic assumptions 110*
 - 5.12.2 Compound Poisson demand - (R, Q) policy 111*
 - 5.12.3 Compound Poisson demand - (s, S) policy 112*
 - 5.12.4 Normally distributed demand - (R, Q) policy 113*
- 5.13 The newsboy model 114**
- 5.14 A model with lost sales 117**

5.15 Stochastic lead-times 119

5.15.1 *Two types of stochastic lead-times 119*

5.15.2 *Handling sequential deliveries independent of the lead-time demand 120*

5.15.3 *Handling independent lead-times 122*

5.15.4 *Comparison of the two types of stochastic lead-times 123*

References 124**Problems 126****6 SINGLE-ECHELON SYSTEMS:
INTEGRATION - OPTIMALITY 129****6.1 Joint optimization of order quantity and reorder point 129**

6.1.1 *Discrete demand 129*

6.1.1.1 *(R, Q) policy 130*

6.1.1.2 *(s, S) policy 132*

6.1.2 *An iterative technique 133*

6.1.3 *Fill rate constraint - a simple approach 135*

6.2 Optimality of ordering policies 137

6.2.1 *Optimality of (R, Q) policies when ordering in batches 138*

6.2.2 *Optimality of (s, S) policies 140*

**6.3 Updating order quantities and reorder points in practice
140****References 145****Problems 146****7 COORDINATED ORDERING 149****7.1 Powers-of-two policies 150****7.2 Production smoothing 154**

7.2.1 *The Economic Lot Scheduling Problem (ELSP) 155*

7.2.1.1 *Problem formulation 155*

7.2.1.2 *The independent solution 156*

7.2.1.3 *Common cycle time 157*

7.2.1.4 *Bomberger's approach 159*

7.2.1.5 *A simple heuristic 160*

7.2.1.6 *Other problem formulations 163*

7.2.2 *Time-varying demand 163*

7.2.2.1 *A generalization of the classical dynamic lot size problem 163*

7.2.2.2 *Application of mathematical programming approaches 170*

7.2.3 *Production smoothing and batch quantities 170*

7.3 Joint replenishments 172*7.3.1 A deterministic model 173**7.3.1.1 Approach 1. An iterative technique 174**7.3.1.2 Approach 2. Roundy's 98 percent approximation 176**7.3.2 A stochastic model 180***References 181****Problems 183****8 MULTI-ECHELON SYSTEMS:
STRUCTURES AND ORDERING POLICIES
187****8.1 Inventory systems in distribution and production 188***8.1.1 Distribution inventory systems 188**8.1.2 Production inventory systems 189**8.1.3 Repairable items 192**8.1.4 Lateral transshipments in inventory systems 192**8.1.5 Inventory models with remanufacturing 194***8.2 Different ordering systems 195***8.2.1 Installation stock reorder point policies and KANBAN policies
196**8.2.2 Echelon stock reorder point policies 197**8.2.3 Comparison of installation stock and echelon stock policies 198**8.2.4 Material Requirements Planning 204**8.2.5 Ordering system dynamics 213***References 215****Problems 217****9 MULTI-ECHELON SYSTEMS:
LOT SIZING 221****9.1 Identical order quantities 222***9.1.1 Infinite production rates 222**9.1.2 Finite production rates 223***9.2 Constant demand 225***9.2.1 A simple serial system with constant demand 225**9.2.2 Roundy's 98 percent approximation 230*

9.3 Time-varying demand 236*9.3.1 Sequential lot sizing 236**9.3.2 Sequential lot sizing with modified parameters 238**9.3.3 Other approaches 240**9.3.4 Concluding remarks 241***References 242****Problems 243****10 MULTI-ECHELON SYSTEMS:
REORDER POINTS 247****10.1 The Clark-Scarf model 248***10.1.1 Serial system 249**10.1.2 The Clark-Scarf approach for a distribution system 256***10.2 The METRIC approach for distribution systems 261****10.3 Two exact techniques 266***10.3.1 Disaggregation of warehouse backorders 266**10.3.2 A recursive procedure 267***10.4 Optimization of ordering policies 271****10.5 Batch-ordering policies 273***10.5.1 Serial system 273**10.5.2 Distribution system 276**10.5.2.1 Some basic results 277**10.5.2.2 METRIC type approximations 278**10.5.2.3 Disaggregation of warehouse backorders 279**10.5.2.4 Following supply units through the system 280**10.5.2.5 Practical considerations 280***10.6 Other assumptions 281***10.6.1 Guaranteed service model approach 281**10.6.2 Coordination and contracts 283**10.6.2.1 The newsboy problem with two firms 284**10.6.2.2 Wholesale-price contract 285**10.6.2.3 Buyback contract 286***References 287****Problems 291****11 IMPLEMENTATION 295****11.1 Preconditions for inventory control 295***11.1.1 Inventory records 296**11.1.1.1 Updating inventory records 296**11.1.1.2 Auditing and correcting inventory records 297**11.1.2 Performance evaluation 298*

11.2 Development and adjustments 299

11.2.1 Determine the needs 300

11.2.2 Selective inventory control 301

11.2.3 Model and reality 302

11.2.4 Step-by-step implementation 303

11.2.5 Simulation 304

11.2.6 Short-run consequences of adjustments 305

11.2.7 Education 306

References 307

APPENDIX 1

ANSWERS AND HINTS TO PROBLEMS 309

APPENDIX 2

NORMAL DISTRIBUTION TABLES 321

INDEX 325