

# Supply Chain Management Models: Forward, Reverse, Uncertain, and Intelligent

Foundations with Case Studies

**Hamed Fazlollahtabar**

Department of Industrial Engineering,  
College of Engineering, Damghan University,  
Damghan, Iran



**CRC Press**

Taylor & Francis Group

Boca Raton London New York

---

CRC Press is an imprint of the  
Taylor & Francis Group, an **informa** business

---

# Contents

---

Preface.....	xiii
Acknowledgments .....	xvii
Author .....	xix

## Section I Forward Supply Chain Models

<b>1 Multi-Layer Multi-Product Supply Chain: Strategic Marketing Model .....</b>	<b>3</b>
1.1 Introduction .....	3
1.2 Problem Definition.....	4
1.3 Strategic Marketing Model .....	4
1.3.1 Quantitative Strategic Planning Matrix (QSPM).....	10
1.3.2 Analytic Hierarchy Process (AHP).....	10
1.4 Discussions .....	15
References .....	15
<b>2 Multi-Layer and Multi-Product Supply Chain: Performance Evaluation Model....</b>	<b>17</b>
2.1 Introduction .....	17
2.2 Problem Definition.....	19
2.3 Data Mining Model .....	20
2.4 Discussions .....	22
References .....	23
<b>3 Multi-Layer Supply Chain: Mathematical Evaluation Model.....</b>	<b>25</b>
3.1 Introduction .....	25
3.2 Problem Definition.....	27
3.3 Mathematical Model for Performance Evaluation .....	27
3.3.1 Objective Functions .....	28
3.3.2 Constraints.....	29
3.4 An Example.....	30
3.5 Discussions .....	32
Bibliography .....	35
<b>4 Supply Chain Inventory Planning: System Dynamics Model .....</b>	<b>37</b>
4.1 Introduction .....	37
4.2 Problem Definition.....	39
4.3 System Dynamic Model .....	40
4.3.1 Dynamic Hypothesis.....	40
4.3.2 Casual-Loop Diagram (CLD) .....	41
4.3.3 Goal Seeking Loop of Sale–Inventory .....	41
4.3.4 Goal Seeking Loop of Transmission .....	41
4.3.5 Goal Seeking Loop of Transmission Material .....	42
4.3.6 Growth Loop of Sale-Transfer .....	43
4.3.7 Growth Loop of Sales-Production.....	43

4.3.8	State-Flow Diagram .....	43
4.4	Discussions .....	46
	References .....	46
<b>5</b>	<b>Supplier Evaluation: Six Sigma Model .....</b>	<b>47</b>
5.1	Introduction .....	47
5.2	Problem Definition.....	48
5.3	Process Control Model .....	49
5.3.1	Quality Control .....	49
5.3.2	C-Chart.....	50
5.3.3	Process Capability Index .....	50
5.3.4	Normalization Process.....	52
5.4	Discussions .....	53
	References .....	53
<b>6</b>	<b>Supplier Selection and Order Allocation: Process Performance Index.....</b>	<b>55</b>
6.1	Introduction .....	55
6.2	Problem Definition.....	57
6.3	Integrated Performance Evaluation Model .....	58
6.3.1	X-bar/S Chart.....	58
6.3.2	Process Performance Index .....	59
6.3.3	Objective Functions .....	60
6.3.4	The AHP.....	60
6.3.5	Construction of the Hierarchy .....	61
6.3.6	Priority Setting.....	61
6.3.7	Logical Consistency.....	62
6.3.8	Identify the Relationships and the Weights of Criteria with AHP.....	62
6.3.9	From Bi-Objective to Mono-Objective .....	65
6.4	Numerical Illustrations .....	66
6.5	Discussions .....	68
	References .....	69
<b>7</b>	<b>Supply Chain: Product Life Cycle Model.....</b>	<b>73</b>
7.1	Introduction .....	73
7.2	Problem Definition.....	76
7.3	Product Life Cycle Model .....	76
7.3.1	Objective Functions .....	77
7.3.2	Constraints.....	78
7.4	Discussions .....	80
	References .....	80
<b>8</b>	<b>Multi Echelon Supply Chain: CRM Model.....</b>	<b>83</b>
8.1	Introduction .....	83
8.2	Problem Definition.....	87
8.3	Integrated Customer Related Life Cycle Model.....	88
8.3.1	Objective Functions .....	89
8.3.2	Constraints.....	89
8.3.3	Linearization .....	90

8.3.4	Weighing the Objectives by AHP.....	91
8.3.5	Construction of the Hierarchy.....	91
8.3.6	Priority Setting.....	91
8.3.7	Consistency Check.....	92
8.4	Numerical Example.....	95
8.5	Discussions.....	100
	References.....	101
<b>9</b>	<b>Supply Chain: Activity-Based Costing, Pricing and Earned Value.....</b>	<b>103</b>
9.1	Introduction.....	103
9.2	Problem Definition.....	104
9.2.1	Activity Based Costing.....	105
9.2.2	Costs of Manufacturing.....	105
9.2.3	The Earned Value.....	105
9.3	Pricing Model.....	106
9.3.1	Calculate the Costs of Supply Chain Based on Activity Based Costing.....	107
9.3.2	Customer Demands.....	107
9.4	Discussions.....	107
	References.....	107
<b>10</b>	<b>Multi-Product Supply Chain: Customer Utility and Risk Model.....</b>	<b>109</b>
10.1	Introduction.....	109
10.2	Problem Definition.....	112
10.3	Utility-Based Model.....	112
10.3.1	Designing Cost Functions.....	112
10.3.2	Functions of Manpower Costs.....	112
10.3.3	The Function of Suppliers' Manpower Cost.....	112
10.3.4	The Function of Manufacturers' Manpower.....	113
10.3.5	Functions of Transportation Costs.....	113
10.3.6	Transportation Costs of Raw Materials from Suppliers to Manufacturers.....	113
10.3.7	The Function of Goods' Transportation Cost from Manufacturers to Consumers.....	114
10.3.8	Functions of Inventory Holding Costs.....	114
10.3.9	The Function of Raw Material Holding Costs by Suppliers.....	114
10.3.10	The Function of the Holding Cost of Products by Manufacturers.....	114
10.3.11	Function of Production Cost.....	115
10.3.12	Product Pricing Based on Customers' Demand and Willingness to Pay.....	115
10.3.13	The Function of Profit.....	116
10.3.14	Supply Chain Risk.....	116
10.3.15	Inflation Rate Risk.....	116
10.3.16	Exchange Rate Risk.....	116
10.3.17	Competitors Risk.....	117
10.3.18	The Risk of Lost Sales.....	117
10.3.19	The Function of Risk.....	117
10.4	Numerical Study.....	118

10.4.1	Supply Chain Costs .....	118
10.4.2	Calculation of the Customers' Favorable Prices .....	119
10.4.3	Calculating the Supply Chain Profit and the Risks .....	119
10.4.4	Calculating Supply Chain Favorable Price according to Supply Chain Profit Considering Risk .....	120
10.5	Discussions .....	121
	References .....	121
<b>11</b>	<b>Flexible Supply Network: VRP Model</b> .....	<b>123</b>
11.1	Introduction .....	123
11.2	Problem Definition .....	125
11.3	Vehicle Routing Model .....	125
11.3.1	Objective Function .....	127
11.3.2	Constraints .....	127
11.4	Numerical Illustrations .....	131
11.5	Discussions .....	133
	References .....	133
<b>12</b>	<b>Multi-Aspect Supply Chain: Depot-Customer-Depot Model</b> .....	<b>135</b>
12.1	Introduction .....	135
12.2	Problem Definition .....	137
12.3	Returning Vehicle Model .....	138
12.3.1	Objective Function .....	139
12.3.2	Constraints .....	140
12.3.3	Linearization .....	142
12.4	Numerical Illustration .....	143
12.5	Discussions .....	143
	References .....	149
<b>13</b>	<b>Food Supply Chain: Two-Stage Model</b> .....	<b>151</b>
13.1	Introduction .....	151
13.2	Problem Definition .....	152
13.3	Bi-Stage Model .....	152
13.3.1	Stage 1: Location-Allocation .....	155
13.3.1.1	Objective Function .....	155
13.3.1.2	Constraints .....	155
13.3.2	Stage 2: MDMTSP .....	156
13.3.2.1	Objective Function .....	156
13.3.2.2	Constraints .....	156
13.4	Numerical Illustration .....	157
13.5	Discussions .....	160
	References .....	160
<b>14</b>	<b>Multi-Period Food Supply Chain: Time-Windows Model</b> .....	<b>161</b>
14.1	Introduction .....	161
14.2	Problem Definition .....	163
14.3	Time-Windows Model .....	166
14.3.1	Objective Function .....	168
14.3.2	Constraints .....	168
14.4	Numerical Example .....	170

14.5 Discussions ..... 172  
 References ..... 172

**Section II Reverse Supply Chain Models**

**15 Return Items in a Multi-Layer Multi-Product Reverse Supply Chain:**  
**Clustering Model..... 177**  
 15.1 Introduction ..... 177  
 15.2 Problem Definition..... 179  
 15.3 Return Items’ Clustering Model ..... 180  
 15.4 Application Study ..... 182  
 15.5 Discussions ..... 187  
 References ..... 187

**16 Sustainable Reverse Supply Chain: Customer Requirement Fulfillment Model....189**  
 16.1 Introduction ..... 189  
 16.2 Problem Definition..... 191  
 16.3 Customers’ Requirement Model ..... 192  
     16.3.1 Sampling by Using STRATA Method ..... 195  
     16.3.2 Average Factors Weight..... 196  
     16.3.3 *k*-Means Algorithm ..... 196  
 16.4 Application Study ..... 197  
     16.4.1 Results of *k*-means Algorithm ..... 197  
     16.4.2 Calculation and Determining the Mathematical Model Parameters... 198  
     16.4.3 Using AHP for Multi-Objective Optimization ..... 200  
     16.4.4 Mathematical Model Results..... 200  
 16.5 Discussions ..... 201  
 References ..... 202

**17 Multi-Layer Multi-Product Reverse Supply Chain: Defects and Pricing Model..... 203**  
 17.1 Introduction ..... 203  
 17.2 Problem Definition..... 205  
 17.3 Defect Model..... 207  
     17.3.1 The Mathematical Model..... 208  
     17.3.2 The Willingness to Pay Function..... 209  
 17.4 Computational Results ..... 210  
     17.4.1 The Model Solutions..... 213  
     17.4.2 The Decision Variables ..... 213  
 17.5 Discussions ..... 214  
 References ..... 215

**18 Reverse Supply Chain Vehicle Routing Problem: Similarity Pattern Model ..... 217**  
 18.1 Introduction ..... 217  
 18.2 Problem Definition..... 219  
 18.3 Similarity Pattern Model..... 221  
 18.4 Computational Results ..... 223  
 18.5 Discussions ..... 224  
 References ..... 225

<b>19 Reverse Supply Chain: Waste Pricing Model</b> .....	227
19.1 Introduction.....	227
19.1.1 Reverse Supply Network.....	228
19.1.2 Framework for Remanufacturing.....	229
19.2 Problem Definition.....	230
19.3 Waste Collection Model.....	231
19.3.1 Pricing.....	234
19.4 Illustrative Example.....	235
19.5 Discussions.....	240
References.....	241
<b>20 Multiple Item Reverse Supply Chain: Comprehensive Mathematical Model</b> .....	243
20.1 Introduction.....	243
20.2 Problem Definition.....	245
20.3 Proposed Comprehensive Model.....	246
20.3.1 Mathematical Formulation.....	248
20.3.2 Objective Function.....	251
20.3.3 Constraints.....	252
20.4 Analytical Example.....	253
20.5 Discussions.....	257
References.....	257
 <b>Section III Uncertain and Intelligent Supply Chain Models</b>	
<b>21 Multi-Layer Electronic Supply Chain: Intelligent Information System</b> .....	261
21.1 Introduction.....	261
21.2 Problem Definition.....	263
21.3 Intelligent Model.....	264
21.3.1 Clustering Algorithms.....	265
21.3.2 Distance Measure.....	266
21.4 Discussions.....	269
References.....	269
<b>22 Multi-Layer Electronic Supply Chain: Agent-Based Model</b> .....	271
22.1 Introduction.....	271
22.2 Problem Definition.....	272
22.3 Agent-Based Model.....	273
22.3.1 Agent-Based Supplier Layer.....	273
22.3.2 Agent-Based Manufacturer Layer.....	273
22.3.3 Agent-Based Distributor-Retailer Layer.....	274
22.3.4 Agent-Based Retailer-Customer Layer.....	274
22.4 Discussions.....	275
References.....	277
<b>23 Multi-Layer Electronic Supply Chain: Dynamic Route Selection in an Agent Model</b> .....	279
23.1 Introduction.....	279
23.2 Problem Definition.....	280
23.3 Route Selection Model.....	281

23.3.1	Information Flow Interaction.....	281
23.3.2	Element Scoring Threshold .....	284
23.3.3	A Dynamic Program for the Optimal Route .....	285
23.4	Numerical Example .....	286
23.5	Discussions .....	289
	References .....	289
<b>24</b>	<b>Electronic Supply Chain Management System: Electronic Market, Customer Satisfaction, and Logistic Model .....</b>	<b>291</b>
24.1	Introduction .....	291
24.2	Problem Definition.....	292
24.3	Web-Based Model .....	294
24.4	Numerical Illustration.....	299
24.4.1	Input Data .....	299
24.5	Discussions .....	301
	References .....	303
<b>25</b>	<b>Electronic Supply Chain System: Fuzzy Logistic Model .....</b>	<b>305</b>
25.1	Introduction.....	305
25.1.1	Ranking Function .....	305
25.2	Problem Definition.....	306
25.3	Fuzzy Logistic Model.....	306
25.3.1	Mathematical Model.....	307
25.4	Discussions .....	310
	References .....	311
<b>26</b>	<b>Multiple Supply Network: Fuzzy Mathematical Programming Model.....</b>	<b>313</b>
26.1	Introduction .....	313
26.2	Problem Definition.....	314
26.3	Fuzzy Mathematical Model.....	316
26.3.1	Fuzzy Mathematical Programming.....	316
26.3.2	Objective Functions .....	317
26.3.3	Constraints.....	317
26.4	Comprehensive Example .....	321
26.5	Discussions .....	339
	References .....	339
<b>27</b>	<b>Facilities Relocation Problem in Supply Chain: Genetic Optimization Model ...</b>	<b>341</b>
27.1	Introduction .....	341
27.2	Problem Definition.....	343
27.3	Genetic Algorithm Model.....	345
27.3.1	Objective Function.....	347
27.3.2	Optimization by Genetic Algorithm.....	351
27.4	Discussions .....	352
	References .....	354
<b>28</b>	<b>Reconfigurable Supply Chain: Immunity-Based Control Model.....</b>	<b>357</b>
28.1	Introduction .....	357
28.2	Problem Description.....	358
28.2.1	Artificial Immune Systems.....	358



28.3	Immunity-Based Model .....	359
28.3.1	An Immunity-Based Control Framework .....	360
28.3.2	The Control Framework.....	361
28.3.3	Strategic Behavioral Control for Facilities Relocation .....	364
28.3.4	The Algorithm.....	366
28.4	Discussions .....	368
	References .....	368
<b>Index</b>	.....	<b>371</b>