

# Contents

## Part I Bi-level Decision Making

<b>1</b>	<b>Decision Making and Decision Support Systems . . . . .</b>	<b>3</b>
1.1	Organizational Decision Making . . . . .	3
1.2	Classification for Decision Problems and Techniques . . . . .	4
1.2.1	Decision Problem Classification . . . . .	4
1.2.2	Decision Support Technique Classification . . . . .	5
1.3	Main Decision Support Techniques . . . . .	6
1.3.1	Mathematical Programming . . . . .	7
1.3.2	Multi-criteria Decision Making . . . . .	8
1.3.3	Case-Based Reasoning . . . . .	10
1.3.4	Data Warehouse and Data Mining . . . . .	11
1.3.5	Decision Tree . . . . .	12
1.3.6	Fuzzy Sets and Systems . . . . .	13
1.4	Decision Support Systems . . . . .	13
1.4.1	Concepts . . . . .	14
1.4.2	Characteristics . . . . .	15
1.4.3	Components . . . . .	15
1.5	DSS Classification . . . . .	17
1.5.1	Model-Driven DSS . . . . .	17
1.5.2	Data-Driven DSS . . . . .	17
1.5.3	Knowledge-Driven DSS or Intelligent DSS . . . . .	18
1.5.4	Group DSS . . . . .	19
1.5.5	Web-Based DSS . . . . .	19
1.6	DSS Software Illustration . . . . .	20
1.6.1	Case 1: Decider . . . . .	20
1.6.2	Case 2: A DSS for Ore Blending Cost Optimization of Blast Furnaces . . . . .	21
1.7	Summary . . . . .	24

<b>2</b>	<b>Optimization Models</b>	<b>25</b>
2.1	Concepts	25
2.2	Linear Programming	28
2.3	Non-linear Programming	29
2.3.1	Varieties of Non-linear Programming	29
2.3.2	Theories and Optimality Conditions of Non-linear Programming	30
2.3.3	Methods for Solving Non-linear Programming Problems	31
2.4	Multi-objective Programming	32
2.4.1	Multi-objective Programming Model	32
2.4.2	Multi-objective Linear Programming Methods	34
2.4.3	A Case-Based Example	36
2.5	Goal Programming	37
2.6	Stackelberg Game Model	41
2.6.1	Stackelberg Game and Bi-level Programming	42
2.6.2	Stackelberg Game and Nash Game	43
2.6.3	Applications of Stackelberg Games	43
2.7	Particle Swarm Optimization	44
2.8	Summary	46
<b>3</b>	<b>Bi-level Programming Models and Algorithms</b>	<b>47</b>
3.1	Bi-level Programming Model	47
3.2	Solution Theories for Linear Bi-level Programming	49
3.3	Kth-Best Algorithm for Linear Bi-level Programming	53
3.4	Kuhn-Tucker Approach for Linear Bi-level Programming	55
3.5	Branch-and-Bound Algorithm for Linear Bi-level Programming	57
3.6	Penalty Function Method for Linear Bi-level Programming	59
3.7	Multi-level Programming Model	61
3.8	Summary	62

## **Part II Multi-level Multi-follower Decision Making**

<b>4</b>	<b>Bi-level Multi-follower Decision Making</b>	<b>65</b>
4.1	Problem Identification	65
4.2	Framework for Bi-level Multi-follower Decision Making	66
4.3	Bi-level Multi-follower Decision Models	68
4.3.1	BLMF Decision Entity-Relationship Diagram	68
4.3.2	Linear BLMF Decision Models	68
4.4	Uncooperative Bi-level Multi-follower Decision Making	76
4.4.1	Solution Concepts	76
4.4.2	Theoretical Properties	77

4.4.3	Uncooperative BLMF <i>K</i> th-Best Algorithm . . . . .	79
4.4.4	Uncooperative BLMF Kuhn-Tucker Approach . . . . .	83
4.5	Semi-cooperative Bi-level Multi-follower Decision Making . . .	85
4.5.1	Solution Concepts . . . . .	86
4.5.2	Theoretical Properties . . . . .	87
4.5.3	Semi-cooperative BLMF <i>K</i> th-Best Algorithm . . . . .	87
4.5.4	Semi-cooperative BLMF Kuhn-Tucker Approach . . . . .	89
4.6	Reference-Uncooperative Bi-level Multi-follower Decision Making . . . . .	91
4.6.1	Solution Concepts . . . . .	91
4.6.2	Theoretical Properties . . . . .	93
4.6.3	Reference-Uncooperative BLMF <i>K</i> th-Best Algorithm . . . . .	95
4.6.4	Reference-Uncooperative BLMF Kuhn-Tucker Approach . . . . .	102
4.7	Summary . . . . .	104
5	<b>Bi-level Multi-leader Decision Making . . . . .</b>	<b>105</b>
5.1	Problem Identification . . . . .	105
5.2	Framework for Bi-level Multi-leader Decision Making . . . . .	106
5.3	Linear Bi-level Multi-leader Decision Models . . . . .	107
5.4	Concepts and Definitions . . . . .	112
5.5	Generalized Nash Equilibrium Solution . . . . .	114
5.6	BLML Particle Swarm Optimization Algorithm . . . . .	115
5.7	A Numerical Example . . . . .	118
5.8	Summary . . . . .	120
6	<b>Tri-level Multi-follower Decision Making . . . . .</b>	<b>121</b>
6.1	Problem Identification . . . . .	122
6.2	Basic Tri-level Decision Models . . . . .	123
6.3	Tri-level Multi-follower Decision Framework . . . . .	125
6.3.1	TLMF Decision Concepts . . . . .	125
6.3.2	TLMF Decision Problem Classification . . . . .	126
6.3.3	TLMF Decision Framework . . . . .	127
6.3.4	TLMF Decision Entity-Relationship Diagrams . . . . .	127
6.4	Tri-level Multi-follower Decision Models . . . . .	133
6.4.1	General Model for TLMF Decision . . . . .	133
6.4.2	Typical Standard Models for TLMF Decision . . . . .	134
6.4.3	Hybrid TLMF Decision Models . . . . .	142
6.5	Case Studies for TLMF Decision Modeling . . . . .	144
6.5.1	Case 1: S28 Model . . . . .	144
6.5.2	Case 2: S27 Model . . . . .	147
6.5.3	Case 3: S54 Model . . . . .	148
6.5.4	Case 4: Hybrid of S41, S45 and S48 Models . . . . .	150

6.6	Tri-level Decision Solution Methods . . . . .	151
6.6.1	Solution Concepts . . . . .	151
6.6.2	Theoretical Properties . . . . .	153
6.6.3	Tri-level <i>K</i> th-Best Algorithm . . . . .	155
6.6.4	A Numerical Example . . . . .	157
6.7	Tri-level Multi-follower Decision Solution Methods . . . . .	159
6.7.1	Solution Concepts . . . . .	159
6.7.2	Theoretical Properties . . . . .	162
6.7.3	TLMF <i>K</i> th-Best Algorithm. . . . .	165
6.7.4	A Numerical Example . . . . .	167
6.8	Summary . . . . .	170

### Part III Fuzzy Multi-level Decision Making

<b>7</b>	<b>Fuzzy Bi-level Decision Making . . . . .</b>	<b>175</b>
7.1	Problem Identification . . . . .	175
7.2	Fuzzy Sets and Systems. . . . .	176
7.2.1	Fuzzy Sets . . . . .	177
7.2.2	Fuzzy Numbers . . . . .	178
7.3	Fuzzy Bi-level Decision Models . . . . .	183
7.4	Fuzzy Approximation <i>K</i> th-Best Algorithm . . . . .	188
7.4.1	Property and Algorithm . . . . .	188
7.4.2	Illustrative Examples . . . . .	197
7.5	Fuzzy Multi-Follower Approximation <i>K</i> th-Best Algorithm . . . . .	201
7.6	Summary . . . . .	205
<b>8</b>	<b>Fuzzy Multi-objective Bi-level Decision Making . . . . .</b>	<b>207</b>
8.1	Problem Identification . . . . .	207
8.2	Fuzzy Multi-objective Bi-level Decision Model . . . . .	208
8.3	Fuzzy Approximation Kuhn-Tucker Approach . . . . .	219
8.3.1	Fuzzy Approximation Kuhn-Tucker Approach . . . . .	220
8.3.2	A Case-Based Example . . . . .	220
8.4	Summary . . . . .	228
<b>9</b>	<b>Fuzzy Multi-objective Bi-level Goal Programming . . . . .</b>	<b>229</b>
9.1	Problem Identification . . . . .	229
9.2	Solution Concepts . . . . .	230
9.3	Fuzzy Bi-level Goal-Programming Algorithm . . . . .	241
9.4	A Numerical Example and Experiments. . . . .	242
9.4.1	A Numerical Example . . . . .	242
9.4.2	Experiments and Evaluation . . . . .	246
9.5	Summary . . . . .	247

**Part IV Rule-set-based Bi-level Decision Making**

**10 Rule-Set-Based Bi-level Decision Making . . . . . 251**

10.1 Problem Identification . . . . . 251

10.2 Information Tables and Rule-Sets . . . . . 252

10.2.1 Information Tables . . . . . 252

10.2.2 Formulas and Rules . . . . . 253

10.2.3 Decision Rule Set Function . . . . . 255

10.2.4 Rule Trees . . . . . 256

10.2.5 Rules Comparison. . . . . 258

10.3 Rule-Set-Based Bi-level Decision Model . . . . . 260

10.3.1 Objectives . . . . . 260

10.3.2 Constraints. . . . . 261

10.3.3 Rule-Set-Based Bi-level Decision Model . . . . . 261

10.4 Rule-Set-Based Bi-level Decision Modeling Approach. . . . . 262

10.5 Rule-Set-Based Bi-level Decision Solution Algorithms . . . . . 264

10.5.1 Concepts and Properties. . . . . 264

10.5.2 Rule-Based-Based Solution Algorithm. . . . . 265

10.5.3 Transformation-Based Solution Algorithm . . . . . 268

10.6 A Case Study. . . . . 273

10.6.1 Problem Modeling . . . . . 273

10.6.2 Solution. . . . . 276

10.7 Experiments and Analysis . . . . . 283

10.8 Summary . . . . . 286

**Part V Multi-level Decision Support Systems and Applications**

**11 Fuzzy Bi-level and Tri-level Decision Support Systems . . . . . 289**

11.1 A Fuzzy Bi-level Decision Support System . . . . . 289

11.1.1 System Configuration and Interfaces . . . . . 290

11.1.2 System Structure. . . . . 291

11.1.3 Linear Bi-level Decision Support Process. . . . . 293

11.1.4 Non-linear Bi-level Decision Support Process. . . . . 302

11.2 A Tri-level Decision Support System. . . . . 306

11.2.1 System Configuration and Tri-level Decision  
Support Process . . . . . 306

11.2.2 Detailed Operational Process  
and System Interface . . . . . 309

11.3 Summary . . . . . 314

<b>12</b>	<b>Bi-level Programming for Competitive Strategic Bidding Optimization in Electricity Markets . . . . .</b>	<b>315</b>
12.1	Background . . . . .	315
12.2	Bidding Strategy Analysis in Competitive Electricity Markets . . . . .	316
12.2.1	Strategic Pricing Model for Power Plants . . . . .	317
12.2.2	Generation Output Dispatch Model for Market Operator . . . . .	318
12.3	BLML Decision Model in Competitive Electricity Markets . . .	319
12.4	A Case Study . . . . .	320
12.4.1	Test Data . . . . .	320
12.4.2	Experiment Results . . . . .	321
12.4.3	Experiment Analysis . . . . .	323
12.5	Summary . . . . .	324
<b>13</b>	<b>Bi-level Pricing and Replenishment in Supply Chains . . . . .</b>	<b>325</b>
13.1	Background . . . . .	325
13.2	Case Study 1: Hi-tech Product Pricing and Replenishment Strategy Making . . . . .	326
13.2.1	Problem Formulation . . . . .	326
13.2.2	Experiments . . . . .	331
13.3	Case Study 2: Hi-tech Product Pricing and Replenishment Strategy Making with Weekly Decline-Rates . . . . .	332
13.3.1	Problem Formulation . . . . .	332
13.3.2	Experiments . . . . .	334
13.4	Summary . . . . .	336
<b>14</b>	<b>Bi-level Decision Making in Railway Transportation Management . . . . .</b>	<b>337</b>
14.1	Case Study 1: Train Set Organization . . . . .	337
14.1.1	Background . . . . .	337
14.1.2	Problem Formulation . . . . .	340
14.1.3	Experiments . . . . .	342
14.2	Case Study 2: Railway Wagon Flow Management . . . . .	344
14.2.1	Background . . . . .	344
14.2.2	Problem Formulation . . . . .	345
14.2.3	Experiments . . . . .	355
14.3	Summary . . . . .	356
	<b>References . . . . .</b>	<b>357</b>