

Contents

1	Introduction	1
1.1	A first look at multilevel systems analysis	1
1.2	The multilevel character of systems	3
1.3	The historical development of multilevel systems analysis	4
1.4	Overview of the volume	6
	References	9
2	Fundamental Concepts	10
2.1	The idealized multilevel approach	10
	2.1.1 <i>Partitioning the overall problem into subproblems</i> , 10	
	2.1.2 <i>Examples of two-level subproblem hierarchies</i> , 12	
	2.1.3 <i>The multilevel solution process</i> , 17	
2.2	Additional aspects of multilevel systems analysis	19
	2.2.1 <i>A more general multilevel approach</i> , 19	
	2.2.2 <i>Institutional interpretations and analogies</i> , 22	
	2.2.3 <i>Related concepts</i> , 23	
	References	25
3	Multilevel Solution Methods	27
3.1	Introduction and overview	27
3.2	Column generation	28
	3.2.1 <i>General discussion</i> , 28	
	3.2.2 <i>The maximal multicommodity network flow problem</i> , 31	
	3.2.3 <i>Solution by column generation</i> , 33	
3.3	The Dantzig–Wolfe decomposition method for linear programs	36
	3.3.1 <i>The representation of a polyhedral convex set</i> , 37	

3.3.2	<i>An outline of the Dantzig–Wolfe decomposition method,</i>	37
3.3.3	<i>Linear programming problems with unbounded solutions,</i>	41
3.3.4	<i>A numerical example,</i>	43
3.3.5	<i>Some further remarks on the Dantzig–Wolfe decomposition method,</i>	45
3.3.6	<i>Block-angular structures,</i>	48
3.4	The Dantzig–Wolfe method for nonlinear programs	54
3.5	The Benders algorithm and some extensions	56
3.5.1	<i>An outline of the Benders algorithm,</i>	56
3.5.2	<i>A note on Step 2 of the Benders algorithm,</i>	61
3.5.3	<i>A numerical example,</i>	63
3.5.4	<i>The application of the Benders algorithm to block-angular structures,</i>	66
3.5.5	<i>On the relation between the Benders and Dantzig–Wolfe algorithms,</i>	69
3.6	The Kornai–Liptak decomposition algorithm	70
3.7	Lagrangean decomposition in nonlinear programming	72
3.7.1	<i>Lagrangean decomposition for separable mathematical programming problems,</i>	73
3.7.2	<i>Duality theory and Lagrangean decomposition,</i>	75
3.8	Heuristic methods	76
3.9	Multilevel control theory: a brief survey	76
3.9.1	<i>Static multilevel control problems,</i>	77
3.9.2	<i>Dynamic open-loop multilevel control,</i>	78
3.9.3	<i>On-line control models,</i>	81
	References	81
4	Numerical Experiences with Dantzig–Wolfe decomposition	84
4.1	On the utilization of structure in solving linear programming problems	84
4.2	Test problem experiences	86
	References	97
5	National and Regional Economic Planning	99
5.1	Introduction and overview	99
5.2	Multilevel national economic planning in Hungary	101
5.2.1	<i>The application of the Kornai–Liptak method to a national economic planning problem,</i>	101
5.2.2	<i>The application of man–machine planning to the 1966–1970 5-year plan,</i>	105
5.2.3	<i>Concluding remarks,</i>	111

5.3	Multilevel national economic planning in Mexico	112
5.3.1	<i>Introduction</i> , 112	
5.3.2	<i>DINAMICO</i> , 115	
5.3.3	<i>ENERGETICOS</i> , 117	
5.3.4	<i>Linkages between DINAMICO and ENERGETICOS</i> , 120	
5.3.5	<i>Conclusions and comparison with multilevel national economic planning in Hungary</i> , 123	
5.4	A problem of regional planning	125
5.4.1	<i>The development network</i> , 125	
5.4.2	<i>An LP model for resource production</i> , 127	
5.4.3	<i>The overall problem and a two-level solution method</i> , 128	
5.4.4	<i>Discussion of the two-level method for regional planning</i> , 129	
	References	130
6	Planning of Production and Sales Programs in Corporations	132
6.1	Introduction	132
6.1.1	<i>The planning problem</i> , 132	
6.1.2	<i>Planning procedures based on decomposition methods</i> , 133	
6.2	A simulation study of a planning procedure based on the Dantzig–Wolfe method in a paperboard factory	137
6.2.1	<i>The planning problem of the paperboard factory</i> , 137	
6.2.2	<i>Information dispersal and information flows</i> , 140	
6.2.3	<i>The simulation experiment</i> , 141	
6.2.4	<i>Implementation of the plan</i> , 142	
6.2.5	<i>Some conclusions</i> , 144	
6.3	A simulation study of planning procedures based on the Dantzig–Wolfe and ten Kate methods in a slaughterhouse	145
6.3.1	<i>The planning problem of the slaughterhouse</i> , 145	
6.3.2	<i>Simulated results using the Dantzig–Wolfe method as a planning procedure</i> , 147	
6.3.3	<i>Simulated results using the ten Kate method as a planning procedure</i> , 149	
6.3.4	<i>Some conclusions</i> , 152	
6.4	Final remarks on planning procedures based on decomposition methods	153
	References	154
7	Operations Management	156
7.1	Introduction and overview	156
7.2	A column generation approach	158
7.2.1	<i>An approximating LP problem</i> , 158	

7.2.2	<i>Generation of dominant schedules and a two-level algorithm, 159</i>	
7.2.3	<i>Applications, 161</i>	
7.3	Hierarchical production planning	162
7.3.1	<i>Introduction to hierarchical production planning, 162</i>	
7.3.2	<i>A three-level disaggregation scheme, 162</i>	
7.3.3	<i>The product-type-level subproblem, 163</i>	
7.3.4	<i>The item-family-level subproblems, 164</i>	
7.3.5	<i>The item-level subproblems, 168</i>	
7.3.6	<i>A three-level solution procedure, 168</i>	
7.3.7	<i>Applications and a comparison with column generation, 170</i>	
	References	171
8	Distribution Systems	172
8.1	Introduction and overview	172
8.2	The optimal design of a distribution system	173
8.2.1	<i>A mixed-integer programming formulation, 173</i>	
8.2.2	<i>Application of the Benders algorithm, 174</i>	
8.2.3	<i>The implementation of Geoffrion and Graves, 176</i>	
8.3	Determining optimal production–distribution programs	179
8.3.1	<i>A network flow formulation, 179</i>	
8.3.2	<i>A column generation method, 180</i>	
8.3.3	<i>The implementation of Folie and Tiffin, 181</i>	
	References	181
9.	Freight Ship Route Scheduling and Electricity Generation	183
9.1	Introduction and overview	183
9.2	Freight ship route scheduling	183
9.2.1	<i>Problem formulation, 183</i>	
9.2.2	<i>The generation of ship itineraries, 185</i>	
9.2.3	<i>A column generation scheme, 187</i>	
9.2.4	<i>A three-level method, 189</i>	
9.3	Planning power generation	190
9.3.1	<i>Problem formulation, 190</i>	
9.3.2	<i>Application of the Dantzig–Wolfe method, 191</i>	
	References	193
10	Water Pollution Control	194
10.1	Introduction and overview	194
10.2	The Miami River case	195
10.2.1	<i>The overall problem, 195</i>	

	10.2.2	<i>A planning procedure based on Dantzig–Wolfe decomposition</i> , 197	
	10.2.3	<i>A Lagrangean solution method</i> , 200	
10.3		Concluding remarks	202
		References	203
11		Conclusion	205
	11.1	Problem structures and solution methods	205
	11.2	An evaluation of the usefulness of multilevel methods	208
	11.3	A final word	213
		References	213
		Index	215