
Contents

Preface	xi
Author Biography	xiii
1 Introduction and Purpose	1
1.1 Operations Planning	1
1.2 Mixed Integer Optimization	2
1.3 Optimization Models in Operations Planning	4
2 The Knapsack Problem	7
2.1 Introduction	7
2.2 Knapsack Problem 0-1 Programming Formulation	8
2.2.1 Relation to the subset sum problem	11
2.3 Linear Relaxation of the 0-1 Knapsack Problem	11
2.4 Asymptotically Optimal Heuristic	15
2.5 Fast Approximation Algorithm	17
2.6 Valid Inequalities	19
2.7 Review	23
3 Set Covering, Packing, and Partitioning Problems	25
3.1 Introduction	25
3.2 Problem Definition and Formulation	26
3.3 Solution Methods	27
3.3.1 Bin packing heuristics	28
3.3.2 Column generation and the set partitioning problem	29
3.3.3 Branch-and-price for the set partitioning problem	33
3.4 Review	37
4 The Generalized Assignment Problem	39
4.1 Introduction	39
4.2 GAP Problem Definition and Formulation	40
4.3 Lagrangian Relaxation Technique	41
4.3.1 Lagrangian relaxation for the GAP	46

4.4	Branch-and-Price for the GAP	47
4.5	Greedy Algorithms and Asymptotic Optimality	49
4.6	Review	54
5	Uncapacitated Economic Lot Sizing Problems	57
5.1	Introduction	57
5.2	The Basic UELSP Model	58
5.2.1	Fixed-charge network flow interpretation	59
5.2.2	Dynamic programming solution method	61
5.3	Tight Reformulation of UELSP	62
5.3.1	Lagrangian relaxation shows a tight formulation	63
5.4	An $\mathcal{O}(T \log T)$ Algorithm for the UELSP	65
5.5	Implications of Backordering	69
5.6	Review	71
6	Capacitated Lot Sizing Problems	73
6.1	Introduction	73
6.2	Capacitated Lot Sizing Formulation	74
6.3	Relation to the 0-1 Knapsack Problem	75
6.3.1	Fixed-charge network flow interpretation	76
6.3.2	Dynamic programming approach	77
6.4	The Equal-Capacity Case	78
6.5	FPTAS for Capacitated Lot Sizing	80
6.5.1	Structure of the dynamic programming approach	80
6.5.2	Approximation of the dynamic program	83
6.6	Valid Inequalities for the CELSP	85
6.6.1	(S, l) inequalities	86
6.6.2	Facets for the equal-capacity CELSP	87
6.6.3	Generalized flow-cover inequalities	90
6.7	Review	93
7	Multistage Production and Distribution Planning Problems	95
7.1	Introduction	95
7.2	Models with Dynamic Demand	97
7.2.1	Serial systems with dynamic demand	97
7.2.2	Production networks with non-speculative costs	101
7.2.3	Constant-factor approximations for special cases	105
7.3	Models with Constant Demand Rates	112
7.3.1	Stationary, nested, power-of-two policies	114
7.3.2	The joint replenishment problem	128
7.3.3	The one-warehouse multi-retailer problem	130
7.4	Review	134

8 Discrete Facility Location Problems	137
8.1 Introduction	137
8.2 Relation to Previous Models in this Book	138
8.2.1 Cost-minimizing version of the FLP	141
8.2.2 Relationship of the FLP to lot sizing problems	141
8.2.3 Single-sourcing version of the FLP and the GAP	142
8.2.4 Set covering and FLP complexity	142
8.3 Dual-Ascent Method for the Uncapacitated FLP	143
8.4 Approximation Algorithms for the Metric UFLP	148
8.4.1 Randomization and derandomization	151
8.5 Solution Methods for the General FLP	154
8.5.1 Lagrangian relaxation for the FLP	154
8.5.2 Valid inequalities for the FLP	157
8.5.3 Approximation algorithms for the FLP	162
8.6 Review	165
9 Vehicle Routing and Traveling Salesman Problems	167
9.1 Introduction	167
9.2 The TSP Graph and Complexity	168
9.3 Formulating the TSP as an Optimization Problem	170
9.4 Comb Inequalities	173
9.5 Heuristic Solutions for the TSP	175
9.5.1 Nearest neighbor heuristic	175
9.5.2 The sweep method	177
9.5.3 Minimum spanning tree based methods	179
9.5.4 Local improvement methods	182
9.6 The Vehicle Routing Problem	182
9.6.1 Exact solution of the VRP via branch-and-price	183
9.6.2 A GAP-based heuristic solution approach for the VRP	185
9.6.3 The Clarke-Wright savings heuristic method	187
9.6.4 Additional heuristic methods for the VRP	190
9.7 Review	191
Bibliography	193
Index	201