

Contents

Preface	vii
1 Classification of Scheduling Problems	1
1.1 Scheduling Problems	1
1.2 Job Data	2
1.3 Job Characteristics	3
1.4 Machine Environment	5
1.5 Optimality Criteria	6
1.6 Examples	7
2 Some Problems in Combinatorial Optimization	11
2.1 Linear and Integer Programming	11
2.2 Transshipment Problems	12
2.3 The Maximum Flow Problem	13
2.4 Bipartite Matching Problems	14
2.5 The Assignment Problem	18
2.6 Arc Coloring of Bipartite Graphs	23
2.7 Shortest Path Problems and Dynamic Programming	26
3 Computational Complexity	37
3.1 The Classes \mathcal{P} and \mathcal{NP}	37
3.2 \mathcal{NP} -complete and \mathcal{NP} -hard Problems	41
3.3 Simple Reductions Between Scheduling Problems	48
3.4 Living with \mathcal{NP} -hard Problems	50
3.4.1 Local Search Techniques	51

3.4.2	Branch-and-Bound Algorithms	56
4	Single Machine Scheduling Problems	61
4.1	Minimax Criteria	62
4.1.1	Lawler's Algorithm for $1 prec f_{\max}$	62
4.1.2	$1 prec; p_j = 1; r_j f_{\max}$ and $1 prec; pmtn; r_j f_{\max}$	63
4.2	Maximum Lateness and Related Criteria	67
4.3	Total Weighted Completion Time	73
4.3.1	$1 tree \sum w_j C_j$	73
4.3.2	$1 sp\text{-graph} \sum w_j C_j$	80
4.4	Weighted Number of Late Jobs	85
4.4.1	$1 r_j; p_j = 1 \sum w_j U_j$	85
4.4.2	$1 p_j = 1 \sum w_j U_j$	85
4.4.3	$1 \sum U_j$	86
4.4.4	$1 r_j; pmtn \sum w_j U_j$	89
4.5	Total Weighted Tardiness	94
4.6	Problems with Release Times and Identical Processing Times	98
4.6.1	$1 r_j; p_j = p \sum w_j U_j$	98
4.6.2	$1 r_j; p_j = p \sum w_j C_j$ and $1 r_j; p_j = p \sum T_j$. .	102
4.7	Complexity of Single Machine Problems	104
5	Parallel Machines	107
5.1	Independent Jobs	107
5.1.1	Identical Machines	107
5.1.2	Uniform Machines	124
5.1.3	Unrelated Machines	136
5.2	Jobs with Precedence Constraints	139
5.2.1	$P tree; p_i = 1 L_{\max}$ -Problems	139
5.2.2	Problem $P2 prec; p_i = 1 L_{\max}$	145
5.3	Complexity Results	150

6	Shop Scheduling Problems	155
6.1	The Disjunctive Graph Model	156
6.2	Open Shop Problems	158
6.2.1	Arbitrary Processing Times	158
6.2.2	Unit Processing Times	161
6.3	Flow Shop Problems	174
6.3.1	Minimizing Makespan	175
6.4	Job Shop Problems	179
6.4.1	Problems with Two Machines	179
6.4.2	Problems with Two Jobs. A Geometric Approach	187
6.4.3	Job Shop Problems with Two Machines	196
6.4.4	A Branch-and-Bound Algorithm	202
6.4.5	Applying Tabu-Search to the Job Shop Problem .	221
6.5	Mixed Shop Problems	226
6.5.1	Problems with Two Machines	226
6.5.2	Problems with Two Jobs	227
6.6	Complexity of Shop Scheduling Problems	232
7	Due-Date Scheduling	241
7.1	Problem 1 $ d_{opt} \sum w_i L_{\sigma(i)} + w_0 \cdot d$	242
7.2	Problem 1 $ d_{opt} w_E \sum E_i + w_T \sum T_i + w_0 d$	245
7.3	Problem 1 $ d \sum w_i L_{\sigma(i)} $	247
7.4	Problem 1 $ d w_E \sum E_i + w_T \sum T_i$	253
7.5	Problem 1 $ d L_i _{\max}$ and $1 d_{opt} L_i _{\max}$	255
7.6	Problem 1 $ d_{opt} \sum w_i L_i $	257
7.7	Problem 1 $ d \sum w_i L_i $	260
8	Batching Problems	265
8.1	Single Machine s -Batching Problems	265
8.2	Single Machine p -Batching Problems	269
8.2.1	The Unbounded Model	270
8.2.2	The Bounded Model	275
8.3	Complexity Results for Single Machine Batching Problems	275

9	Changeover Times and Transportation Times	279
9.1	Single Machine Problems	280
9.2	Problems with Parallel Machines	284
9.3	General Shop Problems	288
10	Multi-Purpose Machines	289
10.1	<i>MPM</i> Problems with Identical and Uniform Machines	290
10.2	<i>MPM</i> Problems with Shop Characteristics	296
10.2.1	Arbitrary Processing Times	296
10.2.2	Unit Processing Times	307
10.3	Complexity Results	311
11	Multiprocessor Tasks	313
11.1	Multiprocessor Task Systems	314
11.2	Shop Problems with <i>MPT</i> : Arbitrary Processing Times	319
11.3	Shop Problems with <i>MPT</i> : Unit Processing Times	325
11.4	Multi-Mode Multiprocessor-Task Scheduling Problems	331
11.5	Complexity Results	338
	Bibliography	342
	Index	360