

1. Introduction	1
1.1. Scheduling	1
1.2. Some Scheduling Activities in Practice	2
1.2.1. Scheduling in Production Planning and Control	2
1.2.2. Project Scheduling	5
1.2.3. Workforce Scheduling	5
1.2.4. Scheduling Reservations and Appointments	5
1.2.5. Pricing and Revenue Management	6
1.3. Some Generic Scheduling Problems	6
1.3.1. The Resource-Constrained Project Scheduling Problem	6
1.3.2. The Machine Scheduling Problem	7
1.3.3. The Classical Job Shop Scheduling Problem	8
1.4. Extensions of the Classical Job Shop	9
1.4.1. Setup Times	9
1.4.2. Release Times and Due Dates	10
1.4.3. Limited Number of Buffers and Transfer Times	11
1.4.4. Time Lags and No-Wait	12
1.4.5. Routing Flexibility	13
1.4.6. Transports	14
1.5. Overview of the Thesis	14
1. Complex Job Shop Scheduling	19
2. Modeling Complex Job Shops	21
2.1. Introduction	21
2.2. Some Formulations of the Classical Job Shop	22
2.2.1. A Disjunctive Programming Formulation	22
2.2.2. A Mixed Integer Linear Programming Formulation	22

2.2.3.	A Disjunctive Graph Formulation	23
2.2.4.	An Example	23
2.3.	A Generalized Scheduling Model	24
2.3.1.	A Disjunctive Programming Formulation	25
2.3.2.	A Disjunctive Graph Formulation	25
2.4.	A Complex Job Shop Model (CJS)	27
2.4.1.	Building Blocks of the CJS Model and a Problem Statement	27
2.4.2.	Notation and Data	28
2.4.3.	A Disjunctive Graph Formulation	30
2.4.4.	An Example	32
2.4.5.	Modeling Features in the CJS Model	34
3.	A Solution Approach	37
3.1.	Introduction	37
3.2.	The Local Search Principle	38
3.2.1.	The Local Search Principle in the Example	38
3.2.2.	The Job Insertion Graph with Local Flexibility	41
3.3.	Structural Properties of Job Insertion	42
3.3.1.	The Short Cycle Property	42
3.3.2.	The Conflict Graph and the Fundamental Theorem	47
3.3.3.	A Closure Operator	48
3.4.	Neighbor Generation	53
3.4.1.	Non-Flexible Neighbors	53
3.4.2.	Flexible Neighbors	54
3.4.3.	A Neighborhood	55
3.5.	The Job Insertion Based Local Search (JIBLS)	56
3.5.1.	From Local Search to Tabu Search	56
3.5.2.	The Tabu Search in the JIBLS	57
II.	The JIBLS in a Selection of CJS Problems	61
4.	The Flexible Job Shop with Setup Times (FJSS)	63
4.1.	Introduction	63
4.2.	A Literature Review	63
4.3.	A Problem Formulation	65
4.4.	The FJSS as an Instance of the CJS Model	65
4.5.	A Compact Disjunctive Graph Formulation	66
4.6.	Specifics of the Solution Approach	67
4.6.1.	The Closure Operator	67
4.6.2.	Feasible Neighbors by Single Reversals	68
4.6.3.	Critical Blocks	70
4.7.	Computational Results	71
5.	The Flexible Blocking Job Shop with Transfer and Setup Times (FBJSS)	79
5.1.	Introduction	79

5.2. A Literature Review	80
5.3. A Problem Formulation	80
5.4. The FBJSS as an Instance of the CJS Model	81
5.5. Computational Results	81
5.6. From No-Buffers to Limited Buffer Capacity	89
6. Transportation in Complex Job Shops	95
6.1. Introduction	95
6.2. A Literature Review	96
6.3. The Job Shop with Transportation (JS-T)	98
6.3.1. A Problem Formulation	98
6.3.2. Computational Results	99
6.4. The Blocking Job Shop with Transportation (BJS-T)	104
6.4.1. A Problem Formulation	104
6.4.2. Computational Results	104
7. The Blocking Job Shop with Rail-Bound Transportation (BJS-RT)	109
7.1. Introduction	109
7.2. Notation and Data	110
7.3. A First Problem Formulation	111
7.3.1. The Flexible Blocking Job Shop Relaxation	111
7.3.2. Schedules with Trajectories	112
7.4. A Compact Problem Formulation	113
7.4.1. The Feasible Trajectory Problem	114
7.4.2. Projection onto the Space of Schedules	118
7.5. The BJS-RT as an Instance of the CJS Model	119
7.6. Computational Results	120
7.7. Finding Feasible Trajectories	124
7.7.1. Trajectories with Variable Speeds	124
7.7.2. Stop-and-Go Trajectories	130
8. Conclusion	137
Bibliography	139