# Contents


**List of Abbreviations** . . . . . xiii

**1 Introduction** . . . . . 1
1.1 Preface . . . . . 1
1.2 Changes in the Manufacturing Environment . . . . . 1
1.2.1 Productivity . . . . . 3
1.2.2 Flexibility . . . . . 3
1.2.3 Attractiveness of the Workplace . . . . . 4
1.3 Shifting Objectives of Manufacturing Control . . . . . 4
1.4 Scheduling in Practice . . . . . 6
1.5 The Weak Points of Conventional Manufacturing Control 9
1.6 References . . . . . 11

**2 Conventional Production Scheduling and Control** . . . . . 13
2.1 Abstract . . . . . 13
2.2 Survey . . . . . 13
2.3 Lead Time Scheduling and Capacity Scheduling . . . . 16
2.3.1 Single Steps in Lead Time Scheduling . . . . . 19
2.3.1.1 Determining Lead Times . . . . . 19
2.3.1.2 Interoperation Time Reduction . . . . . 20
2.3.1.3 Operation Overlapping . . . . . 23
2.3.1.4 Operation Splitting . . . . . 24
2.3.2 Single Steps in Capacity Scheduling . . . . . 25
2.3.2.1 Finite Loading . . . . . 25
2.3.2.2 Capacity Adjustment . . . . . 25
2.3.2.3 Capacity Alignment . . . . . 26
2.4 Evaluation of Conventional Lead Time Scheduling . . 28
2.5 Requirements for New Methods of Production Scheduling and Control . . . . . 31
2.6 References . . . . . 35

**3 Lead Time – A Key Term in Manufacturing Control** . . . . . 37
3.1 Abstract . . . . . 37
3.2 Introduction . . . . . 37
3.3 Lead Time Components . . . . . 41
3.4 Simple and Weighted Mean Lead Time at a Work Center . . . . . 47

3.5 Order Lead Times . . . . . 53
3.6 Statistical Evaluation of Work Center Lead Times . . 55
3.6.1 Absolute and Relative Frequency Distribution of Simple and Weighted Lead Time . . . . . 55
3.6.2 Simple and Weighted Mean Operation Time . 59
3.6.3 Simple and Weighted Mean Operation Time Percentage . . . . . 62
3.6.4 Median of Simple and Weighted Lead Time . . 64
3.6.5 Standard Deviation of Simple and Weighted Mean Lead Time . . . . . 65
3.6.6 Coefficient of Variation of Simple and Weighted Lead Time . . . . . 66
3.6.7 Median, Standard Deviation, and Coefficient of Variation of Simple and Weighted Order Time 66
3.7 Work Center Lead Time in the Shop Calendar . . . . 68
3.7.1 Transformation of Throughput Elements . . . . 68
3.7.2 Frequency Distribution and Statistical Evaluation in the Shop Calendar . . . . . 69
3.8 Uncertainty of Measurement and Accuracy of Computed Lead Time Values . . . . . 72
3.9 Examples of Authentic Lead Time Measurements . . . 75
3.9.1 Work Center Lead Times . . . . . 75
3.9.2 Operation Lead Times . . . . . 78
3.9.3 Order Lead Times . . . . . 82
3.10 References . . . . . 86

**4 The Throughput Diagram – A General, Realistic Model of the Manufacturing Process** . . . . . 89
4.1 Abstract . . . . . 89
4.2 Historical Evolution . . . . . 89
4.3 Basic Form of the Throughput Diagram . . . . . 93
4.4 The Work Center Throughput Diagram and its Basic Data . . . . . 95
4.4.1 How to Produce a Work Center Throughput Diagram . . . . . 95
4.4.2 Mean Inventory . . . . . 101
4.4.3 Mean Time Data . . . . . 103
4.4.3.1 Mean Range . . . . . 103
4.4.3.2 Mean Advance Time . . . . . 104
4.4.3.3 Weighted Mean Lead Time . . . . . 106
4.4.4 Relationships between Mean Range, Mean Advance Time, and Weighted Mean Lead Time. 108
4.4.4.1 Inventory Trend Component of Lead Time . . . . . 108
4.4.4.2 Sequence Component of Weighted Lead Time . . . . . 111
4.4.4.3 Short- and Long-Term Relationships between Time Quantities . . . . . 114
4.4.5 Mean Performance, Mean Capacity, and Mean Utilization . . . . . 114

4.4.6 Relationships between Mean Inventory, Mean Performance, and Weighted Mean Lead Time . 116
4.4.7 Weighted Mean Lateness . . . . . 117
4.5 Order Throughput Diagram . . . . . 121
4.5.1 Extended Work Center Throughput Diagram . 121
4.5.2 How to Produce the Order Throughput Diagram . . . . . 126
4.6 References . . . . . 126

**5 Analysis, Monitoring, and Diagnosis of the Manufacturing Flow** . . . . . 129
5.1 Abstract . . . . . 129
5.2 Manufacturing Flow Monitoring . . . . . 129
5.3 Manufacturing Flow Analysis . . . . . 131
5.3.1 Procedure Outline . . . . . 131
5.3.2 Forms of Evaluation and Representation . . . . 139
5.3.3 Representation of the Results . . . . . 145
5.3.4 General Rules and Possibilities for Improving Manufacturing Flow . . . . . 153
5.4 A Continuous Monitoring System for Manufacturing Flow . . . . . 155
5.4.1 Objectives and Concept . . . . . 155
5.4.2 Example of a Continuous Monitoring System . 158
5.4.3 Results and Use of a Continuous Monitoring System . . . . . 167
5.5 Diagnosis of the Manufacturing Flow in the Throughput Diagram . . . . . 175
5.5.1 Breaking down Inventories . . . . . 175
5.5.2 Breaking down Lead Times . . . . . 180
5.5.3 Measures to be Deduced from Monitoring and Diagnosis Results . . . . . 186
5.6 Use of Graphics for the Representation of Throughput Diagrams and Key Data . . . . . 188
5.6.1 Representation of the Results of Manufacturing Analyses . . . . . 188
5.6.2 Graphics for Medium-Term Manufacturing Flow Monitoring . . . . . 193
5.7 Implications for Manufacturing Control . . . . . 195
5.8 References . . . . . 200

**6 Load-Oriented Order Release** . . . . . 203
6.1 Abstract . . . . . 203
6.2 Fundamental Relationships . . . . . 203
6.3 Procedure . . . . . 206
6.4 Conversion of the Orders to be Loaded . . . . . 212
6.5 Sample Demonstration of the Release Process . . . . . 214
6.6 How to Choose the Load Limit and Loading Percentage Values . . . . . 220
6.7 Interlinking Order Control with Manufacturing Control . . . . . 231

6.8 Effects of the Load Limit and Time Limit Parameters in Simulation and in Practice . . . 232
6.8.1 Simulation of Manufacturing Processes as an Aid in the Testing of Control Algorithms . . . 232
6.8.2 Effects of the Load Limit . . . 245
6.8.3 Effects of the Time Limit . . . 252
6.9 Controller Analogy of Load-Oriented Order Release 254
6.10 Priority Rules and Order Sequencing in Load-Oriented Order Release . . . 256
6.11 References . . . 261

**7 Schedule-Oriented Capacity Planning and Control** . . . 263
7.1 Abstract . . . 263
7.2 The Problem and the Method . . . 263
7.3 Defining the Load Centers . . . 266
7.4 Schedule-Oriented Capacity Planning Procedure . . 269
7.5 References . . . 277

**8 Implementation of Load-Oriented Manufacturing Control** . 279
8.1 Abstract . . . 279
8.2 Prerequisites . . . 279
8.2.1 Influence of the Lot Size on Inventories and Mean Lead Time . . . 279
8.2.2 Orders Must Have a Due Date . . . 286
8.2.3 An Operation Sheet with Standard Times Must Exist . . . 288
8.2.4 Material, Tooling, Fixtures and NC Programs Must Be Available . . . 288
8.2.5 Machine Availability and Personnel Capacity Must Be Known . . . 288
8.2.6 Operation Feedback Must Be Complete and Sufficiently Accurate . . . 291
8.3 Program Modules of Load-Oriented Manufacturing Control . . . 292
8.3.1 Overview . . . 292
8.3.2 Capacity Planning . . . 292
8.3.3 Release Planning . . . 295
8.3.4 Sequencing . . . 296
8.3.5 Calculation of Monitored Data . . . 299
8.4 System-to-User Interfaces and Hardware Configuration 301
8.5 Implementation Strategies . . . 305
8.6 Load-Oriented Manufacturing Control in Automated Production Sites . . . 308
8.6.1 Controlling Flexible Manufacturing Systems . 308
8.6.2 Integration into CIM Concepts . . . 310
8.7 Effects of Load-Oriented Manufacturing Control . . 316
8.7.1 Cost Effectiveness . . . 316
8.7.2 Qualification and Motivation . . . 318
8.8 References . . . 319

**9 Comparison of Load-Oriented Manufacturing Control with Other Methods** . . . . . 323
9.1 Abstract . . . . . 323
9.2 Overview . . . . . 323
9.3 The Kanban Principle . . . . . 328
9.4 The Job-Progress Number System . . . . . 331
9.5 Finite Control with a Graphic Control Unit (Electronic Leitstand) . . . . . 333
9.6 Queueing Models . . . . . 335
9.7 The OPT System . . . . . 337
9.8 References . . . . . 341

**10 Summary** . . . . . 343

**Appendix A** . . . . . 347

**Appendix B** . . . . . 355

**Subject Index** . . . . . 365