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Diese Reihe dient der Veröffentlichung neuer Forschungsergebnisse auf den Gebieten der Produktion und Logistik. Aufgenommen werden vor allem herausragende quantitativ orientierte Dissertationen und Habilitationsschriften. Die Publikationen vermitteln innovative Beiträge zur Lösung praktischer Anwendungsprobleme der Produktion und Logistik unter Einsatz quantitativer Methoden und moderner Informationstechnologie.

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Multi-Stage Simultaneous Lot-Sizing and Scheduling

Planning of Flow Lines with Shifting Bottlenecks

Foreword by Prof. Dr. Herbert Meyr

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Foreword

Management concepts often repeat. Currently, another "wave of lean management" seems to roll, preaching that inventories are waste. Inventories would blur a clear view on mistakes which are made in production planning. Thus, inventories should be reduced. All drivers that necessitate inventories should be eliminated by means of investments. This makes sense in many industries, but not in all. Some industries utilize expensive, automated machines. These cannot easily be replaced by newer ones allowing automated changeovers and thus generating almost no setup times or setup costs. They apply a machinery, which has grown over time. It consists of many machines which show a similar functionality, but have been purchased successively over one or several decades. Hence, there are some older machines, which are less efficient, and a few newer ones, which are more efficient.

An example is the consumer packaged goods industry. There are often only a few production stages (like Make and Pack) with several heterogeneous, parallel production lines per stage. Parallel means that these lines show a similar functionality, i.e., they can be used alternatively to produce—more or less—the same products. Heterogeneous means that they, nevertheless, do not need to be identical. This concerns production speeds, production coefficients, production costs, setup costs and setup times. Both setup costs and times may even be sequence-dependent. The individual work stations of a production line are usually connected by an automated transport system with a fixed cycle time. Thus, each production line can be considered as a single planning unit. Sometimes only one of these stages constitutes a stationary bottleneck. However, sometimes the bottleneck may shift dynamically, dependent on the mix of demand the customers ask for. This book focuses on this kind of industries, more concretely on short- to medium-term production planning and scheduling in this kind of industries when both lot-sizing and scheduling decisions have to be taken simultaneously in order to consider the crucial interdependencies between the various predecessor and successor products on the different production stages.

The author proposes and compares different mixed-integer programming formulations, which base on the so-called General Lot-sizing and Scheduling Problem (GLSP), to accurately model this planning situation. Furthermore, he develops and tests an innovative solution heuristic, combining the principles of Variable Neighborhood Decomposition Search with the Exchange heuristic, which not only behaves well for small "theoretical" problem instances, but also proves to be applicable for a large industrial problem of plastic foil pro-

duction. Despite of the high practical relevance of this type of planning problem, decision support being offered by science and by commercial software (e.g. as part of so-called "Advanced Planning Systems") seemed to be rather poor and disappointing until now. The author manages to make a first—and already very impressive—step to improve this situation.

Thus, I invite the interested production planner, operations researcher and software developer to carefully read this book. Even though it deals with consumer packaged goods, this book is no fast food. You will have to take your time to eat it. It will often taste sweet and sometimes be hard to digest. But I promise—it is worth every bite of it.

Prof. Dr. Herbert Meyr

Acknowledgments

Facing high cost pressure, industries like the consumer packaged goods industry are forced to utilize their machine capacities as efficiently as possible. Hence, simultaneous lot-sizing and scheduling is very important for these industries if they use machines with significant, sequence-dependent setup times or costs in a Make-To-Stock environment. Since often a stationary bottleneck exists, to focus on the corresponding production stage is usually sufficient. Unfortunately, this is not the case if—due to varying product demands/mixes and different production speeds on the machines—the bottleneck shifts between the stages. The thesis at hand is intented for helping solve such multi-stage lot-sizing and scheduling problems. Besides a mathematical model formulation, a new heuristic solution procedure is given which allows finding good solutions for this model including real-world problem sizes.

The results of this thesis were made during my engagement as a research assistant at the Chair of Production and Supply Chain Management at Darmstadt University of Technology. So first of all, I want to thank Prof. Herbert Meyr, the former owner of this chair and my first referee, who gave me this great opportunity to do a doctorate. Due to his deep knowledge and his friendly type, it was a pleasure to work with him. The same is true for Prof. Bernardo Almada Lobo, my second referee. His amicable and positive attitude always stimulated me to achieve the aim. Moreover, I want to thank Prof. Rainer Quick who volunteered for acting as the third referee.

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A special thank goes to my parents. Not only did they allow me this education but they always supported me in everything I did. Last but not least I want to thank my wife Anne. By her happy nature, she was a great backup and let me cope with all the challenges.

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Florian Seeanner

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List of Abbreviations

APS	Advanced Planning Systems
CLSD	Capacitated Lot-sizing Problem with Sequence-Dependent Setup Costs
CLSP	Capacitated Lot-sizing Problem
CSLP	Continuous Setup Lot-sizing Problem
DLSP	Discrete Lot-sizing and Scheduling Problem
FMCG	Fast moving consumer goods
FO	GLSPMS tailored Fix&Optimize
GLSP	General Lot-sizing and Scheduling Problem
GLSPMS	General Lot-sizing and Scheduling Problem for Multiple production Stages
LF	LP&Fix
LTB	Large-time bucket
MLCLSD-PM-ML	Multi-Level Capacitated Lotsizing Problem with Sequence-Dependent Setup Costs using Parallel Machines at Multiple Locations
MLCLSP	Multi-Level Capacitated Lot-sizing Problem
MRP	Material Requirements Planning
MSLS	Multi-level Sequence-dependent Lot-sizing and Scheduling problem
MTS	Make-To-Stock
P2SMM	Two-stage multi-machine lot-scheduling model
PLSP	Proportional Lot-sizing and Scheduling Problem
PLSP-ML-SM	Multi-level single machine PLSP

PLSP-PM	Proportional Lot-sizing and Scheduling Problem with Parallel Machines
PPC	Production Planning and Control
RAM	Random access memory
RF	Relax&Fix
RS	Repeating setup sequence heuristic
SCP	Supply Chain Planning
SITLSP	Synchronized and Integrated Two-Level Lot-sizing and Scheduling Problem
SPL	Simple Plant Location
STB	Small-time bucket
TM	Truncated MIP
TS	Trivial solution heuristic
VND	Variable Neighborhood Descent
VNDS	Variable Neighborhood Decomposition Search
VNDS+E	Variable Neighborhood Decomposition Search with Exchange
VNS	Variable Neighborhood Search
WIP	Work-in-process