Massimiliano Caramia
Paolo Dell'Olmo

Springer Series in Advanced Manufacturing

Effective Resource Management in Manufacturing Systems

Optimization Algorithms for Production Planning

Springer

Massimiliano Caramia
Paolo Dell'Olmo

Springer Series in Advanced Manufacturing

Effective Resource Management in Manufacturing Systems

Optimization Algorithms for Production Planning

Springer

Springer Series in Advanced Manufacturing

Other titles in this series

Assembly Line Design
B. Rekiek and A. Delchambre

Advances in Design
H.A. ElMaraghy and W.H. ElMaraghy (Eds.)

Condition Monitoring and Control for Intelligent Manufacturing
Wang and Gao (Eds.)
Publication due: January 2006

Massimiliano Caramia and Paolo Dell'Olmo

Effective Resource Management in Manufacturing Systems

Optimization Algorithms for Production Planning

With 78 Figures

Springer

Massimiliano Caramia, PhD
Istituto per le Applicazioni del Calcolo
"M. Picone" – CNR
Viale del Policlinico, 137
00161 Roma
Italy

Paolo Dell'Olmo, Prof.
Universitá di Roma "La Sapienza"
Dipartimento di Statistica
Probabilitá e Statistiche Applicate
Piazzale Aldo Moro, 5
00185 Roma
Italy

Series Editor:
Professor D. T. Pham
Intelligent Systems Laboratory
WDA Centre of Enterprise in
Manufacturing Engineering
University of Wales Cardiff
PO Box 688
Newport Road
Cardiff
CF2 3ET
UK

British Library Cataloguing in Publication Data
Caramia, Massimiliano
Effective resource management in manufacturing systems:
optimization algorithms for production planning. -
(Springer series in advanced manufacturing)
1. Production management - Mathematical models
2. Mathematical optimization 3. Algorithms
I. Title II. Dell'Olmo, Paolo, 1958-
658.5'0015181
ISBN-10: 1846280052

Library of Congress Control Number: 2005933474

Springer Series in Advanced Manufacturing ISSN 1860-5168
ISBN-10: 1-84628-005-2 e-ISBN 1-84628-227-6 Printed on acid-free paper
ISBN-13: 978-1-84628-005-4

Printed in Germany

9 8 7 6 5 4 3 2 1

Springer Science+Business Media
springeronline.com

To our wives and sons

Preface

Manufacturing systems, regardless of their size, have to be able to function in dynamic environments with scarce resources, and managers are asked to assign production facilities to parallel activities over time respecting operational constraints and deadlines while keeping resource costs as low as possible.

Thus, classic scheduling approaches are not adequate when (i) a task simultaneously requires a set of different resources and (ii) a trade-off between different objectives (such as time, cost and workload balance) has to be made. In such cases, more sophisticated models and algorithms should be brought to the attention of the managers and executives of manufacturing companies.

In this framework, this book aims to provide robust methods to achieve effective resource allocation and solve related problems that appear daily, often generating cost overruns. More specifically, we focus on problems like on line workload balancing, resource levelling, the sizing of machine and production layouts, and cost optimization in production planning and scheduling. Our approach is based on providing quantitative methods, covering both mathematical programming and algorithms, leading to high quality solutions for the problems analyzed. We provide extensive experimental results for the proposed techniques and put them in practical contexts, so that, on the one hand, the reader may reproduce them, and, on the other hand, the reader can see how they can be implemented in real scenarios.

In writing this book, an attempt has been made to make the book self contained, introducing the reader to the new modelling approaches in manufacturing, presenting updated surveys on the existing literature, and trying to describe in detail the solution procedures including several examples. Yet, the complexity of the topics covered requires a certain amount of knowledge regarding several aspects which, in this book, are only partially covered. In particular, for general quantitative modelling approaches in the management of manufacturing systems and for the large body of machine scheduling mod-

els and algorithms the reader is encouraged to refer to books and articles cited in the text.

The book can be used by Master and PhD students in fields such as Manufacturing, Quantitative Management, Optimization, Operations Research, Control Theory and Computer Science, desiring to acquire knowledge in updated modelling and optimization techniques for non classical scheduling models in production systems. Also, it can be effectively adopted by practitioners having responsibility in the area of resource management and scheduling in manufacturing systems. To facilitate both thorough comprehension and the application of the proposed solutions into practice, the book also contains the algorithms source code (in the C language) and the complete description of the mathematical models (in the AMPL language). It should also be noted that most of the selected topics represent quite general problems arising in practice. Application examples have been provided to help the mapping of real world problem recognition and modelling in the proposed framework.

As with any book, this one reflects the attitudes of the authors. As engineers, we often made the underlying assumption that the reader shares with us a "system view" of the world, and this may not always be completely true. As researchers in discrete optimization, we place strong emphasis on algorithm design, analysis and experimental evaluation. In this case, we made the assumption that someone else took charge of providing the data required by the algorithms. Although this is a preliminary task that a manager cannot underestimate, we believe that current production systems are already equipped with computing and communication capabilities that can make this job manageable.

A glance at the table of contents will provide an immediate list of the topics to be discussed, which are sketched in the following.

In Chapter 1 we describe manufacturing systems according to their general structure, the goals typically pursued in this context, and focus our attention on resource allocation. A brief analysis on algorithmic techniques used in other chapters is presented.

In Chapter 2 we analyze the problem of balancing the load of n machines (plants) in on-line scenarios. We describe known techniques and propose a new algorithm inspired by a metaheuristic approach. The novelty of the approach also stems from the fact that the algorithm is still an on-line constructive algorithm, and thus guarantees reduced computing times, but acts as a more sophisticated approach, where a neighborhood search has to be made in the same way as with a local search method.

Chapter 3 is about resource levelling, i.e., the problem of smoothing the shape of the resource profile in a schedule. This problem is discussed in the scenario in which tasks require more than one resource at a time, and the

total amount of resources is limited. The problem is off-line. We propose a metaheuristic approach to the problem and a comparison with the state of the art.

Chapter 4 studies the problem of scheduling jobs in a robotized cell with m machines. The problem consists of a case where each part entering the production system must be loaded by means of a robot on one available machine, and, when the machine finishes the execution of its task, the part must be unloaded and must exit the system.

The last part of the book is dedicated to tool management on flexible machines (Chapter 5). We study the problem of managing tool changeovers and consequently setup times, in flexible environments, where parts are not produced in batch. Different heuristics are proposed for this problem, and a comparison with known algorithms for the same problem is presented.

Rome, *Massimiliano Caramia*
May 2005 *Paolo Dell'Olmo*

Contents

List of Figures