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A review of: "*Operations scheduling with applications in manufacturing and services*"M. Pinedo and X. Chao McGraw-Hill, New York 1999, 310 pages, ISBN 0-07-289779-1

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cost), which may well be a good perspective to give students. Traditional scheduling models take the processing times to be cast in stone, and in practice it is often worthwhile to go down into the shop and see whether in fact things cannot be somewhat improved.

The final chapter addresses two graph-related problems that have significant scheduling connections. The Traveling Salesman Problem is well-known to be closely related to machine-scheduling models with sequence-dependent setup times. A number of special cases of the problem where Hamiltonian tours can be generated efficiently are examined, as well as a number of heuristics. The interesting addition here is the Chinese Postman problem, which is frequently encountered in logistic contexts but is very seldom treated in relation to scheduling. This is valuable knowledge for many practitioners whose work may take them into both machine scheduling and larger-scale logistics arenas.

Overall, the book provides an excellent overview of combinatorial techniques for machine scheduling problems, with a bias towards graph-theoretic approaches, polynomial-time procedures and analysis of heuristics. The exposition is wonderfully clear, and stands as a model of clarity and rigor without ever becoming pedantic in tone. Considerable thought has obviously been devoted to the problems, which I found interesting and challenging. It provides a thorough grounding in combinatorial approaches to scheduling problems for the novice; a useful reference for the veteran researcher; and a good sourcebook on the available mathematical results for the practitioner who has formulated a problem and now needs to find out what theoretical artillery is available to call in. It is a book that your university library should certainly have, and which is well worth owning if you do research in this area.

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Operations scheduling with applications in manufacturing and services

M. Pinedo and X. Chao

McGraw-Hill, New York 1999, 310 pages, ISBN 0-07-289779-1

It has been an interesting experience to review this book, which is a rather different kind of scheduling text from what we are used to. In the old days when one bought a scheduling book one knew what one was going to get. They started out with a description of some example to show how scheduling problems arise; gave definitions of various machine environments, and then started to discuss them in increasing order of complexity, going from single machine to parallel machine to multi-stage systems like jobshops and flowshops. In most cases, the discussion was restricted to machine scheduling, although project scheduling was also sometimes considered, as in the book by Baker [1]. Much of the emphasis was on showcasing various mathematical, techniques, such as adjacent pairwise interchanges, dynamic programming algorithms and the development of dominance properties to enhance the performance of enumerative algorithms.

I find it refreshing that several recent books in this area, including that by Parker [2] and this book, have broken this mold and have tried to broaden the definition of what is included in the field. However, the two books do it in rather different ways. Parker's book is very much driven by the underlying mathematical structures, which leads it to include the Traveling Salesman and Postman problems, as well as timetabling, classroom scheduling and project scheduling in addition to machine scheduling. This book, on the other hand, is driven by the models that are of interest to practitioners, which leads to a rather different mix of subjects.

The book begins by laying out a variety of problems that can be viewed as scheduling problems, in that they involve the allocation of resources to tasks over time. The first is project scheduling, in which the standard CPM-PERT calculations are presented along with a discussion of time–cost tradeoffs with both linear and nonlinear costs. The time–cost tradeoff problem is treated with a heuristic, and linear programming formulations are also given. The resource-constrained project scheduling problem is presented as an integer programming formulation only, with the note that many heuristics developed for job shop scheduling can be applied. This chapter does a good job of laying out what the problems are, and giving a feel for why they are hard and what kind of solution methods are available.

The chapter on job shop scheduling is fairly conventional in its treatment, beginning with the disjunctive graph representation and a branch-and-bound algorithm based on enumerating active schedules. It then proceeds to discuss the Shifting Bottleneck heuristic based on that developed by Adams *et al.* [3] to the makespan and total weighted tardiness measures, and then gives an algorithm for minimizing total weighted tardiness in a flexible flowshop with sequence-dependent setup times. What is different is that the single and parallel machine models are not treated at all. For the kind of audience this book is aimed at I think this is worth it. The alternative is to spend a great deal of time discussing models which are of very limited practical relevance, and which are often dismissed as such by students. Although they are important to discuss at the graduate level due to the mathematical tools they allow us to formulate and in terms of building insights for attacking more complex problems, the approach in this chapter seems to be a refreshing change for the better, at least in terms of an undergraduate presentation. The chapter could be made even more appealing by relating the heuristics presented to Goldratt's Theory of Constraints [4], which is widely used in practice and which both industrial engineering and operations management students ought to be familiar with. The discussion of Flexible Assembly systems, which is in the same general style, also presents a type of problem which many students are likely to encounter, and provides a good starting point for understanding the complexities encountered in this environment.

The inclusion of Chapter 7, which covers lot sizing and scheduling models, goes a long way towards bridging the gap between detailed shop scheduling and higher level production planning systems which has not been treated nearly enough in textbooks. In recent years there has been a growing body of work at the interface of these two areas (for example, Webster and Baker [5]; Potts and van Wassenhove [6]). The discussion of EOQ is a good start, although I would have liked more discussion on the practicalities of setup costs. In many manufacturing environments, setups cost time, but the actual marginal cost in money of a setup is often negligible. Thus the setup cost for a machine changes over time depending on the demand for the machine over time. Detailed scheduling models capture this directly by considering times explicitly, but this is often not brought out in the relatively simple lot sizing models used in classrooms. The book proceeds to present a number of related problems, many of which explicitly consider setup times. It would be interesting to consider the effects of reduction in setup times here, in order to make students aware that rather than taking setups for granted and scheduling around them they ought to be looking for ways to eliminate them entirely, simplifying the scheduling problem significantly.

Chapters 8 and 9 discuss a variety of scheduling problems that are not directly related to conventional machine scheduling problems. The main ones are reservation systems, where jobs must be processed in a given time window, and timetabling problems, where a variety of side constraints are considered. Again, the emphasis is on giving the reader a good flavor of what the problems are and what kinds of algorithms are out there.

The final class of models convered is that of workforce scheduling, which treats a variety of problems in this extensively studied domain. Days-off scheduling, shift scheduling, cyclic staffing and crew scheduling are considered. I particularly liked the inclusion of the column generation approach for crew scheduling, which gives a good idea of how these large problems have to be treated in practice. It ought to be possible to give students at least an intuitive feel for what the column generation procedure is trying to do, and is a good illustration of how to model a complex problem by decomposing its complexities between master and subproblems.

A major distinction between this book and most others on the market is the heavy emphasis on developing successful implementations of scheduling systems. This discussion makes up Chapters 10 and 11, of the book, and begins with a treatment of the various components needed for such an implementation. databases, knowledge bases and object-oriented implementations are discussed, albeit at a rather superficial level. The discussion of schedule generation and regeneration gives a good insight into what the issues are, although it does not discuss solutions in any detail. In general, I feel that this chapter is a worthwhile addition to the book in that it at least tries to raise awareness of these issues, which are critical to implementing scheduling systems effectively. However, it is probably optimistic to hope that the student will get a good idea of how to resolve these issues. In order for real learning to take place the book material will probably have to be supplemented by a term project or case study where students do an implementation the wrong way and then the right way, and analyze the difference. In fairness to the authors, solutions are often very context-specific, so it is hard to see how one could do more in a book at this level than what has been done here. Chapter 11 then discusses a series of brief case studies of scheduling system implementations from a variety of industries. Most of the different models covered in the book are included here. These do a good job of outlining the basic complexities encountered in practice, along with high-level system designs. An interesting common thread throughout this chapter is that almost all the systems resort to some form of heuristic decomposition, in that a solution is developed in several stages by solving a series of simpler models. This could be discussed at more length, as I think it is a common theme in many practical implementations.

The final chapter discusses a number of new directions. The first is that of scheduling in uncertain environments, which has been getting increasing interest in the literature lately and has long stood as a major bottleneck to the implementation of much scheduling research. The discussion is rather weak, giving a brief discussion of the issue and not really doing justice to the existing literature. Another area not usually treated is that of learning mechanisms, which has also seen increasing interest recently. The presentation of neural networks for parallel machine scheduling is interesting. However, most learning algorithms in scheduling to date are aimed at learning when to apply dispatching rules based on system state, or how to update certain parameters as information on performance becomes available. Reconfigurable scheduling systems, where we try to develop system designs that can be configured to different environments easily, and Internet-based systems are also discussed.

The basic style of the book does not require a deep mathematical background, although the notation used is all math and I am curious to see how some business students will take this. I think this depends on the students' backgrounds, and can be managed if the instructor is thoughtful and recognizes this as a problem. The material in the book requires an entire semester, but many sections are useful reference material for the more conventional undergraduate production planning and control class. For example, I would very much like to use the material on jobshops and assembly systems in our undergraduate production course – it beats the pants off what I have done in the past, which is a review of single and parallel machines, dispatching rules and then Johnson's Algorithm! While the book can be used as intended, as a main text for a senior-level elective, it could also be used in a dual-level (advanced undergraduate – beginning graduate) course if supplemented with more mathematical background in selected areas. It is probably ideal for a continuing education course in this area aimed primarily at practicing engineers who wish to learn about these issues.

The enclosed software is also a plus – I have used the software in a distance learning course, making it available for download over the Internet (which requires the authors' permission), and students found it reliable and easy to use. There is also a website with the authors' suggestions for supplementary material such as books, videotapes and software at http://*www.stern.nyu.edu/om/pinedo/book2.html.*

Overall, I feel that the book accomplishes what it sets out to do, which is to give a mathematically low-key overview of basic problems and solution techniques for scheduling problems that are of practical interest. It makes a good deal of recent research available to a potentially much broader audience than could get at it in the past. Although it covers much of the same material as the Parker book, it a completely different beast, and aimed at a very different type of audience. The Parker book does complement this one, though, in the sense that the reader wishing for more mathematical background on a given problem can get it (for many of the models discussed) in the Parker book. This is a book that anyone with an interest in scheduling should be familiar with, and anyone teaching in this area should probably own a copy.

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