OPTIMIZATION APPLICATIONS IN SCHEDULING THEORY

Introduction and An Overview

Selcuk Karabati

Koc University
The Graduate School of Business
Istinye, Istanbul, 80860 Turkey

Panos Kouvelis

Washington University in St. Louis
Olin School of Business
Campus Box 1133, 1 Brookings Drive
St. Louis, MO 63130-4899

This Special Issue is devoted to scheduling theory. More specifically it addresses various issues and provides successful examples on the use of various aspects of optimization theory, deterministic or stochastic, for the development of scheduling results for a variety of application environments.

Scheduling is the field of study concerned with the optimal allocation or assignment of resources, over time, to a set of tasks or activities. It is a decision making process that has as goal the optimization of one or more objectives. Scheduling decisions lead to purely combinatorial questions regarding how a list of tasks are to be arranged or sequenced.

The combinatorial nature of scheduling problems makes them mathematically challenging and extremely difficult to solve. There has always been a strong link between advances in optimization theory, and scheduling theory. During the 1960's, a significant amount of work was done on dynamic programming and integer programming formulations of scheduling problems. The development of complexity theory influenced the scheduling research in the 1970's and resulted in substantial developments on the complexity hierarchy of scheduling problems. Advances in stochastic optimization in the 1980's and '90's resulted in an increasing amount of attention paid to stochastic scheduling problems.

In our issue we continue the tradition of a fruitful relationship between optimization methodologies and scheduling/production planning applications. We have included in the issue eleven papers of prominent scheduling researchers that apply in an innovative way optimization techniques to solve interesting scheduling applications.

Journal of Global Optimization 9: 223–226, 1996.

In "Earliness and Tardiness Single Machine Scheduling with Proportional Weights," W. Szwarc and S.K. Mukhopadhyay present an efficient method to solve an earliness-tardiness single machine multijob scheduling problem. The paper is motivated by applications in Just-In-Time (JIT) production environments. In their model the earliness and tardiness penalties are proportional to the processing times of the jobs. The properties of adjacent job orderings provide tools to decompose the problem and reduce it to a smaller number of candidate sequences that are then examined for optimality. The paper that follows by J.N.D. Gupta on "Comparative Evaluation of Heuristic Algorithms for the Single Machine Scheduling Problem with Two Operations per Job and Time Lags" addresses another single machine scheduling problem with multiple operations per job separated by minimum specified time lags. The problem is motivated by scheduling applications in Flexible Manufacturing System (FMS) environments. Among the interesting results in the paper are the complexity classification of the problem and the presentation of effective polynomically bounded heuristic algorithms for it. In "Using Profit Maximizing Scheduling Models to Structure Operational Tradeoffs and Manufacturing Strategy Issue" R. Daniels, P. Kouvelis and L. Morgan demonstrate how simple single machine scheduling models can be used to structure strategic manufacturing decisions. Their model accounts for varying processing time, delay penalty, and revenue characteristics among the jobs available for processing by a single facility with jobs partitioned into multiple classes such that a setup is incurred each time two jobs of different classes are processed in succession. Given limited processing capacity, the objective is to simultaneously determine the subset of jobs to accept for processing and the associated order in which accepted jobs should be sequenced to maximize the total profit realized by the facility. A dynamic programming algorithm is used for the solution of the problem. Then a series of example problems are presented to illustrate how the detailed scheduling models can be used to evaluate operational tradeoffs that result from strategic decision making, first focusing on the need to coordinate marketing and manufacturing policies, and finally by considering important issues related to manufacturing focus.

Network flow shops are challenging scheduling environments which generalize traditional flowshops by requiring not only to sequence and schedule but also to determine the process routing of the job through the shop. In "Scheduling in Network Flowshops," R. Ahmadi establishes the computational complexity of this scheduling problem and proposes a general purpose heuristic procedure. The performance of the heuristic is analyzed for various objectives. In the paper that follows, "Three Stage Generalized Flowshop: Scheduling Civil Engineering Projects," by M. Dror and P. Mullaseril a three stage flexible flowshop, a restricted class of network flowshops, is used to model the operation of an engineering firm specializing in land development and public work design. The scheduling objective is to minimize the total tardiness for all the projects. In view of the problem complexity the authors consider only heuristic solution methods. The impact of post-heuristic optimization techniques such as pairwise swaps of tasks are evaluated extensively on real-life data. A return to traditional flowshop environments is the paper "Clustered Flow Shop Models" by W. Szwarc, which studies a special class of flowshops where items are grouped in fixed sequences called clusters. The clusters are to be processed on the various machines in the same technological order. Clustered problems arise in practice in a variety of situations. Clusters may represent a set of items to be shipped to a different destination or may be required parts for assembly of a specific module. The author discusses approximate solution techniques along with new lower bounds for this class of problems.

In "The Master-Slave Paradigm in Parallel Computer and Industrial Settings," S. Sahni and G. Vairaktarakis address a useful scheduling paradigm with important applications in parallel computer scheduling, semiconductor testing, transportation, maintenance and other industrial settings. The master-slave paradigm involves two sets of processors. The master processors that are responsible for pre and post processing of work orders, and the slave processors that are responsible for the actual execution of orders. The number of slave processors is no less than the number of work orders. The authors consider the problem of minimizing makespan in a system that consists of several master processors and develop bounded performance approximation algorithms. Another interesting class of scheduling problems is introduced in the paper "Interval Scheduling on Identical Machines" by K. Bouzina and H. Emmons. Interval Scheduling is a class of scheduling problems where independent tasks, each with a fixed start and end time, are to be processed in a parallel machine environment.

The authors assume that all machines are identical and attempt to find the schedule that maximizes the number of jobs completed. The paper presents variations of the interval scheduling problem, discusses polynomial solution procedures for some of them and addresses computational complexity issues in situations where bounds are imposed on the total operating time of the machines. The paper that follows "Machine Scheduling with an Availability Constraint," by C.Y. Lee addresses an important issue for industrial scheduling environments. Machines may not be always available due to unexpected machine breakdowns or scheduled preventive maintenance. The paper studies a large class of scheduling problems under machine non-availability situations and for a variety of performance measures. Interesting results of this work include rigorous complexity analysis of the various problems, development of pseudo polynomial dynamic programming algorithms whenever possible, and presentation of bounded performance heuristic procedures.

The only paper addressing stochastic scheduling environments in this issue is "Stochastic Programming Approaches to Stochastic Scheduling" by J. Birge and M. Dempster. The paper uses a stochastic programming approach to the hierarchy of decisions in typical stochastic scheduling situations. All levels of the hierarchy can appear in the same model to allow for various methods of decomposition, approximation and solution. The authors explored three methods for incorporating optimization procedures into stochastic scheduling problems as part of the decision hierarchy At the capacity planning level growing approximations yield a convenient model when lower timing effects are not significant. At the aggregate production level, a convex approximation can yield useful characterizations of optimal policies. At the lowest level of detailed scheduling Langrangian relaxation methods obtain smaller duality gaps as stochastic program formulation sizes grow.

Material Requirements Planning (MRP) is the most widely used production scheduling software method and has become a defacto standard in manufacturing management. In "Material Allocation in MRP with Tardiness Penalties," U.S. Karmarkar and R.S. Nambimadom address some flaws in the material allocation function of MRP. The authors formally model the material allocation problem in MRP systems, show it to be NP-Complete, and then suggest lower bounds and heuristic procedures for it.