

DISSERTATION PROPOSAL

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Deterministic and Stochastic Models for Practical Scheduling Problems

My dissertation examines three scheduling problems motivated by real life situations. In the first chapter, I work on a single machine scheduling problem with a long time horizon and tasks with deterministic durations, but different release times and deadlines. I use a hybrid method, introducing Benders cuts for different objective functions. In the second chapter of my dissertation I examine a stochastic scheduling problem: staffing of a service center, inspired by IBM, with cross-trained employees, heterogenous customers and quality guarantees. I model this as a multi-server queueing system under preemptive-resume priority classes. I introduce an approximation method and analyze it numerically with the goal of providing managerial insights for the service center to determine an appropriate employee base. In the third chapter of my dissertation I study a project scheduling problem with disruptions, cross-trained employees, heterogenous projects and quality guarantees at an IBM service center. A project consists of several tasks. The arrivals of the projects and the duration of each task are uncertain. I analyze data from IBM and propose a robust scheduling model.

Chapter 1: Scheduling over Long Time Horizons by Logic-based Benders Decomposition

The first chapter is joint work with Professor John Hooker. We consider a single machine scheduling problem with a long time horizon and tasks with deterministic durations, but different release times and deadlines. We solve this scheduling problem by combining Constraint Programming and Mixed Integer Linear Programming with a hybrid method: logic-based Benders decomposition. We choose logic-based Benders decomposition because incorporating it can typically solve planning and scheduling problems much faster than either Constraint Programming or Mixed Integer Linear Programming alone. We show that a similar technique can be beneficial for solving pure scheduling problems; especially as the problem size scales up. Specifically, we solve single-facility nonpreemptive scheduling problems with time windows and long time horizons. The Benders master problem assigns jobs to predefined segments of the time horizon, where the subproblem schedules them. In one version of the problem, jobs may not overlap

the segment boundaries (which represent shutdown times, such as weekends), and in another version, there is no such restriction. The objectives we consider include finding feasible solutions, minimizing makespan, or minimizing total tardiness.

We show that with the introduced Benders cuts, the Benders method solves much larger instances of the segmented problems in which jobs are not permitted to overlap segment boundaries than Constraint Programming. Further, its speed advantage increases as the problem size increases. For the unsegmented problem in which jobs may overlap the segment boundaries, Constraint Programming solved about two-thirds of the instances much more quickly than Benders method and Mixed Integer Linear Programming. However, Constraint Programming failed to solve the remaining instances, all of which Benders method solved in a few seconds and much faster than Mixed Integer Linear Programming. Moreover, Constraint Programming begins to lose its ability to solve instances as they scale up, whereas Benders method continues to solve them, usually in a few seconds. Thus, we conclude that the logic-based Benders decomposition may perform better than either Constraint Programming or Mixed Integer Linear Programming (without added cuts).

Chapter 2: Staffing of a Service Center with Cross-Trained Employees, Heterogeneous Customers, and Quality Guarantees

In the second chapter, I study a stochastic scheduling problem: staffing a service center with cross-trained employees, heterogeneous customers and quality guarantees. This is joint work with Professor Alan Scheller-Wolf and Dr. Aliza Heching (from IBM TJ Watson Research Center). We model a system, inspired by an IBM service center, with employees who are either high or low skilled. These employees serve customer requests that are also heterogeneous - with respect to both the skills required to complete them and their priority: (i) Higher priority customer requests preempt lower priority customer requests in the queue; and (ii) Less skilled employees can only service less demanding requests, while highly skilled employees can service all types of requests. We capture this service center's operations with a multi-server queueing system under a preemptive-resume priority service discipline, and model this system as a Markov chain. However, as an exact solution of such a system is numerically intractable, we apply approximation and bounding techniques to evaluate different control policies.

We consider the class of threshold-based priority policies that prioritize the requests according to the number of each class of requests in the system. By approximating the interval of time during which the employee is busy without interruption, we turn the intractable Markov chain into a tractable one, allowing application of standard Matrix Analytic Methods. We have shown that four different types of customer requests and two different skilled employees can be successfully handled by our method: our method is accurate and fast when compared to simulation of the original service center's operations (i.e., without any approximation). We are currently extending our work to more employees and classes, and generating managerial insights about the capacity provisioning problem at the service center.

Chapter 3: Project Scheduling with Uncertainty at an IBM Service Center

In the third chapter, I analyze a project scheduling problem with disruptions, cross-trained employees, heterogeneous projects and quality guarantees where the durations of a project's tasks and the arrivals of the projects are uncertain. This problem is inspired by a real problem at an IBM service center. This chapter is based on joint work with Professor John Hooker, Professor Alan Scheller-Wolf, Professor Nicola Secomandi and Dr. Aliza Heching (from IBM TJ Watson Research Center). We analyze the real data of the IBM service center to estimate the system parameters, such as time windows (i.e., release time and deadline) and durations of the tasks. We also use Critical Path analysis to show which activities are critical. Our goal is to find an effective assignment and scheduling of the tasks for each employee capturing the uncertainties of the system in a robust scheduling model.

My dissertation widens our knowledge of deterministic and stochastic models for three practical scheduling problems. To our knowledge, the first chapter is the first attempt to solve a pure scheduling problem (including any side constraints) with logic-based Benders decomposition. In the second chapter, I contribute with an approximation method to provide managerial insights for a service center's operations with cross-trained employees, heterogeneous customers and quality guarantees. Current numerical experiments show that the approximation method is accurate and fast. In the last chapter, I will contribute with a robust project scheduling model to capture an IBM service center's operations with disruptions, cross-trained employees, heterogeneous projects and quality guarantees. I propose to extend this chapter by including an analysis of the robust model and computational results based on instances using the estimated IBM service center's parameters.