Staff Planning with Structural Estimation and Optimization: Methodology and Application

Introduction

Labor costs at a hospital can often be up to 90% of variable cost. Managing labor at hospitals is challenging because of the uncertainty in demand for services and the specialized skill set of staff. Hospitals mitigate the effects of these challenges by using staffing resources that can be made flexible in volume — calling additional employees, and through overtime.

While overtime is a key feature in achieving flexibility, excessive overtime of clinical staff has been associated with lower patient safety, higher employee burnout, and deteriorating employee health (Rogers et al. 2004). Thus, to reduce reliance on overtime, staff planners often use additional employees who can be called on a short notice. The use of this contingent labor supply reduces the number of overtime hours. However, this may give rise to additional costs. These costs consist of both explicit costs such as extra payments made to these staff who arrive on a contingent basis, and implicit costs, such as the inconvenience to employees due to changing their schedule at a short notice.

The principal challenge in implementation of algorithmic staff planning methodologies is incorporating these implicit human costs of the employees being scheduled. Not incorporating all the human costs would likely lead to failure in acceptance of these systems. Several implementations of automated staff planning systems have been unsuccessful at large retail organizations due to these reasons (Bernstein et al. 2014).

In this paper we analyze the problem of staff planning for surgical anesthesiologists at a large academic medical center (AMC) in the United States. The hospital was keen on developing an analytical solution to the problem of staff planning for surgical anesthesiologists. We develop a data driven optimization based solution to this problem. We ensure that the model incorporates both implicit and explicit costs of staff planning. We infer the implicit costs by a structural estimation approach using the historical data of staff planning at the AMC.
The AMC performs more than 26,000 surgeries per year, across 5 service lines and 2,700 procedure types. The operating services department of the hospital manages the staffing for physician anesthesiologists for all surgeries. The staff planning for anesthesiologists is performed in a two-phased manner. In the first phase, conducted once a month, the staff planners create two lists of anesthesiologists, in the first list are anesthesiologists who would be on regular duty for each day of the upcoming month. The anesthesiologists on the second list are on stand-by. The second phase of the planning occurs the day before the surgery. Based on surgical booked times, if the planners realize they do not have sufficient anesthesiologists, they call some of these stand-by anesthesiologists. If these stand-by anesthesiologists are called, they are paid an additional $1000 per day. If they are not called, these anesthesiologists incur an inconvenience cost. The use of these stand-by anesthesiologists allows the plan to be flexible without relying solely on overtime.

We model the monthly and daily staff planning at the AMC as a two-stage stochastic integer program incorporating both the explicit and implicit costs. We provide a closed form solution for the second stage problem and structural properties for the first stage problem. Using these properties, we develop a computationally tractable heuristic solution.

In order to estimate the implicit cost parameters, we use the approach for the structural estimation of a Markov Decision Problem (Rust 1994). For this, we assume that the staff planners is a risk-neutral agent who seeks to minimize the expected forward looking cost at every stage, and is aware of the cost parameters when making planning decisions. We use a maximum likelihood approach to estimate the implicit cost parameters which best explains the staff planner’s decisions as observed in the data. Similar approaches for estimating operational cost parameters from historical data has been performed by Aguirregabiria (1999), Olivares et al. (2008), and Allon et al. (2011).

Following validation the estimation and optimization models with historical data, we implement the staff planning model at the AMC.
Contributions

Our paper makes the following contributions. First, we develop a data-driven integer stochastic dynamic programming model for medium and short term planning for anesthesiologists, while incorporating implicit costs, demand uncertainty and service specialties. To the best of our knowledge, this is the first paper to consider this approach in the health care industry. Second, this paper employs a data driven structural estimation method to estimate implicit cost parameters used in the model. This provides a framework for creating staff planning models that overcome the shortcomings of dynamic optimization models in situations where some cost parameters may be implicit, as often the case in service organizations. Third, we develop a general method for solving the two-stage integer stochastic dynamic program and also provide structural results. These can also be used in other applications. Fourth, we validate our model with real data and demonstrate cost savings from such a joint estimation and optimization approach. Finally, we implement the model at the operating services department at the academic medical center. This has led to significant economic and organizational impact.

References


