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Nurse scheduling with lunch break assignments in operating suites



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ABSTRACT

Motivated by the need to make frequent changes in operating suites, this paper presents a highly scalable and efficient solution framework for scheduling nurses in operating suites over the day. This framework consists of two core optimization models that are necessary for scheduling OR nurses in the clinic. The first model addresses the multi-objective optimization problem of assigning nurses to upcoming surgery cases based on their specialties and competency levels. The second model is designed to generate lunch break assignments for the nurses once their caseloads are determined. The latter problem has been largely overlooked by the research community despite its importance. Because the multi-objective model is too large to solve using commercial software, we developed both a column generation algorithm and a two-phase swapping heuristic to find feasible assignments in a fast manner. For both approaches, initial solutions are obtained with a restricted model and lunch breaks are scheduled in a post-processing step. Experiments were conducted to determine the value of the models and the performance of the algorithms using real data provided by MD Anderson Cancer Center in Houston, Texas. The results show that the two approaches can produce implementable daily schedules in a matter of minutes for instances with over 100 nurses, 50 surgery cases and 33 operating rooms.

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1. Introduction

The ability of healthcare systems to deliver high-quality, costeffective care to an aging population is under assault by a worldwide shortage of nurses [1]. As the population ages, the demand for surgery has grown. Not having enough skilled nurses in clinical settings can have a significant negative impact on nurse retention rates, patient safety and healthcare outcomes [2–4]. Given the current situation, hospital managers are in dire need to maximize the utilization and retention of their nursing staff without jeopardizing job satisfaction.

Assigning each available nurse to the right place at the right time to do the right job is a major concern for healthcare organizations. Such organizations are typically divided into specialized units that house numerous job positions, each requiring a specific set of skills. This leads to a large number of possible work schedules when coupled with demand and case variability. To determine "optimal" schedules, one must consider nurse availability by skill level,

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http://dx.doi.org/10.1016/j.orhc.2016.07.001 2211-6923/© 2016 Elsevier Ltd. All rights reserved. their shift preferences, patient demand classifications and uncertainty (e.g., demand, case durations, and resource capacity). Additional considerations include regulatory and union requirements, working contract options, overtime, and break times during a shift, to name a few. Moreover, each unit in the hospital may have a host of individual rules and policies that play a role in staffing decisions.

Motivated by this need as well as the desire to avoid a heavy computational burden when generating solutions, the purpose of this paper is to present a series of models to support the timely construction of daily schedules for the nursing staff at surgerycentered hospitals. The work was done in consultation with MD Anderson Cancer Center in Houston, Texas, one of the largest cancer treatment facilities in the US. The primary model produces a daily roster that specifies the assignment of nurses to shifts in accordance with their skills and planned cases. A second model is used to adjust the corresponding schedules to allow for lunch breaks without disrupting the surgeries underway. As in most realistic situations, there are multiple objectives that must be weighed in the rostering process. The most prominent include the minimization of overtime and idle time, the minimization of changes in assignments during the day to accommodate breaks, and the maximization of case demand satisfaction in light of nurse competency levels and specialties. Solutions are constrained by shift options, contract details, and nurse availabilities. In particular, nurses are assigned to cases based on how closely their specialty and procedure competency match the nature of the case and the procedure requirements.

In previous work [5], we developed a solution pool method (SPM) and a modified goal programming method (MGPM) to produce daily schedules. However, we found both methods computationally challenging as they required the solution of largescale MIPs at intermediate steps. Knowing that staff availability can change at any time during the day, the main contribution of our work centers on the computational efficiency of the proposed methodology. We developed two independent algorithms, both starting with the same feasible schedule derived from a third model, which is a restricted version of the original model. The first algorithm is based on column generation, and the second is a twophase swapping heuristic that iteratively works towards reducing staff shortages, overtime and idle time. Updated schedules can be obtained in less than a few minutes as case lengths and staffing needs change over the day. After a solution is obtained, our lunch break model is called to ensure that lunch breaks are provided to all eligible nurses. The modeling of this problem has been largely overlooked by the research community and represents the second contribution of the paper.

The remainder of the paper is organized as follows. In Section 2, we review the most recent research on nurse scheduling. Section 3 introduces our optimization models for assigning nurses to different surgery cases and assuring that each nurse is given a lunch break when required. The two solution algorithms are discussed in Section 4 and partially illustrated with examples. Numerical results are presented in Section 5 for six data sets obtained from MD Anderson. Conclusions are drawn in Section 6.

2. Literature review

Given the benefits that can be achieved with more efficient use of staffing resources, there has been a great deal of work directed at solving general shift and tour scheduling problems (e.g., see [6]). With respect to nurse scheduling and rostering problems, researchers have published surveys that cover the period from 1965 to 2004 [7,8]. Since that time, dozens of additional studies have appeared in the literature presenting new models and solution methodologies for tackling a variety of related problems. Much of this work has centered on integer programmingbased methods with the objective of either minimizing cost or maximizing nurse preferences. Planning horizons considered can be as short as a shift or as long as a year [9-12].

In contrast to the short-term problem addressed in this paper, most of the work on nurse scheduling has focused on monthly (mid-term) scheduling. Some relevant papers can be found in [13, 14,12]. One of the few studies that considered daily scheduling was undertaken in [15], where the authors developed a reactive planning model for dealing with staff shortages for the 24 h. Taking a hospital-wide view, the model was aimed at minimizing the costs of covering all shifts for the current day by considering the use of overtime, agency nurses, pools, and canceling days off. Solutions were found with a branch and price algorithm in conjunction with mixed-integer rounding cuts to tighten up the relaxed feasible region of the master problem.

As mentioned in Section 1, due to specific nurse restrictions and the complexity of surgery procedures, scheduling nurses in operating suites should be considered separately from scheduling nurses in other areas. The surgery scheduling process of elective cases can be classified into four planning phases [16]. First, one determines how much operating room time is assigned to the different surgeons or surgical groups. This phase is often referred to as case mix planning and is viewed as a strategic consideration. The second phase, which is tactically oriented, concerns the development of a master surgery schedule, i.e., defining the number and type of operating rooms available, the hours that rooms will be open, and the surgeons or surgical groups to whom the operating room time is assigned. In the third phase, individual patients or cases are scheduled on a daily base. In the fourth phase, the surgery schedule is monitored online and rescheduling is considered when the current schedule is disrupted due to uncertainties. The nurse scheduling problem is present in the first three phases on strategic, tactical and operational levels. This paper deals with the nurse scheduling problem on an operational level, i.e., daily assignment of nurses to surgery cases.

Beliën and Demeulemeester [17] tackled an integrated nurse and surgery scheduling problem using integer programming. They enumerated all possible ways of assigning operating blocks to different surgeons subject to individual preferences, surgery demand and capacity restrictions. Solutions were found with a column generation algorithm. To generate columns, they implemented two types of pricing algorithms: the first generates a new roster line using a dynamic programming recursion and the second generates a new surgery schedule using a mixed-integer programming (MIP) scheme. Van Huele and Vanhoucke [18] combined three types of constructive heuristics with two priority rule classes to solve an integrated physician and surgery scheduling problem. They proposed a goal programming model for the problem when open scheduling strategy is used. The objectives were to balance the physicians' workload while satisfying their preferences subject to constraints on breaks between shifts, skill levels, and on-call nurses. Xiang et al. [19] investigated an integrated daily surgery and nurse scheduling problem using a mixed-integer nonlinear programming model. The model considered a variety of nurse constraints such as role, specialty, qualification and availability. To find solutions, they developed a modified ant colony optimization (ACO) algorithm with a two-level ant graph.

The above mentioned papers have mainly focused on the surgery scheduling problem while incorporating nurse scheduling constraints into the model. Wong et al. [20] studied a nurse scheduling problem for an emergency department in which seniority, qualifications, preferences, and legal regulations were taken into account. As is the norm, each case required a proper mix of manpower with different skill sets and proficiency levels. A two-stage approach combining a shift assignment heuristic and sequential local search was developed to find feasible solutions with the objective of minimizing the violations of soft constraints. Mobasher et al. [5] proposed a multi-objective MIP model for the daily scheduling of nurses in operating suites. The overall goal was to assign the nurses to surgery cases based on their specialties and competency levels, subject to a series of hard and soft constraints related to nurse satisfaction, idle time, overtime, and role changes during a shift. They developed a solution pool method as well as a modified goal programming approach to find solutions.

Uncertainty is an inherent characteristic of patient care problems. Van den Bergh et al. [21] proposed three main classes for the uncertainty in personnel scheduling problems: uncertainty of demand, arrivals, and capacity. Uncertainty of process times (e.g., surgery durations) can also be considered as another main class. In fact, provider time with the patient is a prevalent source of uncertainty in planning and scheduling problems in healthcare. Gutjahr and Rauner [22] proposed an ACO algorithm to solve a dynamic nurse scheduling problem for a group of 15 hospitals in Vienna, Austria. They considered uncertainty of demand and arrivals, along with a variety of constraints related to working patterns, nurse Download English Version:

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