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A goal programming model for scheduling residents in an anesthesia and reanimation department

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ABSTRACT

Medicine residency is three to seven years of challenging graduate medical training that puts a lot of mental and physiological burden over the residents. Like other surgical branches, anesthesia and reanimation departments provide 24 h continuous service and the residents are the main providers of this service. The residents are assigned for on-call shifts during their training, as well as working during the regular day shifts. These schedules must address several considerations like preferences of the residents and coverage requirements of two different locations: the intensive care unit (ICU) and the surgery room (SR). In this study we develop a goal programming (GP) model for scheduling the shifts of the residents in the Anesthesia and Reanimation Department of Bezmialem Vakif University Medical School (BUMS). The rules that must be strictly met, like the number of on-duty shifts or preventing block shifts, are formulated as hard constraints. The preferences of the residents like increasing the number of weekends without shifts and assigning duties on the same night to the same social groups are formulated as soft constraints. The penalties for the deviation from the soft constraints are determined by the analytical hierarchy process (AHP). We are able to solve problems of realistic size to optimality in a few seconds. We showed that the proposed formulation, which the department uses currently, has yielded substantial improvements and much better schedules are created with less effort.

1. Introduction

The physicians in departments like brain surgery, general surgery, anesthesia and reanimation work under great stress, both mentally and physically. For example a brain operation may last more than ten hours and the physicians may not even have a chance to eat. A physician who works in an intensive care unit (ICU) deals with patients who are at the border of life and death. It is a frequent incidence for them to perform cardiopulmonary resuscitations, commonly known as heart massage, to the patients whose heart has stopped beating. This process takes about an hour and can happen more than once in a day. Moreover they have to inform the families of the those patients about the current situation and they need to address the irrational behavior of families/relatives resulting from anxiety. These departments also provide non-stop services for their patients, i.e., they continue their operations at nights and in the weekends. Residency is a stage of graduate medical training. A resident physician, or resident for short, is a person who has received a medical degree who practices medicine under the supervision of fully licensed physicians, usually in a hospital or clinic. Residents, who are students as well as being a physician, have to learn simultaneously while fulfilling all duties of a physician. On top of these, there are two shifts at medical schools and hospitals in Turkey: the day shift and the night shift. All of the residents are obliged to work in the regular daily shift[1] and are assigned for on-call shifts at nights and on the weekends as well. Although the scheduling of the shifts for the nights and the weekends can be easy when the number of residents is small, it is well known that the problem quickly gets complex when there is a large number of residents with different levels of experience and when there are several constraints like coverage requirements and resident preferences.

The residents must take a good rest in order to perform well in the physical tasks required by the job. More importantly, they must have a good mental rest in order to continue their educational process and to avoid job burnouts. Studies have shown that the scheduling of shifts has a significant impact on shift workers physiologically, psychologically and socially (Knauth, 1993, 1996) and better schedules prevent job burnout (Nelson, 2007). Moreover, it is demonstrated that the sleep deprivation that is seen in the residency training programs lead to medical errors (Grantcharov, Bardram, Peter, & Rosenberg, 2001) as well as serious

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[1] The only exception is the emergency service. They have a different shift structure.

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problems in daily life like traffic accidents (Marcus & Loughlin, 1996). We refer the reader to Owens (2001) for a review on effect of sleep deprivation on the residents. Following unfortunate statistics are relevant in this context: it is reported that the physicians working in anesthesia and reanimation departments rank third among all physicians in committing suicide (Roy, 2000). In Turkey, between 2008 and 2010, 10 physicians, who work in an anesthesia and reanimation department committed suicide (Cengiz, 2010).

Being established in 2010 in Istanbul, Turkey, Bezmialem Vakif University adopted a training and research hospital to establish a new school of medicine and started resident training programs at the beginning of 2011. Although a few of the residents are transferred to BUMS, most of the former residents continued their training at different hospitals. With two transferred residents and four new residents, the anesthesia and reanimation department started its medicine residency program in January 2011 with six residents. In 2012 September, there are 10 residents working in the department. The schedules of the residents in the anesthesia and reanimation department of BUMS are prepared manually by a physician who devote almost a week for preparing the schedule. In this paper we present a goal programming (GP) model for the scheduling problem of the residents in the department. The resulting formulation, which is currently in use, yields high-quality schedules in a few seconds. The mathematical model that we provide can easily be generalized for the use of any medical school hospitals in Turkey with small modifications since the shift structure of the other surgical departments is almost the same in the hospitals all over the country.

The rest of the paper is organized as follows. Section 2 gives some literature review. In Section 3, we give the current state of the department and define the problem. We give the GP model in Section 4. We comment on the benefits and give some computational results in Section 5 and finally conclude in Section 6.

2. Literature review

The major scheduling focus in health systems has been in nurse scheduling (Ernst, Jiang, Krishnamoorthy, & Sier, 2004). Nurse scheduling problem (NSP) is a type of resource-allocation problem, in which the workload needs to be assigned to nurses periodically, taking into account a number of constraints and requirements. Starting with the early studies Warner and Prawda (1972) and Miller, Pierskalla, and Rath (1976), the NSP has attracted attention from the operation researchers. There are various studies that use GP to solve the scheduling problem. For example, Ozkarahan and Bailey (1988), Berrada, Ferland, and Michelon (1996) and Azaiez and Sharif (2005) propose GP models which accounts for conflicting objectives of the hospital (continuous service with appropriate nursing skills and staffing size) and the preferences of the nurses (fairness for night and weekend shifts). Another approach is to use heuristic solutions. Aickelin and Dowsland (2004) and Tsai and Li (2009) propose genetic algorithm approaches, Bard and Purnomo (2005) uses column generation and Burke, Li, and Qu (2010) propose a hybrid model. For a survey on NSP, please refer to Cheang, Li, Lim, and Rodrigues (2003) and Ernst et al. (2004).

The differences in staffing requirements, worker preferences, specialties and policies distinguish the physician scheduling from the nurse scheduling. The literature on physician scheduling concentrates especially on the emergency room physician scheduling problem (ER-PSP). Beaulieu, Ferland, Gendron, and Michelon (2000) propose a mixed integer program to solve the ER-PSP. They formulate the problem over six months and solve the schedule of one month by considering the schedules of the previous five months. Carter and Lapierre (2001) classify the schedules of ER-PSP into three groups: the acyclic schedules, the cyclic schedules with rotation and the cyclic schedules without rotation. They develop general mathematical formulation of the physician scheduling problem and describe an application two different cases one of which has simple and the other having complex scheduling rules. In a recent work, Ferrand, Magazine, Rao, and Glass (2011) study the scheduling problem of the physicians at Cincinnati Children's Hospital Medical Center using integer programming to build cyclic schedules for eight weeks that can be repeated throughout the year. Based on their surveys with physicians, they showed that the new schedule provided well-balanced work patterns.

The resident scheduling problem (RSP) is different than the physician scheduling problems in the sense that the residents are students as well as being the providers of the medical services. The residents have seniority groups which determines the rule of thumbs of the scheduling rules. Ozkarahan (1994) provide the first attempts on RSP and proposes a GP model that solves weekly schedules and incorporates the preferences of the residents and the requirements of the residency program into the objective of the model. Sherali, Rahami, and Saifee (2002) formulates the problem as a mixed integer program and proposed heuristic solution procedures that are developed for different scenarios. Cohn, Root, Kymissis, Esses, and Westmoreland (2009) study the scheduling of residents of the psychiatry program at Boston University School of Medicine. They combine heuristic approaches and mathematical programming to come up with schedules that assigns 10 to 20 residents for the on call shifts at three different hospitals over 365 days period.

The Accreditation Council for Graduate Medical Education (ACGME) come up with certain rules in order to increase well-being of residents and the patient safety and reduce job burn-outs. The ACGME is a private, non-profit council that evaluates and accredits medical residency programs in the USA. Some of its rules include an upper limit of 80 hours per week and 24 h of continuous work. Day, Napoli, and Kuo (2006) provide an integer programming model for scheduling the weekly work hours of surgery residents considering the ACGME rules. Topaloglu and Ozkarahan (2011) develop a mixed integer programming model for scheduling residents shifts under the ACGME regulations. Their solution is based on the column generation which generates feasible schedules using constraint programming and then allocates residents to a subset of these schedules optimally considering demand coverage requirement.

Topaloglu (2006) develop a goal programming model for scheduling emergency medicine residents in Turkey. Her model accommodates both hard and soft constraints and the deviations from the soft constraints are penalized with the coefficients that are determined by the analytical hierarchy process (AHP). She showed that problems of realistic size can be solved efficiently. Topaloglu (2009) proposes a multi-objective programming model for scheduling residents with different seniority levels. The model considers the shift coverage requirements, seniority-based workload rules and preferences of the residents for their on and off days. For a recent review on RSP, we refer the reader to Rais and Viana (2011) and Kreeft (2012).

Although the model in Topaloglu and Ozkarahan (2011) is extensive and covers the ACGME rules, the residency programs in Turkey does not conform with the ACGME rules. For example, the residents may be assigned 15 shifts in a month which means 450 h of work in a month whereas ACGME proposes an upper bound of 320 h per month. Besides, the residents in Turkey work for 36 h if they are on-call for a night shift, however ACGME regulations has an upper bound of 24 h for continuous work. Similarly, the shift structure of the emergency room studied in Topaloglu (2006) is different than the other departments. They can take a day off after an on-duty shift. However, this is not the case in the surgical residency programs. Hence, our problem is different than the one that is given in Topaloglu and Ozkarahan (2011) and Topaloglu (2006). Topaloglu (2009)