Scheduling the Resident 80-Hour Work Week: An Operations Research Algorithm

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OBJECTIVE: The resident 80-hour work week requires that programs now schedule duty hours. Typically, scheduling is performed in an empirical "trial-and-error" fashion. However, this is a classic "scheduling" problem from the field of operations research (OR). It is similar to scheduling issues that airlines must face with pilots and planes routing through various airports at various times. The authors hypothesized that an OR approach using iterative computer algorithms could provide a rational scheduling solution.

METHODS: Institution-specific constraints of the residency problem were formulated. A total of 56 residents are rotating through 4 hospitals. Additional constraints were dictated by the Residency Review Committee (RRC) rules or the specific surgical service. For example, at Hospital 1, during the weekday hours between 6 AM and 6 PM, there will be a PGY4 or PGY5 and a PGY2 or PGY3 on-duty to cover Service "A." A series of equations and logic statements was generated to satisfy all constraints and requirements. These were restated in the Optimization Programming Language used by the ILOG software suite for solving mixed integer programming problems.

RESULTS: An integer programming solution was generated to this resource-constrained assignment problem. A total of 30,900 variables and 12,443 constraints were required. A total of man-hours of programming were used; computer run-time was 25.9 hours. A weekly schedule was generated for each resident that satisfied the RRC regulations while fulfilling all stated surgical service requirements. Each required between 64 and 80 weekly resident duty hours.

CONCLUSIONS: The authors conclude that OR is a viable approach to schedule resident work hours. This technique is sufficiently robust to accommodate changes in resident numbers, service requirements, and service and hospital rotations. (Curr Surg 63:136-141. © 2006 by the Association of Program Directors in Surgery.)

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INTRODUCTION

Institution of the 80-hour work week for residency programs poses many challenges for general surgery residency programs. Although it is imperative that residency programs are viewed as educational experiences rather than service functions, a wide variety of stakeholders draw on the available 80 hours. Therefore, constructing a schedule for a group of residents that will comply with the requirements of the Residency Review Committee (RRC) and the needs of various hospitals, general surgery, and specialty surgical services can prove to be extremely challenging and frustrating. Typically, a schedule is made empirically via "trial-and-error" and multiple iterations are constructed weekly or monthly, as gaps arise in residency hours or patient care responsibilities. Fortunately, the scheduling of the resident 80-hour work week is an example of the classic "scheduling" problem in the discipline of operations research or management science and is commonly taught to first year students in M.B.A. programs.

Operations research (OR) is the science of decision making. Operations research originated before World War II with the establishment of scientific teams to study strategic and tactical problems in military operations. The objective was to find the most effective utilization of limited military resources by the use of quantitative techniques, such as linear and nonlinear programming, network analysis, Markov processes, or stochastic programming.[1] In our setting, resident scheduling is a classic OR problem, typically termed "staff scheduling." Given a set of employees, assign them to a schedule such that they are working when most needed, while ensuring that certain constraints (such as work hours) are maintained. With the advent of more powerful personal computing resources over the last 15 years, optimization methodologies that combine ideas from OR with techniques from logic and artificial intelligence are available to a wide array of users. Given the history of successful implementation of OR techniques in the realm of business decision making, the authors hypothesized that OR techniques would be

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applicable for scheduling the resident 80-hour work week. Equally important, the lack of an OR solution would indicate that the problem is overly constrained, suggesting too many rotations, service requirements, and/or hospitals or, conversely, too few available residents. Finally, this technique could be generalized to set schedules while changing the number of residents, make-up of the resident teams, number of participating hospitals, number of rotations, or work-hour requirements.

METHODS

The scheduling problem was modeled based on the following assumptions. This schedule was generated for Duke Hospital, as a proof of concept. However, the same iterative process can be performed for other hospitals, based on manpower availability as described below.

Conditions for the 80-Hour Work Week Problem

x1 Residents are divided into 5 clinical years, labeled R1 through R5. R5s are the most senior.

x2 There are a total of 25 R1, 10 R2, 7 R3, 7 R4, 7 R5, and 1 R6 residents.

P The residents are allowed to work a total of 80 hours per week averaged over 4 weeks.

Q Residents must have off 1 complete 24 hour day out of 7 days, averaged over 4 weeks.

A There must be at least a 10-hour period of rest between duty periods.

B Residents cannot work more than 24 hours straight, although an additional 6 hours of time may be used for learning or outpatient clinic activities.

x7 The resident work day begins at 6:00 AM.

The residents rotate through 4 hospitals: Duke, Durham Regional Hospital (DRH), Durham VAH (VA1), and Ashville VAH (VA2). At Duke, the primary services (n = 5) are Gastrointestinal, Vascular, Surgery Oncology, Trauma, and Transplant. On some services, there are additional caregivers, Fellows, who can cover the residents' uncovered hours. These Fellows are not subject to work hour restrictions. Our first priority is to cover the services at Duke.

C Gastrointestinal, Vascular, Surgery Oncology, and Trauma must have at least 1 R5, 1 R3 or R4, and 1 R1 or R2.

R Vascular has an R6 resident. Gastrointestinal and Surgery Oncology each have a Fellow.

D Transplant must have an R3 and R2. Transplant has a Fellow.

E VA1 must have 1 R5, 1 R3 or R4, and 1 R1 or R2.

F VA2 must have 1R5, 1 R3 or R4, and 2 R1 or R2s (or a combination thereof)

G DRH must have 1 R3 or R4 and 1 R1 or R2.

From this point onward, the manpower requirements at Duke are listed. The other hospitals will configure their schedules, once the residents are assigned.

H During the hours of 6 AM to 6 PM, Monday through Friday, each service at Duke must have an R4, R5, R6, or Fellow on duty.

I During the hours of 6 AM to 6 PM, Monday through Friday, each service at Duke must have an R1, R2, or R3 on duty.

J During the hours of 6 PM to 6 AM, Monday through Friday, all of Duke will have a single R4, R3, or R5 on duty.

K During the hours of 6 PM to 6 AM, Monday through Friday, all of Duke will have 2 or 3 R1s or R2s on duty.

L On Saturday and Sunday, from 6 AM to 10 AM, each service at Duke must have an R4, R3, or R5 on duty.

M On Saturday and Sunday, from 6 AM to 10 AM, each service at Duke must have an R1 or R2 on duty.

N On Saturday and Sunday, from 10 AM to 6 AM, all of Duke must have 2 or 3 R1s or R2s on duty.

14 Two R2s are assigned to Critical Care, and they rotate 12 hours on, 12 hours off, then 24 hours on, followed by 24 hours off. There is an Anesthesia resident who rotates with these 2 Surgery R2s.

15 Each resident changes services once per month.

16 Each resident is allowed 4 weeks of vacation per year. This can be taken as a lump or spread through out the year in week-long blocks.

The questions to be answered are as follows:

1. Can these manpower needs be accommodated within the total number residents available and the 80-hour work week requirements? If so, what is the minimum number of R1 through R5 residents required?
2. If there are excess residents, how many are there and what is the total number of excess hours available? The authors would like to know this so they can rotate residents through elective courses.
3. Can this solution be configured in a general format as the numbers of residents change from year-to-year? The manpower requirements do not.

Problem Formulation

Let N_{Ri} be the number of residents i for i=1,...,6.

Let N_R be the total number of residents 1 through 5, not 6.

Let N_F be the number of Fellows.

Let N_W be the total number of workers.

$$N_R = N_{R1} + N_{R2} + N_{R3} + N_{R4} + N_{R5}$$

$$= 25 + 10 + 7 + 7 + 7 = 56$$

$$N_W = N_R + N_{R6} + N_F = 56 + 1 + 3 = 60$$

Let N_S be the total number of services. $N_S = 11$.

Let N_T be the total number of shifts. $N_T = 42$.

Indices

The authors will use 3 subscripts: i, j, and k. The first number (i) refers to the numeral assigned to each resident (Table 1). The