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DRIVING IMPROVEMENT WITH OPERATIONAL RESEARCH AND DECISION ANALYTICS

IMPACT

AUTUMN 2017

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Analytics provide considerable cost savings and managerial insight

THE OPERATIONAL RESEARCH SOCIETY

CONTENTS

MANAGING THE OPERATING ROOM SUITE AT UCLA RONALD REAGAN MEDICAL CENTER

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Can operational research be used to effectively manage costs at operating room suites of large multi-specialty hospitals? The answer is a resounding yes. A decision support system has been implemented to minimize daily expected resource usage and overtime costs across multiple parallel resources such as anesthesiologists and operating rooms, which are used to conduct a variety of surgical procedures at a large multi-specialty hospital: the UCLA Ronald Reagan Medical Center (UCLA RRMC), one of the leading hospitals in the U.S. This system successfully incorporates the flexibility in the resources and uncertainty in surgical durations, and explicitly trades off resource usage and overtime costs. It has increased the average daily utilization of the anesthesiologists by 3.5% and of the operating rooms by

3.8%, leading to average daily cost savings of around 7%, estimated to be $2.2 million on an annual basis. Furthermore, insights based on this model have significantly influenced decision making in the operating services department (OSD).

PROBLEM DESCRIPTION

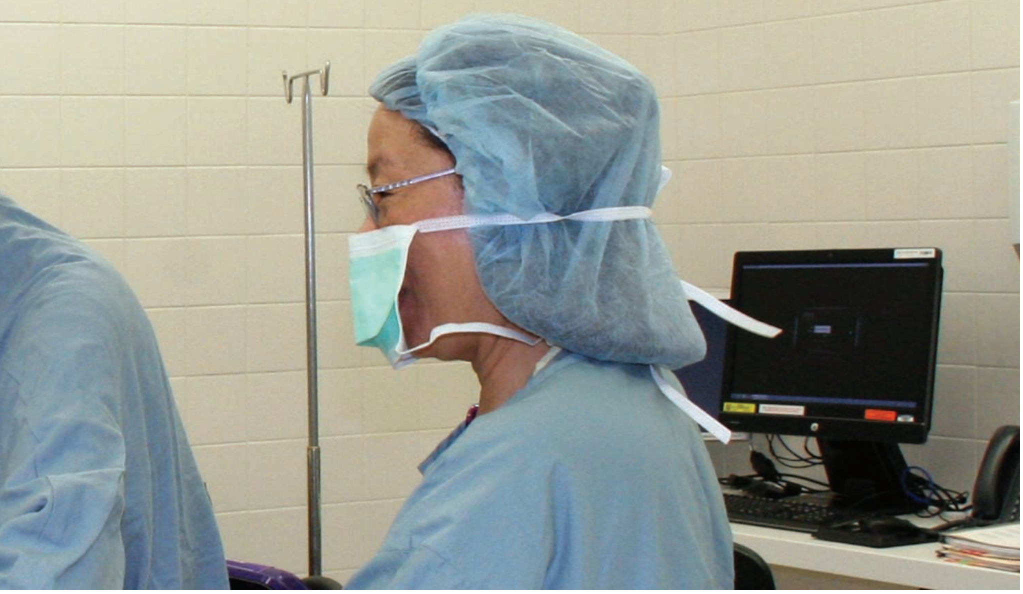
Surgical procedures are complex tasks requiring the use of several specialized and expensive resources. The OSD is responsible for managing resources used in surgical procedures. Every day, this department assigns to each surgery an operating room, an anesthesiologist, a nursing team and the requisite surgical materials. The department also determines the sequence in which these surgeries will be performed and the scheduled start times. While performing these actions, the department ensures that the cost of the operating room suite is minimized by reducing resource usage and overtime costs. A significant amount of time is devoted to making these resource management decisions. The complexity of these decisions at any large hospital occurs for four primary reasons. First, operating room resources are expensive, and thus in short supply. Second, surgical procedures are often very specialized. Third, the durations of surgical procedures are very difficult to predict. Finally, the scale of large hospitals, in terms of the number of operating rooms, procedures conducted, the number and types of equipment and anesthesiologists used, makes the simultaneous scheduling of multiple resources a computationally challenging task.

"Operating services is one of the largest departments at UCLA RRMC" reports Aman Mahajan, executive director of the OSD, "with around $120 million in annual revenues representing about 10% of this hospital's revenues. My department serves around 27,000 patients annually by conducting around 2700 types of elective and emergency surgical procedures across 12 specialties".

This system has increased the average daily utilization of the anesthesiologists by 3.5% and of the operating rooms by 3.8%, leading to average daily cost savings of around 7%, estimated to be $2.2 million on an annual basis

Emergency surgeries are conducted in three dedicated operating rooms with a separate team of anesthesiologists. Since emergency surgeries are separated from elective surgeries and account for only about 15% of revenues, we focused on elective surgeries, which can only be scheduled to start between 7am and 3pm. To perform these surgeries, OSD uses 23 Operating Rooms (ORs), which are scheduled and staffed simultaneously and shared by the 12 specialties. Some specialties (Plastics, ENT, Urology, Eyes, General) can use any of the ORs, but for others (Vascular, Neuro, Liver, Thoracic, Cardiac Trauma, Pediatric) three or fewer rooms are available. There are fixed costs for opening an operating room each day: initial cleaning and equipment setup costs along with daily nurse and technician staffing costs, whose assignments do not depend on specialty. In addition, overtime costs are incurred for nurses and technicians if the rooms are required to be open beyond 3pm.

The 92 anesthesiologists at UCLA RRMC for the 12 specialties are assigned according to the specialty required for the surgery. There are three shifts of equal duration, with regular working hours of eight hours. They can only be assigned to surgeries that begin during their shift. Overtime costs for anesthesiologists are incurred if surgeries in progress exceed the duration of the shift. A certain number of anesthesiologists who are not scheduled to work on a given day are asked to be on standby, so that they can be called to work if necessary. However, when they are assigned from call, there are significant costs for using such an option, but they do not incur overtime costs. The anesthesiologists on call are informed of their status the previous day and assigned surgeries that day as required.



It is important to note that in the context of large multi-specialty hospitals such as UCLA RRMC, surgeons are not part of OSD. They are usually from the independently administered specialty departments at this hospital and sometimes can be from other hospitals. The surgeons bring their patients and use OSD as a service provider. Thus, OSD does not have the option of assigning surgeons to patients. Thus, each surgery-surgeon combination is already set and is considered together.

SCHEDULING SURGERIES

Typically, a request to schedule a surgery is initiated by the surgeon on behalf of the patient with general admissions at the hospital. This request is assigned a date based on the earliest availability in the block reservations for the particular specialty. Once all the elective surgery requests have been received the day before the surgery, OSD decides which operating room to open, finalizes assignment of these rooms and anesthesiologist to surgeries, determines start times of surgeries and effectively specifies the sequence of all the surgeries. These decisions are made the previous day for all the surgeries that need to be conducted in the following day. Consequently, the planning horizon is a single day. The current planning process to make these decisions uses an experience-based practitioner's heuristic consisting of the following steps.

Step 1: Assign surgeries to operating rooms in sequential fashion in order of start times requested by the surgeons, by surgery specialty and duration estimates from surgeons, until the last surgery in the room can start before the end of the shift for the operating room.

Step 2: Assign one anesthesiologist to each room such that the anesthesiologist can perform most of the surgeries in the room.

Step 3: A few anesthesiologists are assigned to surgeries across rooms to ensure all surgeries have been assigned an anesthesiologist by specialty.

Step 4: If this plan cannot be implemented by anesthesiologists on regular duty, assign anesthesiologists from call.

While this practitioner's heuristic is easy to understand and implement, it does not consider two important aspects. First, it does not explicitly consider uncertainty in surgical durations. Second, it does not directly consider that most anesthesiologists and operating rooms can perform more than one specialty. Thus, it does not exploit the flexibility in these resources.

Inefficient assignment and scheduling of anesthesiologists and operating rooms to surgeries leads to low utilization (the fraction of the available shift time that is used by a particular resource) and overtime. Average daily utilization across the anesthesiologists is close to 0.75, with around 25% of days having an average daily utilization of less than 0.70. However, despite these lower levels of utilization, the average number of anesthesiologists on call is around 6 per day. Similarly, for operating rooms the average daily utilization is close to 78% but the average overtime per day is around 18 hours. Taken together, average call and overtime costs for anesthesiologists and rooms at this department are about 33% of revenues. A more effective optimization based assignment and scheduling process that considers uncertainty in surgical durations and flexibility in the resources could potentially reduce overtime and on call costs. To achieve these objectives, we developed a decision support system at the UCLA medical center. The core of this system was a large-scale, two-stage mixed-integer stochastic dynamic program with recourse. The first stage allocates these resources across multiple surgeries with uncertain durations, and prescribes the sequence of surgeries to these resources. Assuming that each surgery should be scheduled as early as possible, this consequently provides a scheduled start time for surgeries. The second stage determines the actual start times to surgeries based on realized durations of preceding surgeries, and assigns overtime to resources to ensure all surgeries are completed using the allocation and sequence determined in the first stage. The size and complexity of the problem precluded a solution using conventional methods. Therefore, this was solved using a data driven robust optimization approach that solves

SUMMARY OF RESULTS BEFORE AND AFTER IMPLEMENTATION OF DECISION SUPPORT SYSTEM			
ATTRIBUTES	BEFORE	AFTER	% REDUCTION
Average number of anesthesiologist on call per day	6.0	5.6	6.7
Average overtime per day for anesthesiologist (hours)	18.2	17.5	3.7
Average daily utilization of anesthesiologist (%)	75	77.6	-3.5
Average number of operating rooms used per day	20.4	18.6	8.6
Average overtime per day for operating rooms (hours)	18.5	18	2.7
Average utilization of operating rooms per day (%)	78	81	-3.8
Average daily operating room costs ($)	57,350	52,417	8.6
Average daily overtime costs ($)	2,2375	2,1754	2.8
Average daily call costs ($)	7,145	6,527	8.5
Average total daily costs ($)	86,870	80,729	7.1

large-scale real-sized versions of this model close to optimality. (For details on the model formulation, properties and solution techniques see Rath, S., K. Rajaram and A. Mahajan (2017). Integrated Anesthesiologist and Room Scheduling for Surgeries: Methodology and Application. *Operations Research* **65**: 1460-1478).

RESULTS

The results before and after the implementation of the model are summarized in the Table, which shows, for instance, that the average number of anesthesiologists on call decreased by 6.7%, and average overtime hours for the anesthesiologists on regular duty reduced by 3.7%. The improvements in these and all the other metrics reduced average daily operating room costs by 8.6%, average daily overtime costs by 2.7%, and average daily call costs by 8.5%. This translates to an overall average daily cost saving of 7%, estimated to be $2.2 million on an annual basis.

There are two main reasons for these improvements. First, the model was more effective at utilizing the flexibility in the resources. Most anesthesiologists and operating rooms can perform more than one specialty, typically a primary and a secondary specialty. This system identified these operating room/anesthesiologist combinations and allocated surgeries across these different specialties to them. This led to better usage of resources than the previous approach, in which surgeries from a single specialty were assigned to an operating room and anesthesiologist as much as possible. A surgery of a different specialty was assigned to an operating room only when there were high volume of surgeries in a particular day and this was often done without explicit consideration of the allotted anesthesiologists' specialty. Thus, this frequently required a separate anesthesiologist to perform these surgeries, who were often assigned from call and this was costlier. Second, this system explicitly considered uncertainty in surgical durations while determining the daily schedule of an operating room. By using an estimation method, it determined which surgeries could be longer and more uncertain, and which surgeries could be shorter and more certain. It then combined long uncertain surgeries with short certain surgeries to effectively utilize gaps in the schedule in each operating room. This in turn reduced the number of operating rooms each day with the resulting cost reduction being more than any potential increases in overtime costs, thus reducing total costs. In contrast, the previous approach used surgeons' predictions of surgery durations. To compensate for the errors in these predictions, planners often underutilized operating rooms by leaving sufficient gaps between surgeries. This was done as they did not want to create delays from scheduled start times of succeeding surgeries and incur overtime costs. However, this often led to a larger number of operating rooms being used each day and consequently higher total costs.

Finally, the impact of the schedules generated by this system on the surgeons was evaluated. While surgeons were not part of OSD, they are a critical component in the surgical process. First, we found that the average idle time between surgeries was 8 minutes shorter, but the surgeons did not find this reduction significant enough to be disruptive, and in fact some of them preferred this as it made their schedule more efficient. Second, there was only a marginal increase, from 1.54 to 1.57, in the average number of surgeons per OR per day. This suggests that most of the benefits of this system came from making the correct assignment of operating rooms and anesthesiologist to surgeries. Both these aspects were important to verify that the surgeons were not inconvenienced by the model based approach.

MANAGERIAL INSIGHTS

The decision support system generated several managerial insights. First, various scenarios were simulated to consider the impact of reducing variability in surgical durations. The results showed that rather than invest in capital-intensive medical equipment to achieve radical reductions in variability in surgical durations, the major cost benefits can be gained by focusing on incremental reduction in variability. Potentially, this can be achieved by more detailed data collection for improved predictive analytics, and better procedures, such as check lists, improved information technology, following the correct sequence in tasks and standardized operating protocols derived from best practices.

Second, this system was used to consider the impact of allowing surgeries to start in operating rooms after 3pm but before the end of the late shift of the anesthesiologists at 7pm. This would require additional fixed technician and nurse staffing costs. Such extensions can be considered if surgical demand on any day is significantly larger than average daily surgical demand. The results suggest that it is beneficial to allow such extensions and the number of operating rooms used depends on the level of demand. This analysis helps management understand how best to react to different levels of daily surgical demand and also estimate the corresponding changes in total costs.

Finally, the benefit of increasing cross functionality of the operating rooms was examined. To do so, the system was used to calculate the potential reduction in costs if the number of operating rooms available for each specialty is increased. Such increases can be achieved by investing in special equipment to convert general surgery operating rooms to have the cross functionality to accommodate a particular specialty. "The results show" says Mahajan "that increasing the number of operating rooms that could be used for a particular specialty can lead to a significant reduction in total resource usage and overtime costs, and these benefits are often more pronounced in certain specialties." This analysis enables the priority for which specialties additional operating rooms should be made available to be determined. An additional advantage of making operating rooms cross functional is that a higher number of daily surgeries can be more effectively accommodated without conducting new surgeries after 3pm. In particular, it was estimated that this approach led to at least an additional 5% reduction from the lowest costs attainable for all the demand scenarios considered. This provides further justification for management to make more operating rooms cross functional.

The use of the model resulted in considerable cost savings, and has encouraged the management to investigate other problems in this department using a structured and rigorous approach by employing operational research-based methodologies

ORGANIZATIONAL IMPACT

This work has demonstrated the value of a model based approach and analytical methods in dealing with complexity. The organizational impact of this work has been significant. The use of the model resulted in considerable cost savings, and has encouraged the management to investigate other problems in this department using a structured and rigorous approach by employing operational research-based methodologies.

The managerial insights generated from our model have also contributed to the organizational impact. Our analysis of the effect of variance reduction provided management with the further impetus to implement six sigma programs to reduce variability at OSD. It also provides management with clear guidance on when to start new surgeries after the day shift and in how many rooms, allowing mitigation of the impact of varying levels of daily surgical demand on costs. Finally, this work showed the benefits of making some operational rooms cross functional and how to prioritize implementation among the specialties. Furthermore, it was demonstrated that this could potentially be a very effective way to accommodate changes in daily surgical demand.

The methodology has had a major economic and organizational impact at UCLA RRMC's OSD. "The OSD expects to maintain the described gains and to increase them continuously several years into the future", says Mahajan. "Furthermore, this system is general enough to be adapted to other multi-specialty hospitals and similar benefits can be expected to be accrued".

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