A new mathematical model streamlines hospital OR scheduling

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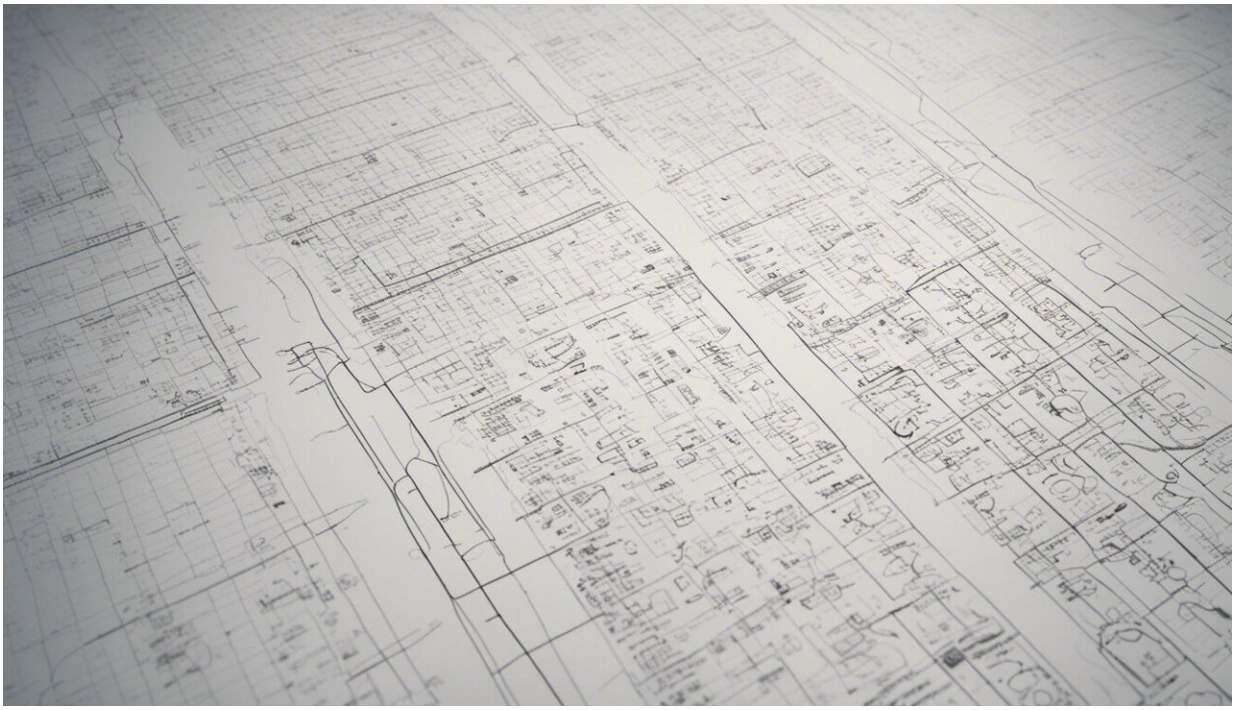

Credit: AI-generated image (disclaimer)

The scheduling of surgeries in a hospital operating room is a process fraught with uncertainty. The most carefully planned day can be upended by the unexpected arrival of a patient requiring an emergency operation. If a surgeon needs more time than expected to complete a procedure, if a patient shows up late or if a nurse has to call out sick, an entire day's

procedures can be delayed.

Operating rooms (ORs) consume about 40 percent of a hospital's budget, says Miao (Mark) Bai, who earned his Ph.D. in industrial and systems engineering (ISE) at Lehigh earlier this year. Not surprisingly, OR scheduling has been the object of much scrutiny from researchers.

Bai and his colleagues in Lehigh's ISE department have developed a scheduling model that they believe outperforms other scheduling methods by dealing both proactively and reactively with disruptions and by accounting for bottlenecks in post-surgery recovery rooms.

The model is designed for a surgical suite with multiple ORs that share a post-anesthesia care unit (PACU) where patients recover from anesthesia. The model schedules surgeries one day in advance and is then adjusted dynamically on the day of surgery to respond to disruptions.

The model's proactive algorithm develops a robust OR schedule that can accommodate a certain level of disruptions, says Bai, who is now a research associate at the Mayo Clinic in Minnesota.

"This robust schedule is developed the day before surgery, when we do not know exactly what will happen on the day of surgery," says Bai. "However, we derive statistical information…from historical data. By incorporating this information, we build predictions of potential day-of disruptions into our methodologies."

The model's reactive algorithm performs the same tasks as the OR manager or charge nurse who is responsible for handling disruptions on the day of a surgery, says Bai, but with a critical advantage.

"In contrast to the charge nurse's experience-based adjustments, our algorithm dynamically coordinates adjustments in all ORs in a more

systematic and data-driven way…based on information obtained on the day of the surgeries," says Bai. "In addition, based on mathematical optimization and statistics, our algorithm can provide a more accurate estimate on how much a surgery should be postponed or moved up.

"If, for example, there is an excessively long delay at the beginning of the day, our algorithm can calculate the times by which following surgeries should be postponed to avoid unnecessary wait."

Bai described the Lehigh OR scheduling model in an article published recently by IISE Transactions and titled "A sample gradient-based algorithm for a multiple-OR and PACU surgery scheduling problem." The article was coauthored with Robert H. Storer and Gregory L. Tonkay, professors of industrial and systems engineering at Lehigh.

In their study, the Lehigh researchers considered a variety of factors that cause disruptions. These included uncertainty over the duration of a surgery, the availability of PACU recovery beds, surgical emergencies, surgery cancellations and patient punctuality.

The unavailability of PACU beds can have a "blocking" effect, delaying surgeries by requiring patients to remain longer than necessary in ORs, says Storer.

"A lot of researchers have written about OR scheduling," says Storer. "Mark was one of the first to take into account the role that PACUs play. A hospital typically has more OR than PACU beds. If all of its PACUs are full, patients must remain in the OR even if their surgery is concluded.

"This has a blocking effect, slowing the flow of patients from the OR to the PACU, causing surgeries to be delayed or postponed, increasing wait times for surgeons and patients, and creating idle time for staff.

"Mark determined that the OR scheduling problem should not be solved without at the same time solving the blocking effect caused by full PACUs."

In developing its model, the Lehigh group also considered the "to-follow" policy used by most hospitals in OR scheduling.

"One feature of our work that distinguishes it from previously published surgery scheduling studies is that it utilizes the 'to-follow' policy, a practice used in all surveyed hospitals," the researchers wrote.

Under the to-follow policy, if a surgery is completed before its scheduled time, or if a surgery is canceled, other scheduled surgeries are moved up 'to-follow' the completed procedure as soon as possible.

"The scheduling literature has used the standard assumption that no surgery can begin before its scheduled start time," the researchers wrote. "[Our] use of the 'to-follow' policy in hospitals updates this assumption."

The Lehigh researchers tested their scheduling model using numerical simulations and concluded that the model was able "to identify near-optimal solutions and to outperform the scheduling method used in practice."

Based on national statistics concerning median compensation for different medical occupations, the researchers estimate that their method can reduce overall OR costs by an average of just under 10 percent.

Bai, the lead author of the IISE paper, has studied OR scheduling for five years. Storer has conducted research into the subject for eight years.

In his research, Bai visited local hospitals to observe surgery departments, to shadow nurses who manage operating rooms, to attend

surgery scheduling meetings and to interview healthcare practitioners. He also conducted a formal survey of surgeons in the United States, Canada and the United Kingdom, as well as an informal survey of healthcare practitioners in China.

He was assisted in his efforts by Dr. Terrill Theman, the retired former director of the Cardiac Surgery Program at St. Luke's Hospital in Bethlehem who is now an adjunct professor in Lehigh's graduate-level program in Healthcare Systems Engineering.

"Instead of dealing with data alone, Mark interviewed people involved in making decisions at hospital ORs and built this into his model to give it the tang of reality," says Theman. "His model does not remove human beings from the process of managing ORs, but it makes their job easier. Frankly, I think it's a brilliant solution."

Bai is the lead author on three more articles on OR scheduling and planning that are currently under review or in revision with scholarly journals. One of them, titled "Proactive-reactive surgery scheduling under disruptions and the 'to-follow' policy," is coauthored with Storer, Tonkay and Theman. It discusses the results from the group's study of proactive and reactive scheduling.

Bai is applying the same theoretical framework to solve scheduling problems in the Radiology Department at the Mayo Clinic.

More information: Miao Bai et al. A sample gradient-based algorithm for a multiple-OR and PACU surgery scheduling problem, *IISE Transactions* (2016). DOI: 10.1080/0740817X.2016.1237061

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