Simulation Based Optimization Of A Pre-Surgical Screening Clinic

Phil Troy, Nadia Lahrichi, Dana Porubska, Lawrence Rosenberg
Sir Mortimer B. Davis Jewish General Hospital and McGill University
3755 Chemin de la Cote-Sainte-Catherine Montreal, QC H3T 1E2
Lawrence.Rosenberg@mcgill.ca

1. Introduction

To ensure that surgical patients at the Sir Mortimer B. Davis Jewish General Hospital are appropriately prepared for their surgical procedures, the hospital is creating a pre-surgical screening (PSS) clinic. Given the limited space availability and the cost of staffing, when designing a pre-surgical screening clinic, it seems desirable to simultaneously optimize space requirements, together with the scheduling of patients and staff. This is because patient scheduling affects staff scheduling, which in turn affects space requirements.

The objective of this research was to use simulation based optimization to simultaneously generate a patient schedule, a staff schedule, and space requirements. To the best of our knowledge, the simultaneous simulation based optimization of schedules and space requirements has not been used before in the concept stage of project development to insure that operational efficiency and cost effectiveness are an integral part of the functioning of a hospital clinic.

This abstract is organized as follows. In section 2 we describe the optimization problem. In section 3 we describe the simulation model built to analyze specific space, staff and schedule configurations. In section 4 we propose an optimization approach, and in section 5 we discuss possibilities for future work on this problem.

2. The Problem

PSS clinics are not all identical. Some PSS clinics, such as those in the interior health authority in British Columbia [1] and the Royal Victoria hospital in Montreal, have no physicians. In contrast, this clinic will have both general practitioners and internists, and will provide four levels of pre-surgical screening: (1) nurse calls to patients in good health having minor surgery, (2) nurse visits for similar patients whom the nurse felt would be better off seen in person, (3) medical exams performed by a general practitioner for patients having relatively minor surgery or for those with co-existing medical issues, and (4) medical exams performed by an internist for patients having major surgery or more significant co-existing medical issues.

After arriving at the clinic for their scheduled visit, depending on the level of screening need, patients will, in this order, register with the admissions clerk, watch an orientation video, meet with a pharmacist, go into an exam room, change into a gown, have an EKG performed, see either a general practitioner or internist, change back into their street clothes, attend a group training session, and attend a one-on-one training session with a nurse. In contrast to most other pre-surgical screening clinics that we have investigated, we have added the orientation video and the group training sessions to improve the quality of training without unnecessarily requiring more resources. To ensure privacy, patients will stay in their exam room from the time they start changing into a gown until the time they finish changing back into street clothes. Patients will also provide insurance and contact information to registration staff during any idle time they have after registration. Should patients need to have blood taken or a urine sample collected, they can do so at any idle time they have after watching the orientation video.

Having decided to develop this new clinic, the hospital needs to determine the size of the space to be allocated, and how the space should be renovated to meet the needs of the clinic. To do so, there is a need to determine the number of exam rooms, the number of nurse training rooms, the space needed for the blood takers and the EKG technicians, and the size of the waiting area. To adequately establish the size of these individual spaces, the number of each type of staff that will be working at the same time needs to be determined, and to accomplish this, staffing schedules must be developed in an informed manner.

The decision making process is being driven by management's desire to:

- Minimize the space used by the clinic, because this will minimize the renovation related cost.
- Minimize the amount of time physicians have to wait between exams.

- Minimize staffing costs, including overtime.
- Minimize excessive waiting by patients.
- Minimize patient overflow from the clinic into hospital hallways.

Note that all but the last of these are readily amenable to being included in a single cost function, and using a weight variable, the last one can also be added to such a function.

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Complicating the decision making process is the randomness inherent in patient visits to the clinic. This randomness occurs throughout the process, starting with whether patients are available when called to schedule their visit, in the needs each patient has of the screening process, and in the physical condition of patients as it affects the length of time needed for each step of the screening process.

3. The Simulation Model

To analyze specific space allocations, staffing decisions, and staff and patient scheduling, we developed a simulation model of the clinic. To provide increased flexibility with respect to modeling staff arrival times, breaks, lunches and start times, the model treats physicians, staff, patients and exam rooms as entities. The model also treats the arrival time of each individual as a potential decision variable, thus making it possible to individually set arrival times so as to minimize costs. To provide a basis for specifying the mix of patient types to be addressed by the clinic, we compiled a table profiling patient screening needs that includes the percentage of all patients associated with each profile. While there are many ways of profiling patient screening needs, our initial profile is based both on the four broad levels of pre-surgical screening discussed above, and on whether the patient will require extra time for individual tasks, e.g. to get into and out of a surgical gown.

Because of the multiple interactions between staff members and patients, rather than build this model as a flow chart as is often done with commercial simulation software packages, we instead built it to trigger programming specified handlers for events such as staff members arriving for work, needing to take a break, needing to go for lunch, finishing serving a patient, needing to go home, and going home. For similar reasons, the animation of the simulation is that of a console showing the number of each type of staff member in each state they can be in.

Collecting data for the model has been a serious challenge. In particular, the fraction of patients in each profile can only be guessed at, as there is no way to collect this data until the clinic commences operations. To address this, the patient profile table mentioned above was created so that the fractional distribution of patients can be easily adjusted, and so that the simulation can use the table to specify the patients to be simulated.

Likewise, estimating the distribution of times needed for each task undergone by patients in each profile has also been a serious challenge. This is because many of the tasks are not currently being performed for patients in the hospital, and when they are, they are done so in a different environment where the process times may be different. To address this lack of information we have consulted with several domain experts, and are creating a survey [6] to collect data on the duration of time taken by patients going through the existing pre-admission testing clinic, though the scope and goals of that clinic are very different than those of the proposed clinic. As with the patient profiles, the distribution of times for each combination of patient task and profile will be set from parameters specified in easily adjustable tables so as to facilitate sensitivity analysis of the results.

4. Simulation Based Optimization

Due to the randomness inherent in the model, we feel that the best approach for identifying better decisions to the problem described above is to use simulation based optimization. This is in contrast to the more common approach of using non-stochastic optimization techniques to statically create schedules, and to then test the results of those schedules using simulation [3]. Queuing network theory will not be used because the heterogeneity of the processing time distributions for each node in the network would violate the conditions required by that theory.

In our simulation, we will generate a large number of days. For each day, the number of patients generated from each of the major profiles will equal the mean number of patients in each of the major profiles operated on each day; what will vary from day to day is the length of time each patient takes for each task. We will then minimize the costs of the clinic with respect to the scheduling of a single set of arrival times for staff and patients, staff levels, and facility size values, so as to determine values for these decision variables that work well across all of the simulated days. To perform the optimization, we will use a metaheuristic such as Tabu Search [5], which has been found effective in a large variety of scheduling problems [2,4]. To determine the effectiveness of our approach, we will compare it retrospectively with what might have been possible on all of the days individually, by solving the optimization problem statically for each day in context of the times used in the simulation.

5. Future Work

Since the solution found in the approach proposed above is the same for all of the days being simulated, it is possible that while good overall, it may be possible retrospectively to find daily schedules that are significantly better once the times for each patient's tasks are known. To address this possibility, in the future and in context of fixed capacity and staff schedules, we will consider more dynamic approaches, including the possibility that as the state of the clinic changes on a particular day, the priorities of individual patients for their remaining tasks are adjusted so as to minimize the total operating costs for that day.

References

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