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USING SIMULATION OPTIMIZATION FOR INTERDEPENDENT OPERATIONS IN HEALTH CENTERS

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ABSTRACT

Many patients require multiple services provided by different departments and facilities during one visit to a health center or hospital. These multiple services provided to common patients define interdependencies among departments within a hospital, in which the operation and efficiency of one department may impact the other interrelated departments. In order to minimize the total patient length of stay for those with multiple services, a simulation-optimization framework is constructed. The day-to-day operation of each department is simulated using discrete-event simulation modeling. At the beginning of each iteration, an optimization model for each node defines the patient and provider schedules and resource allocation for each hour of the day. The simulation results, inflows, and outflows of each department are used to inform the next day optimization model. This iterative procedure continues, until the performance gap become minimal.

1 PROBLEM OVERVIEW

Although existing literature advocates the need for outpatient clinics, inpatient wards, and Emergency Rooms (ER) to increase efficiency and quality of care, there is a dearth of studies analyzing aggregate efficiency of two or more health center units when there exist interdependent operations among the departments. Most research focuses on a specific clinic or a department in a hospital and seeks to optimize the performance of that unit accordingly. But many patients need to visit two or more hospital departments in one visit, such that even if each department is locally efficient, that does not guarantee that patients will experience timely care when they are required to visit multiple departments. On the other hand, inefficiency in one department can cause the interrelated departments to experience inefficiencies, as a result of these interdependencies. The integrated patient length of stay, the difference between the arrival and departure of the patient from the hospital, is often overlooked by department managers, either because of a lack of information sharing between the departments or a failure to understand the importance of unified decision-making among departments which can maximize overall patient quality of care.

Interdependencies in hospital operations can be characterized by the scope and the type of the dependency. While the scope of interdependencies refers to the number of departments that are interconnected, the type refers to the nature of the relationship that causes interdependency between two or more departments. The first type of interdependency can be defined as a one-to-one (1:1) relationship, where one department has interdependent operations with another department in the hospital and the interdependency can be bi-directional. One example of this type of interdependency is an obstetric outpatient clinic with a labor and delivery inpatient ward. Patients of the outpatient clinic are expected to go to the inpatient ward for delivery within a certain timeframe. Hence, the outpatient clinic patient volume and the rate of new patients to the clinic is expected to directly affect the demands on the inpatient labor and delivery unit months later. Additionally, the patient volume in the labor and delivery department will directly affect the patient volume for postpartum services in the obstetrics department.

The second type of interdependency can be defined as a one-to-many relationship (1:N), meaning that one department is interconnected with multiple other departments, but the relationship is not necessarily bi-directional. An example of the one-to-many interdependency relationship is the Emergency Room (ER) with inpatient units of a hospital. The complexity of ER operations is due, in part, to the extensive variety of types of patients that are seen, both with regard to the type of injury and the severity of the ailment. Patients in the ER can be subsequently admitted to many different departments of a hospital including operating rooms, imaging services, or inpatient units. Correspondingly, the operation of the ER, whether efficient or inefficient, directly effects many departments within the hospital and these destination departments need to plan accordingly. Another example of a one-to-many interdependency is the operation of medical interpreter groups within a hospital. Interpreters scheduling is very complex based on the variety of languages provided and uncertainty regarding demands among different departments. Correspondingly, a delay in the availability of interpreters can lead to significant delays in many departments throughout the hospital that are waiting for these services. The third type of interdependency is defined as a many-to-one relationship (N:1) where many departments require a service from one department and where the relation is not bi-directional. For example, the radiology and imaging department often operates as a critical hub, where patients from many different departments of a hospital visit to obtain required imaging services as part of the treatment process. Patients from many different specialties, including primary care, surgery, orthopedics, and rheumatology need imaging services before, in the middle of, or after their visit. Hence, the efficiency of the radiology department's operations impact several outpatient and inpatient departments(Vahdat et al. 2017).

2 PROPOSED SOLUTION APPROACH

The complexity of patient flows and uncertainty of processes within single clinics often supports the need to study these systems with the use of discrete-event simulation (DES) models. While this DES method can be used to show the day-to-day operations of each department, simulation per se cannot optimize shared decisions that impact interdependent departments. Hence, a simulation-optimization algorithm is proposed to address the three types of interdependency defined above. The general framework for the proposed solution is as follows. A network model is constructed in which nodes correspond to the departments and the edges represent interdependencies among nodes. Note that edges can be uni-directional or bi-directional, depending on the type of interdependency, and there may be outflows or inflows to each node. At each node, a simulation model is constructed that corresponds to detailed processes within each department.

To minimize integrated patient length of stay, certain decision variables are optimized at the beginning of each iteration in each node. These decision variables include patient and physician scheduling and resource allocation. The simulation model at each node uses optimized decision variables as input parameters and runs for a specified time frame. The outputs of the simulation model for each unit are used as performance metrics of the proposed solution. Additionally, information pertaining to outflows and inflows from each node per hour of the day are used as inputs to the next optimization model iteration. The optimization model is again used to find the value of decision variables in each node based on the information from the simulation model. This iteration process continues until either the improvement gap becomes very small or a predefined timeframe is reached. The simulation-optimization framework can be adjusted to address the three types of interdependencies defined above.

REFERENCES

Vahdat, V., J. Griffin, S. Burns, and R. Azghandi. 2017. "Proactive Patient Flow Redesign for Integration of Multiple Outpatient Clinics". In *Proceedings of the 2017 Winter Simulation Conference, editedby W. K. V. Chan, A. D'Ambrogio, G. Zacharewicz, N. Mustafee, G. Wainer, and E. Page.* Piscataway, New Jersey: Institute of Electrical and Electronics Engineers, Inc.