

Optimization of Surgery Allocation

Problem Identification & Scope Definition

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1. PROBLEM IDENTIFICATION

Surgeries are stressful. The thought that a surgery might go wrong often haunts patients waiting for surgeries, leaving them in an undesirable mental state. In order to reduce the effects of stress accumulated in patients, it is crucial to minimize the time that a patient needs to wait to have surgery.

On top of this, surgical interventions are responsible for 52% of all admissions to the hospital and account for more than 40% of the total expenses of a hospital². Since most of these costs are associated to salaries paid to surgeons and other staff which are at the hospital at fixed schedules, these costs can be minimized by maximizing the use of the operation rooms available¹.

With these problems in mind, we devised this simulation project with the purpose of optimizing the allocation of surgeries to operating rooms and with the more specific goals of:

- Minimizing waiting time for surgery.
- Minimizing costs associated with the use of operating rooms.

1-Ronald D. Miller, *An Operating Room Scheduling Strategy to Maximize the Use of Operating Room Block Time*

2-Amin Abedini, *An Optimization Model for Operating Room Scheduling to Reduce Blocking Across the Perioperative Process*

2. DOMAIN CHARACTERIZATION

In a hospital, there are rooms designed specifically for the purpose of performing specific surgeries. With our simulation project, we want to test different procedures that will schedule surgeries, allocating them to operating rooms.

Each operating room has an availability time per day which can be divided into many time blocks in which surgeries occur. The time blocks don't have a specific size, they are defined according to the times that each surgery needs. The surgeries are then allocated to block times.

Since, the scheduling of surgeries does not happen all at once, we will simulate the arrival of patients in a queue, with a linear distribution, for simplicity purposes. The allocation of surgery to block times of operating rooms happens as the patients arrive in the queue.

In this scenario, we need to consider that there are various degrees of urgency associated with each patient's surgery and that urgent cases need to be attended faster than others. This urgency can be expressed as the maximum time that a patient can wait for surgery. Since the allocation happens upon the patient's arrival, scheduling an urgent surgery might result in having to reschedule another surgery.

When it comes to medical staff, we assume that each surgery has a head surgeon already defined. We will need to make sure that there are no multiple surgeries with the same surgeon happening at the same time. For simplicity purposes, we will consider that all the remaining staff needed for surgery doesn't need to be allocated specifically to a surgery. There will always be staff available during the operating rooms hours.

3. SIMULATION SCENARIOS

3.1. Hypotheses to test

- The average waiting time increases with a decrease in the average urgency time. If there are more urgent cases, that means that more non-urgent surgeries will be pushed back in time, increasing the respective waiting time.
- The average waiting time increases with an increase in the number of patients.
- The Best Fit operating procedure gives the best results in terms of occupancy rate of operating rooms.
- The First Fit operating procedure gives the worst results in terms of respect of urgency boundaries and rescheduling rate.

3.2. Possible performance measures to evaluate

In order to evaluate the performance of each operation policy, we might check the following variables:

- **The average waiting time and Deviation in waiting time:** The procedures with the least average waiting time would be better. However, having a small average waiting time is not enough to evaluate whether a procedure is the most efficient for every customer since there might be patient's that have large waiting times despite the low average. To solve this problem, we will also analyse the deviation in the waiting time. A good solution has both one of the best average waiting time as well as a small deviation in waiting time.
- **The occupancy rate of operating rooms:** To make sure that the minimization of costs is accomplished,

the procedure should maximize the use of operating rooms. This way, a desirable solution should have a high occupation rate of operating rooms.

- **The respect rate of urgency boundaries:** To make sure that the patients that need to have surgery have it before it's too late, we will also evaluate if the urgency rate of each patient (maximum waiting time) has been respected. A good procedure has a high rate of respect of urgency boundaries.
- **The rescheduling rate:** Since rescheduling a surgery might also contribute to increasing a patient's stress levels, the rescheduling rate of surgeries also helps evaluate whether a procedure is desirable. The scheduling rate is good if it has small values.

3.3. Operation policies to demonstrate

We chose the following operation policies:

- **Random Allocation:** The surgery is scheduled to a random operation room in a random day and block time in which the surgery fits. This allocation serves as the baseline model for this study since it is the simplest.
- **Next Fit:** The surgery is scheduled to the earliest block time that is available.
- **First Fit:** The surgery is scheduled to operating rooms in the earliest day when the operating room already has surgeries scheduled and have enough time for the surgery. If there are no operating rooms with surgeries scheduled and time for the surgery, this algorithm would behave like the Next Fit.
- **Best Fit:** The surgery is scheduled to operating rooms that already have a surgery allocated in the same day and that the remaining time is not only enough for the surgery, but it also is the smallest frame of time.
- **Worst Fit:** The surgery is scheduled to operating rooms that already have a surgery allocated in the same day and that the remaining time is not only enough for the surgery but also is the largest frame of time.

	1st day	2nd day	3rd day	4rd day
09:00h	Next Fit			
10:00h				
11:00h		First Fit	Worst Fit	
12:00h				
13:00h				Best Fit

The following example allows to see which schedule would be chosen by applying each of these procedures. The red squares represent time blocks where the operating room is occupied with surgery and the grey squares show the allocation of a 2-hour long surgery using these procedures:

3.4. Other assessment strategies

Each operation policy will be assessed through comparison with one another, by analysis of the performance

measures indicated above. On top of this, we will send a survey to the FEUP community to understand how long each person would be willing to wait to have a surgery, in order to compare with the results obtained in each policy.

4. RELATED WORK

There are plenty of papers reflecting this theme, with the main goal of optimizing the allocation of surgeries to operating rooms.

https://journals.lww.com/anesthesia-analgesia/Fulltext/1999/07000/An_Operating_Room_Scheduling_Strategy_to_Maximize.3.aspx

This first paper uses simulation to test different algorithms for this allocation with the goal of maximizing the use of operating rooms. The simulation includes the arrival of patients. This system, in our eyes, presents a rather big limitation that we want to address in our system: it doesn't consider urgent cases.

<https://www.sciencedirect.com/science/article/pii/S2351978917302020>

This paper uses simulation to test different algorithms for this allocation with the goal of reducing blocking across the perioperative process, such as intra-operation and post-operation stages. This paper tests the effectiveness of their model under variations of patient arrivals and doesn't consider urgent cases.

https://www.researchgate.net/publication/228675197_Simulation_models_for_optimal_schedules_of_operating_theatres

This paper also uses simulation to test the impact of different models on the schedule of the operating room. These studies consider patients' priority rules and the pre-operation and post-operation stages.

5. WORK PLAN

1. Data collection and analysis
2. Model conceptualisation
3. Model translation
4. Verification
5. Validation and Calibration
6. Experimental design
7. Production and analysis
8. Final report with simulation results

For a more detailed version see Gantt chart in the appendix.

6. APPENDIX

