PROCESS SIMULATION: HEALTHCARE OPTIMIZATION

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I. Problem Definition

Patients with critical medical conditions necessitate high level time and resource management within an emergency hospital setting. Staff shortages and ER facility resource constraints make efficient triage and treatment difficult. There has been a recent increase in patient wait times and time spent in this department, leading to management concerns. This simulation will provide the insights necessary for these issues to be accurately identified and addressed, promoting enhanced operational performance and patient care.

II. Abstract

Hospital emergency departments see a large volume of patients with urgent needs for medical attention. These teams are often operating under resource constraints and must identify ways in which they can provide high quality care to the most people in the least amount of time. The resources that hospital workflow is constrained by are staffing, such as doctors, nurses, and laboratory technicians on shift, and available examination rooms in which patients can be examined and treated. This process simulation utilizes Python programming in an effort to identify an optimal emergency department scenario. Key insights gleaned from the simulation will act as guidelines and best practices for hospitals to maximize patient care while efficiently allocating and preserving resources.

III. Introduction

The nature of most medical cases that enter an urgent care or emergency facility are time sensitive and require efficient diagnoses and care. As patients wait to be examined and treated by a medical professional, facilities can become overcrowded and hospital resources may be overleveraged resulting in delays and errors. Studies have shown that excessive wait times and delays in emergency settings result in dissatisfaction amongst patients, and in severe cases,

mortality (Shen and Lee 2018). Given that the impacts of emergency department inefficiencies can be so great, hospitals must determine the best way to allocate the resources they have at their disposal. Optimizing the day to day processes by increasing staffing or utilizing the facility in a more streamlined manner can allow for a larger volume of patients to be cared for and for their wait times to be shorter.

Optimization through process simulation is an effective approach to operational practices that have multiple variables impacting overall performance. These simulations allow organizations to see the impacts that proposed or hypothetical changes could have on their workflow, production, and services before altering current policies or standard operating procedures (Lal et al. 2015). This study emphasizes the use of these techniques in a healthcare setting by simulating the patient throughput in the emergency department of a hospital. The data and analysis focus on patient visit flow and activity times for four practices performed upon initial intake of an urgent care patient. These include the time it takes to perform triage, laboratory testing, testing result interpretation, and patient follow-up conversations. The data also include the duration of time spent in the emergency department before discharge or admittance into the hospital. The constraints affecting this duration are the number of doctors, nurses, and lab technicians on staff as well as the availability of exam rooms. The simulation is achieved in the Python programming environment using the SimPy library along with Pandas. A discrete event simulation is run on the data to provide insights into the patient visit process to identify where bottlenecks and inefficiencies are present and under what conditions efficiency improves.

IV. Literature Review

In an article published in the Journal of Imaging Informatics in Medicine, the authors outline their approach to optimizing the interventional radiology department within a hospital.

The aim of the study is to address patient wait times and treatment delays while acknowledging that uncertainties in patient arrivals, varying procedure times, and staff availability often constrain the efficiency of a workflow (Tellis et al 2020). Using data from thousands of patient visits, the authors were able to identify arrival patterns and calculate process times to analyze in the simulation. They utilized discrete event simulation and interviews with hospital personnel to model the workflow as patients make their way through the processes performed in this department (Tellis et al 2020). The key insights from their study resulted in a number of operational changes such as extending hours, prioritizing different types of appointments depending on the time of day, and re-assigning time blocks to reduce wait times for CT scans.

V. Methods

The SimPy library in Python provided the framework necessary to perform the discrete event simulation. Simulation parameters were controlled by defining various constants: RANDOM_SEED(42) to ensure reproducibility, NEW_PATIENTS(5) to represent the initial number of patients in the hospital, INTERVAL_PATIENTS(10) for the average amount of time between patient arrivals, SIM_TIME(360 minute) as the total duration of the simulation, and average times for each of the four processes TREATMENT_TIME(15 minutes), TEST_TIME(10 minutes), RESULTS_WAIT_TIME(20 minutes), and FOLLOW_UP_TIME(5 minutes). Resource constraints were also defined as the number of doctors, nurses, lab techs, and exam rooms. These were modeled as SimPy resources in the EmergencyDepartment class. Simulating the time taken for the triage, treatment, lab test, and follow up processes was accomplished using env.timeout. The movement of each patient through the emergency department was modeled and timestamps for each event were recorded in a list to be further analyzed. The simulation was run for the specified amount of time by using env.run(until=SIM_TIME). Data collected through this

method was stored in a Pandas dataframe and analyzed to identify bottlenecks and pursue resource optimization.

VI. Results

The worst results came from the simulation with 1 nurse, 1 doctor, 1 lab technician, and 1 exam room. 22 patients were seen during the simulation run time. Average time to discharge was 221.17 minutes and average time to be admitted was 164.44 minutes. Results improved significantly when resources were increased to 5 nurses, 5 doctors, 5 lab technicians, and 5 exam rooms. 45 patients were seen in the simulation. The average discharge time was 56.5 minutes and the average admitted time was 58.07 minutes. Results continued to improve when resources were increased further to 10 nurses, 10 doctors, 10 lab technicians, and 10 exam rooms. The emergency department was able to see 54 patients. The average time to discharge was 47.97 minutes and the average time to admit to the hospital was 49.67 minutes.

VII. Recommendations

Increasing resources from 1 for each variable to 5 resulted in a significant improvement in efficiency. Number patients seen doubled and average time to discharge and admit was cut by over a third. While efficiency continues to improve with increasing resources, the net increase decreases. Number of patients seen only increased by 9 and average times were cut by 10 minutes.

Without further variables and constraints such as maximum total salary or work shifts, 10 resources for each would result in the most efficient emergency department. Increasing further would not yield enough of an improvement. However, it is also true that 5 resources should be the minimum given the large difference in efficiency below that threshold. Further study would be needed to improve the simulation, though broad bounds can be surmised from this study.

VIII. References

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