CS 351: Simulation Project

Due: Wednesday, December 12, 2018 at 11 PM (Central)

Overview

This project involves modeling the system described below, implementing it in software, and analyzing it using simulation. You may complete the project either individually or in groups of up to three people; if you intend to complete the project as a group, one member should send an email to the professor by 5 PM on November 26 indicating the members of the group (be sure to carbon copy all group members on the email).

Deliverables for the project include:

1. An implementation of the model in Java using DESMO-J, either from an event-oriented perspective or from a process-oriented one, submitted as source code in a **single zip archive**. This may be either an exported Eclipse project or just a `.zip` of the relevant `.java` files (**do not** include the DESMO-J `.jar` file in your `.zip` archive, as this can cause problems when uploading to D2L).
2. A brief written report that includes answers to the study questions on page 3 *along with* explanations of how you arrived at those answers (e.g., number of runs, replication results, calculations of confidence intervals, etc.). The report should be in `.pdf` format (**do not submit** your report in another format such as `.doc`, `.docx`, or `.pages`), should clearly identify the group members, and adhere to professional writing standards (e.g., written in complete sentences with reasonable formatting).

One member of your group should submit the above items to the project dropbox on D2L the project due date.

Note that while you do **not** need to submit a design model for this system, you may find it helpful to do so **prior** to starting your implementation. (An hour or two of planning can potentially save several hours or more of refactoring and debugging!)

System Description

A walk-in medical clinic is open from 8:00 AM until 8:00 PM seven days a week. Interarrival times for patients are exponentially distributed but vary throughout the day according to the following table:

Time Frame	Mean Interarrival Time (minutes)
8 AM – 10 AM	$\lambda^{-1} = 15$
10 AM – 4 PM	$\lambda^{-1} = 6$
4 PM – 8 PM	$\lambda^{-1} = 9$

When a patient arrives, they stay in a waiting room until they are called to see the nurse practitioner. If a patient arrives when there are already k patients in the waiting room (not including himself/herself), the arriving patient immediately leaves (i.e., balks) and instead seeks treatment at a nearby emergency care center with probability $k/8$ (for $k = 1, 2, 3, \ldots, 8$).

The nurse practitioner treats one patient at a time according to a "first come, first served" policy. Treatment times are exponentially distributed with a mean of 8 minutes. After treating a patient, the nurse practitioner must decide whether to refer that patient to the medical specialist employed by the clinic to resolve more urgent medical needs. Each patient has a 40% chance of being referred to the specialist. Patients who need care from a specialist cannot wait too long to receive it. If the nurse practitioner wants to refer a patient to the specialist for more urgent treatment, but the patient has already been in the clinic for more than 30 minutes (including time in the waiting room and time being seen by the nurse practitioner), the patient must instead be diverted to the nearby emergency care center to be treated (note that this occurs only if the nurse practitioner wants to refer this patient to the specialist).

The specialist has four examination rooms, each of which can hold one patient. The specialist can treat one patient at a time; if the specialist is currently treating another patient when the nurse practitioner refers a patient to the specialist, the patient waits in one of the other examination rooms until they are seen by the specialist. Because there are only four examination rooms, only three patients can wait to see the specialist at any time (not counting the patient being treated, who uses the fourth examination room). Any patient referred to the specialist while all examination rooms are full is immediately diverted to the nearby emergency care center. The specialist's treatment times are distributed exponentially with a mean of 25 minutes.

The clinic closes at 8:00 PM, after which no new patients arrive. Any patients already in the clinic after it closes will remain in the clinic until their treatment is complete (which will include being seen by the nurse and possibly the specialist, assuming they are not diverted to the emergency care center after finishing treatment by the nurse practitioner). The nurse and specialist will both remain in the clinic until all patients have left.

The clinic's current operating expenses include:

- $1200 per day for the nurse's salary, plus $100 for each patient treated by the nurse;
- $1500 per day for the specialist's salary, plus $200 for each patient treated by the specialist;
- $300 per day for each exam room (this includes cleaning, maintenance, and utilities).
- An *additional* $500 for each patient that gets diverted to the emergency care center for any reason (e.g., a patient treated by the nurse practitioner and then diverted to the emergency care center incurs a cost of $600, while a patient who leaves the clinic before being seen by the nurse practitioner incurs a cost of $500).

The clinic manager wishes to understand the expected daily operating costs, and also identify ways in which these costs can be minimized. To achieve this second goal, the clinic can:

- hire additional nurse practitioners at a cost of $1200 per practitioner per day;
- hire additional specialists for a cost of $1500 per specialist per day; and
- add additional exam rooms for a cost of $300 each per day.

However, such hires or examination rooms must be justified by a savings in overall expected costs incurred by the clinic. Note that hiring additional specialists does not increase the number of examination rooms unless new examination rooms are also purchased; for example, if you increase the number of specialists to three, but do not increase the number of examination rooms, then three examination rooms contain specialists, with only one examination room left to contain a patient who is waiting to be seen by a specialist. You may assume that any new hires are indistinguishable from the current nurse practitioner and specialist, from the perspective of the distributions of treatment times.

Study Questions

Current Configuration

For the current configuration of the clinic, provide estimates of the mean and standard deviation of each of the following quantities:

1. the clinic's daily operating costs (this includes the costs for the existing staff and exam rooms!)
2. the number of patients per day that:
   - arrive at the clinic for treatment;
   - balk due to an overcrowded waiting room;
   - get diverted to the ER after being seen by the nurse;
   - get fully treated at the clinic;
3. the average response time of patients that get fully treated at the clinic (i.e., they don't balk or get diverted to the emergency room);
4. the utilization rates for the nurse and specialist, computed across the time period from 8 AM until the nurse and specialist leave the clinic (which is *not necessarily* 8 PM!); and
5. the average number of patients in the waiting room, computed across the time period from 8 AM until the nurse and specialist leave the clinic.

System Comparison

Compare the daily operating costs of the current system with the operating costs of two alternative configurations, one in which an additional nurse practitioner is hired and one in which an additional specialist is hired.

1. Is there a statistically significant decrease in daily costs when adding an additional nurse?
2. Is there a statistically significant decrease in daily costs when adding an additional specialist?

System Optimization

1. Explore possible alternative configurations for the clinic based on acquiring additional nurses, specialists, and/or exam rooms, and find a configuration that minimizes the clinic's expected daily operating costs.

Hints

(Will be added soon)