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Assignment 4: Family doctor practice queuing

Contents

1 Problem description

Dr. Soslow runs a family doctor practice that currently consists of three doctors, including Dr. Soslow. The three doctors in the practice all share their patients so that when a patient arrives for an appointment, the patient is seen by the first available doctor in the practice, as opposed to having to wait for a particular doctor to be free. Since the doctors in the practice do not get to choose their patients (some doctors might otherwise have more/less patients or more/less complex patients), a fee-for-service payment system seems unfair. On the plus side, the doctors in the practice do not have to worry about finding patients or managing health records and billings.

To attract good doctors to her practice, Dr. Soslow treats each doctor (including herself) as a salaried worker earning \$250,000 per year, assuming a 40-hour work week and 44 work weeks per year. This scenario might not be completely realistic/legal in Ontario, but let's just pretend.

Unfortunately, while the doctors in Dr. Soslow's practice are extremely unhappy about unreasonable wait times; even Dr. Soslow has noticed that she and her colleagues often have to stay late to see everyone in the waiting room. Several patients have already notified Dr. Soslow that they intend to leave her practice to find one with shorter wait times. Thus, Dr. Soslow wants to figure out how many more doctors she should hire into her practice to optimally serve patients at a minimum cost.

Your job is to build an Excel DSS that uses queuing theory to tell Dr. Soslow the optimal number of doctors that are needed in her practice to balance doctor salaries with wait times. Dr. Soslow should be able to change values in the spreadsheet according to different scenarios to see the resulting recommendation. For simplicity, assume that there is no limit to the queue length, and ignore the fact that the clinic is only open for eight hours per day.

2 The data

Luckily, after observing Dr. Soslow's practice for several days, you determine that both the service times per doctor and the patient arrival rates are exponentially distributed, and that there are no significant differences between doctors or patients. Details are in Table 1. Currently, Dr. Soslow thinks that every minute a patient waits is worth \$5. She may change her mind later, but it seems like a reasonable starting point at the moment.

Table 1: Arrival and service data

	Value
Number of doctors	3
Patient arrival rate	30 patients/hour
Doctor service rate	5 patients/hour

3 Questions

Submit your Excel files and a brief PDF report that analyzes your findings and answers the following questions:

1. What is the average wait time currently?
2. What is the optimal number of doctors needed?
3. What is the average wait time with the optimal number of doctors?
4. How much can the wait cost of a patient go up or down before more/fewer doctors are needed?
5. For every scenario you test, plot the wage costs, hourly costs, and total costs per number of servers.

4 Helpful hints

- The traffic intensity must be < 1 for a solution to be feasible.
- You can find the optimal number of servers by minimizing hourly costs. Note that starting from the minimum feasible number of servers, as you add servers, costs will decrease up to the optimal solution, and then they will increase. So, you can just enumerate different numbers of servers until the costs start to increase.
- Calculate hourly costs as follows:

$$\begin{aligned}\text{Hourly cost} &= \text{Wages per hour} + \text{Queuing cost per hour}\\ &= (\#\text{ servers} \times \text{hourly wage rate}) + (\text{hourly arrival rate} \times \text{hourly wait cost} \times W_q)\end{aligned}$$