Simulation-Based Analysis of Patient Flow in an Urgent Care Clinic

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Problem Statement:

In healthcare, especially in Urgent Care (UC) settings, optimizing patient flow is critical to ensure timely and effective service delivery. The management of patient arrivals, service times, and prioritizations can significantly impact the overall efficiency of the clinic and the satisfaction of the patients.

Background:

The UC in consideration operates with three doctors and one nurse during the day, managing a mix of high-priority and low-priority patients. The interarrival time of the patients is exponentially distributed with varied service times, influenced by the priority of the patients and the service procedures, including triage by a nurse and consultation with a doctor. Patients might balk (leave before being triaged) due to excessive wait times, and low-priority patients might depart if their wait times exceed a certain limit post-triage.

Objectives:

The aim of this project is to simulate the patient flow in the UC to gain insights into:

- The average flow time for high-priority and low-priority patients.
- The probability of balking by low-priority patients.
- Potential areas for process improvement and resource optimization.

Problem details:

- On a typical day, the interarrival time is Exponentially distributed with a mean of 6 minutes.
- 25% of patients are high-priority, and the remaining are low-priority.
- Upon arrival at UC, the patients are triaged by a nurse into one of the two types of patients. The service time for triage is distributed by Triangular distribution with min = 3, max = 10, and the most likely value = 5 minutes.
- Then, the patients wait in the waiting room and get called to visit doctors on a first- come-first-served basis. If more than 10 people are waiting for service, an arriving patient will exit before being triaged.
- Finally, low-priority patients may depart if they have to wait longer than20$\pm$5 minutes (Uniformly distributed) after triage.
- The doctor service time distributions are given as follows.

Priority	Service Time Distribution (in Minutes)
High	Normal(mean = 40, sd = 5)
Low	Gamma(shape = 15, rate = 1)

Assuming that the UC opens at 8 hours, we will simulate the process for 50 replications. The UC would like to estimate the following: (1). the average flow time of each type of patient. (2). the probability that low-priority patients balk.

Solution

(1). In this problem, we will simulate the process of an Urgent Care (UC) clinic with three doctors and one nurse serving patients during the day. Patients arrive at the clinic with an exponentially distributed interarrival time with a mean of 6 minutes. Upon arrival, the patients are triaged by a nurse and categorized as either high-priority (25%) or low-priority (75%). The triage process service time follows a triangular distribution.

Patients then wait in the waiting room, and doctors attend to them on a first-come-first-served basis. If more than 10 people are waiting for service, an arriving patient will exit before being triaged (balking). Low-priority patients may also depart (renege) if they have to wait longer than 20±5 minutes after triage. The doctor's service time for high-priority patients follows a normal distribution, while for low-priority patients, it follows a gamma distribution.

```
library(triangle)
library(simmer)
set.seed(12)

envsh <- lapply(1:50, function(i) {
  env <- simmer("UrgentCare") %>%
    add_resource("nurse", 1) %>%
    add_resource("doctor", 3)

  patient <- trajectory("patients' path") %>%
    branch(function() sample(1:2, size=1, replace=TRUE, prob=c(0.25, 0.75)),
           continue=c(T, T),
           trajectory("High Priority") %>%
             set_attribute("priority", 2) %>%
             set_prioritization(c(2, 7, T)) %>%
             # Balking policy, leave if queue in nurse and doctor > 10
             leave(prob = function()
               ifelse((get_queue_count(env, "nurse") +
                    get_queue_count(env, "doctor")) > 10, 1, 0)) %>%
             seize("nurse", 1) %>%
             timeout(function() rtriangle(1, 3, 10, 5)) %>%
             release("nurse", 1) %>%
             seize("doctor", 1) %>%
             timeout(function() rnorm(1, 40, 5)) %>%
             release("doctor", 1),

           trajectory("Low Priority") %>%
             set_attribute("priority", 1) %>%
             set_prioritization(c(1, 7, T)) %>%
             # Balking policy, leave if queue in nurse and doctor > 10
             leave(prob = function()
               ifelse((get_queue_count(env, "nurse") +
                    get_queue_count(env, "doctor")) > 10, 1, 0)) %>%
             seize("nurse", 1) %>%
             timeout(function() rtriangle(1, 3, 10, 5)) %>%
             release("nurse", 1) %>%
```

```r
            renege_in(function() runif(1, 15, 25), out = trajectory()) %>%
            seize("doctor", 1) %>%
            renege_abort() %>%
            timeout(function() rgamma(1, shape = 15, rate = 1)) %>%
            release("doctor", 1)
    )
  env %>%
  add_generator("patient", patient, function() rexp(1, 1/6), mon = 2)
  env %>% run(480)
})

# (a) the average flow time of each type of patient
x1 <- get_mon_arrivals(envsh)
x2 <- get_mon_attributes(envsh)
all <- merge(x1, x2, by=c("name", "replication"), all = T)
all <- na.omit(all)
Type1 <- subset(all, all$value == 1)
Type2 <- subset(all, all$value == 2)
type1.flowTime = (Type1$end_time - Type1$start_time)
type2.flowTime = (Type2$end_time - Type2$start_time)
mean(type1.flowTime, na.rm = T)
```

```
## [1] 49.2462
```

```r
mean(type2.flowTime, na.rm = T)
```

```
## [1] 54.07314
```

Based on the simulation results, we find the following average flow times for each type of patient:

(a) High-priority patients: 49.2462 minutes.
(b) Low-priority patients: 54.07314 minutes.

These values represent the average total time spent by each type of patient in the Urgent Care clinic, including waiting and service times.

(2). bellow we report the probability that low-priority patients balk.

```r
# (b) probability of bulk for low priority
mean(all$activity_time == 0 & all$value == 1)
```

```
## [1] 0.03271693
```

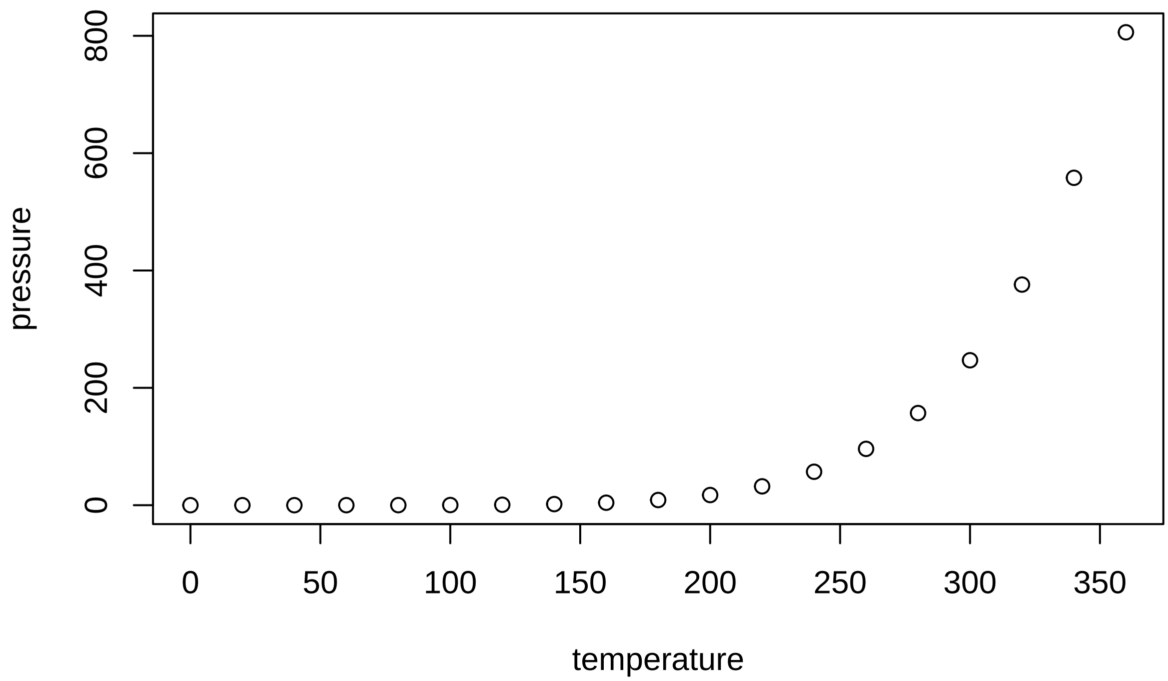
the probability that low-priority patients balk (exit before being triaged due to more than 10 people waiting for service) is found to be approximately 0.03271693 or 3.27%. This percentage represents the likelihood of a low-priority patient choosing to leave the Urgent Care clinic without being attended due to excessive wait times.

```r
summary(cars)
```

```
##      speed           dist
##  Min.   : 4.0   Min.   :  2.00
##  1st Qu.:12.0   1st Qu.: 26.00
##  Median :15.0   Median : 36.00
##  Mean   :15.4   Mean   : 42.98
##  3rd Qu.:19.0   3rd Qu.: 56.00
##  Max.   :25.0   Max.   :120.00
```

Including Plots

You can also embed plots, for example:



Recommendations:

1. Reduce High-Priority Patients' Flow Time

- Given that high-priority patients have an average flow time of approximately 49.25 minutes, which is substantial, consider reviewing the service process to identify bottlenecks or inefficient practices that could be addressed to streamline the flow.
- Allocating additional resources, whether human or technological, specifically for high-priority cases can be beneficial. Expedited service processes or dedicated service lanes for high-priority patients can also be considered to reduce their waiting time and overall flow time.

2. Optimize Service Process for Low-Priority Patients

- The average flow time for low-priority patients is approximately 54.07 minutes. Optimizing the service process, perhaps by implementing lean principles, can help in reducing the flow time and improving overall efficiency.
- Implementing a scheduling system for low-priority patients can also help in managing the patient flow better, reducing wait times and improving patient satisfaction.

3. Address Balking of Low-Priority Patients

- With a 3.27% balking rate, it is important to address the reasons causing patients to leave without being served. Managing patient expectations regarding wait times or providing real-time updates on expected wait times can help in reducing balking.
- Increasing the capacity of the waiting area and optimizing the triage process can help in managing more patients efficiently, thus reducing the likelihood of patients leaving due to overcrowding.

4. Enhance Triage Efficiency

- Consider investing in training for nursing staff to enhance efficiency in triage processes and reduce service time.
- Implementing technology solutions, such as automated check-in kiosks or online pre-registration, can also help in reducing the load on nursing staff and speeding up the triage process.

5. Demand Forecasting and Staff Allocation

- Develop a dynamic staff allocation model that can adapt to varying patient demand throughout the day. This can help in ensuring that there are adequate resources available to meet the demand and reduce wait times.
- Implementing demand forecasting techniques can help in predicting the patient inflow and enable better planning and resource allocation.

6. Patient Communication and Education

- Effective communication regarding expected wait times and service processes can help in managing patient expectations and reducing dissatisfaction.
- Educating patients on the urgency levels and the corresponding service processes can also help in reducing anxiety and frustration levels among patients.

7. Continuous Monitoring and Improvement

- Regularly review the performance metrics and conduct simulations to identify areas of improvement.
- Implement continuous improvement practices to ensure that the service processes are optimized, and patient satisfaction is maximized.

Implementing these recommendations can aid in improving the operational efficiency of the Urgent Care clinic and enhance the overall patient experience. The recommendations need to be considered in conjunction with the available resources, organizational constraints, and strategic priorities of the Urgent Care clinic.