Simulation Exam

14:540:384: Simulation Models in IE (Spring 2025)

RUID: _____

2024-04-23

Problem Statement

There is a bank in New York Penn Station that has a small room with 2 ATMs that is open 24/7. When ATM customers arrive, they immediately proceed to an ATM if there is one available. Otherwise, they form a queue which is served on a first-in-first-out basis. There is enough space for a maximum of 3 people (including those at an ATM). If there is not enough room, potential customers leave and do not join the queue. From 8:00 AM to 7:00 PM, customers arrive according to a Poisson distribution of 53/hr. Service time at the ATMs has been obtained and provided below. For this problem, a simulation will be created and simulated for 22 days during these hours (to represent working hours of the month).

Your tasks are to:

1) Select and justify three candidate distributions to fit to the service time. (3 pts)
2) Write `R` code (with comments) to fit two of the distributions to the data. (2 pts)
3) Examine the selection criteria summary table. Select and justify which of the distributions (A, B, or C) best fits the data. (5 pts)
4) Write `R` code (with comments) to sample the arrival and service distributions. (4 pts)
5) Write `R` code (with comments) to develop a `simmer` simulation environment (trajectories, environment, resources, generators). (7 pts)
6) Examine the provided results and answer the questions in that section. (9 pts)

```
# Loading Packages
library("tidyverse")
library("fitdistrplus")
library("simmer")
library("simmer.bricks")
library("simmer.plot")
library("knitr")
```

1 Candidate Distributions (3 pts)

The service time data is presented in Figure 1, Figure 2, and Table 1 below. Examine these and select three distributions you believe represent the data well. Justify your conclusions.

```
data <- read_CSV("service_data.csv")
```

1.

2.

3.

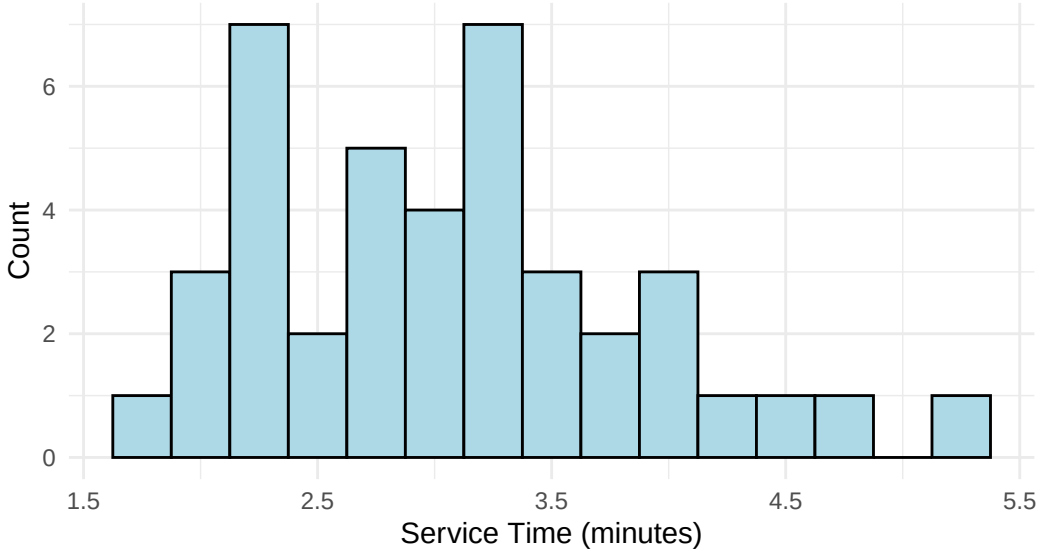

Figure 1: Histogram of Service Data

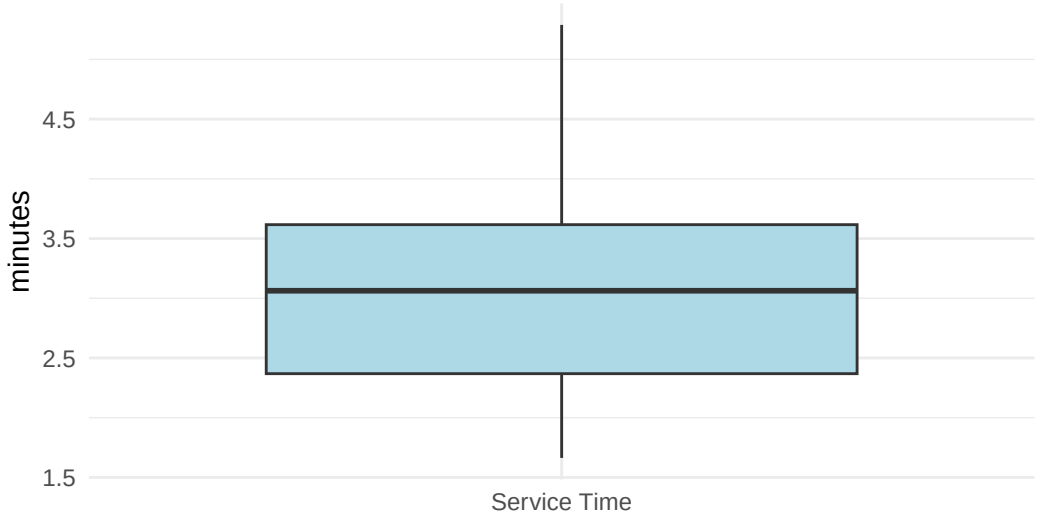

Figure 2: Service Time Boxplot

Table 1: Service Time Descriptive Statistics

name	value
n	41.0
Min.	1.7
1st Qu.	2.4
Median	3.1
Mean	3.1
3rd Qu.	3.6
Max.	5.3

2 Distribution Fitting (2 pts)

Write `R` code (and comments as necessary) to fit two of your chosen distributions to the data:

```
# write code to fit your first distribution
```

```
# write code to fit your second distribution
```

3 Distribution Selection (5 pts)

Three distributions, referred to in this section as A, B, and C have been fit to the data. The results of the selection criteria are provided in Table 2. A comparison of the fitted distributions theoretical densities and the actual data are provided in Figure 3. Which distribution (A, B, or C) would you choose to represent the data and why?

Table 2: Selection Critera Summary

	A	B	C
Number of Parameters	1.000	2.000	2.000
Log-Likelihood	-87.129	-50.466	-47.904
AIC	176.258	104.932	99.808
BIC	177.972	108.359	103.236

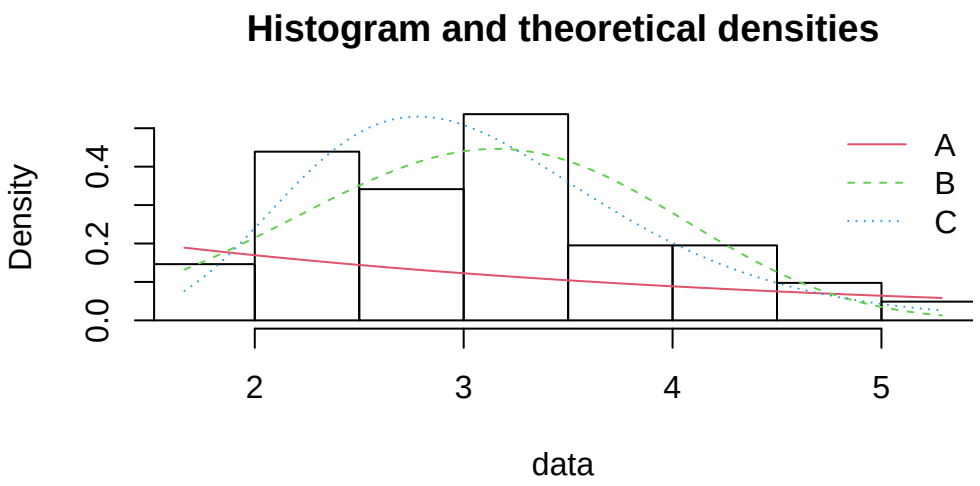

Figure 3: Distribution Fit Comparison

4 Distribution Sampling (4 pts)

1. Write `R` code (and comments as necessary) to sample the interarrival time of customers.

2. Assume that the best fit for the service time is a Weibull distribution with shape parameter = 2.81 and scale = 3.37. Write `R` code (and comments as necessary) to sample this service time.

5 Simmer Environment (7 pts)

Write `R` code (and comments as necessary) to define your simulation. You do not need to write the code for running and replicating the simulation.

6 Results Discussion (9 pts)

Write code to extract the results of your simulation (1 pt):

Use the figures that follow to answer the following question. Refer to the figures by number when using them to justify your answer (i.e. "Based on Figure 5 I conclude that…"). Provide approximate answers where appropriate (2 pts each).

1. If you were a customer, what is your probability of completing your buisness at the ATM and how long would it take? What is the probability that you will spend more than 1.5 minutes in the system?

2. Does the current system seem adequate for the demand observed? Would you recommend any changes? Justify your response.

3. One of the ATMs broke and the branch manager is wondering whether it is worth it to repair the ATM for $3,000. The bank manager considers each potential customer that does not complete service to be a cost of $0.25. Without running a new simulation, what would you recommend the manager do and why?

4. How would you adjust the simulation to account for the broken ATM to get a specific answer?

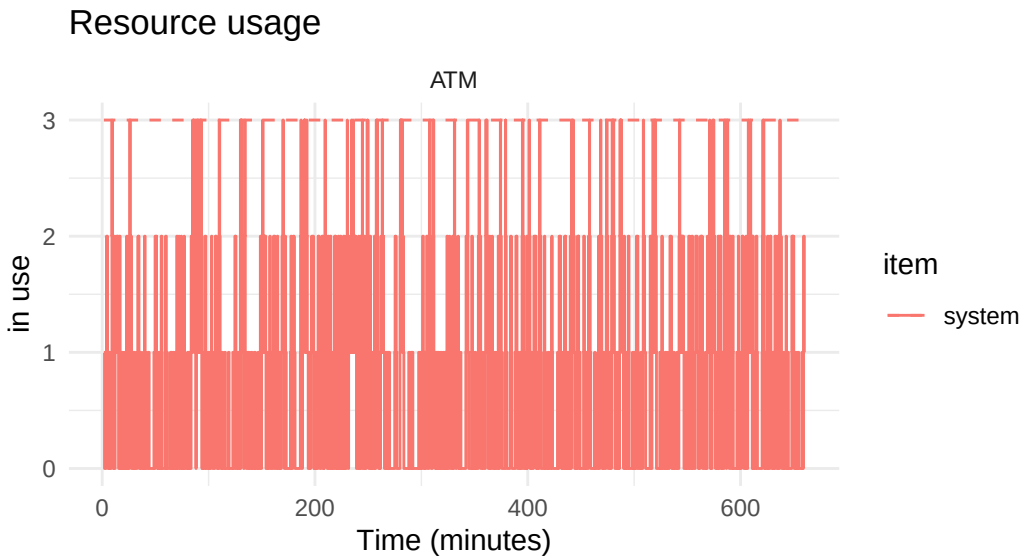

Figure 4: Instaneous System State for Replication #1

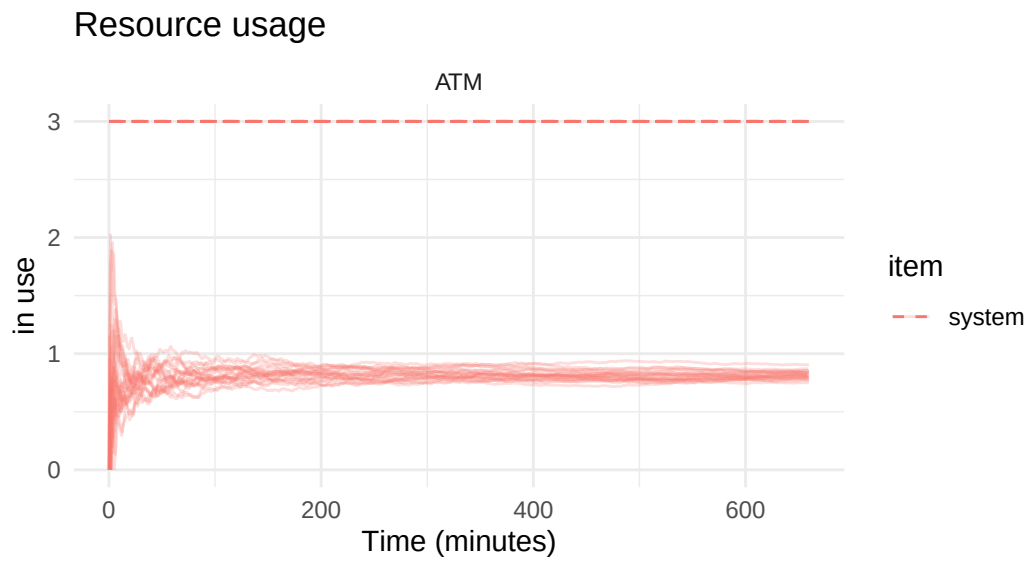

Figure 5: Average System State

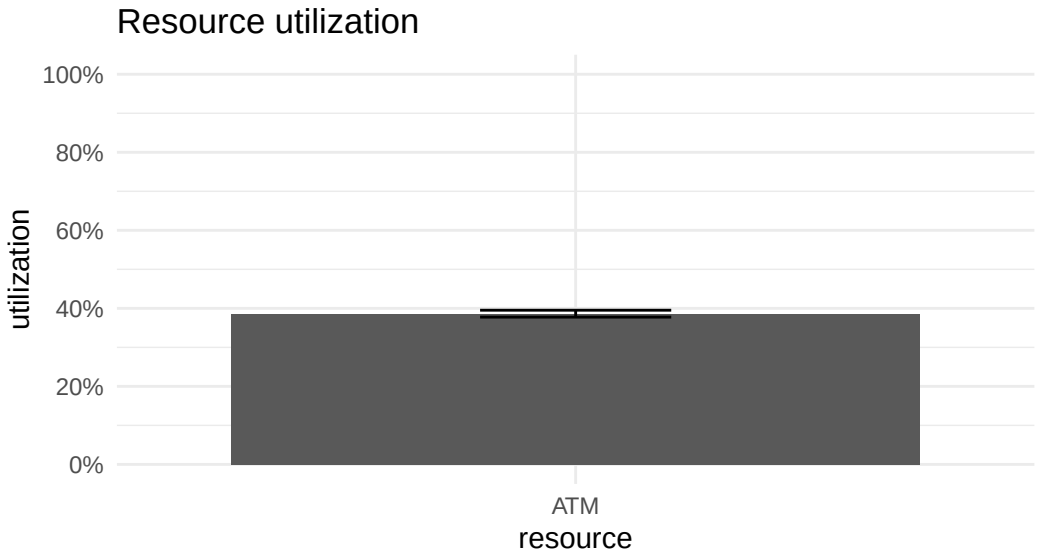

Figure 6: ATM Resource Usage

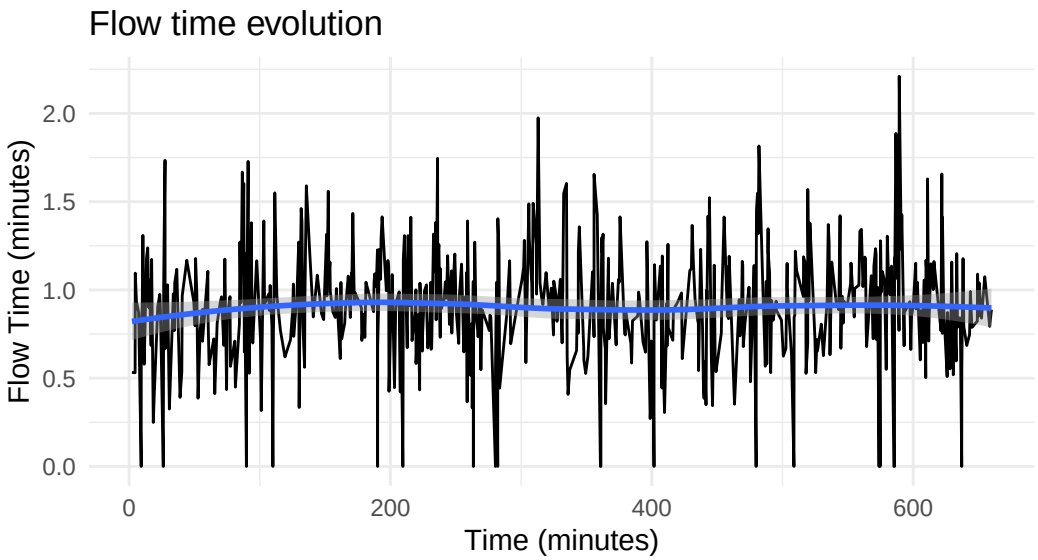

Figure 7: Customer Flow Time for Replication #1

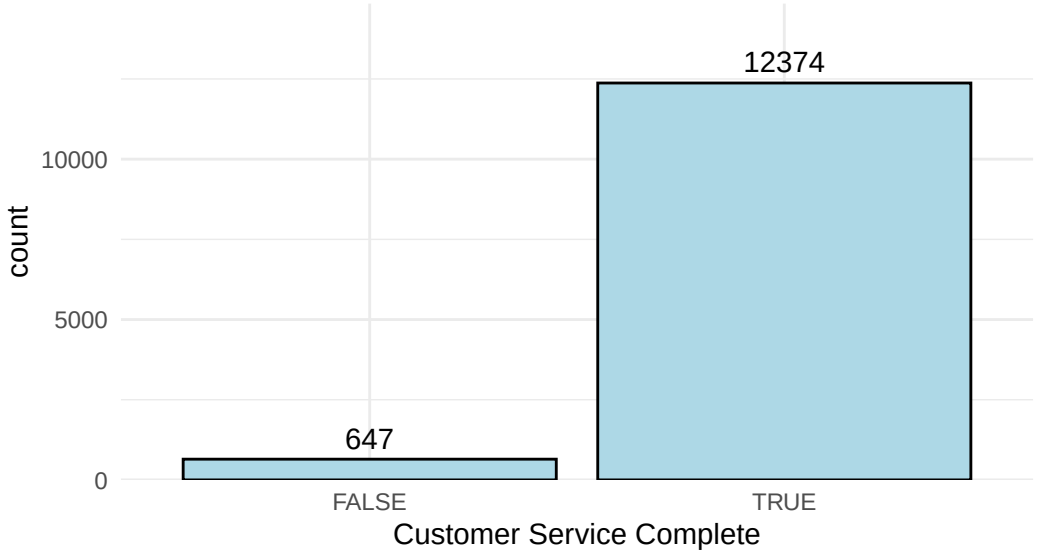

Figure 8: Bar Plot of Customer Status

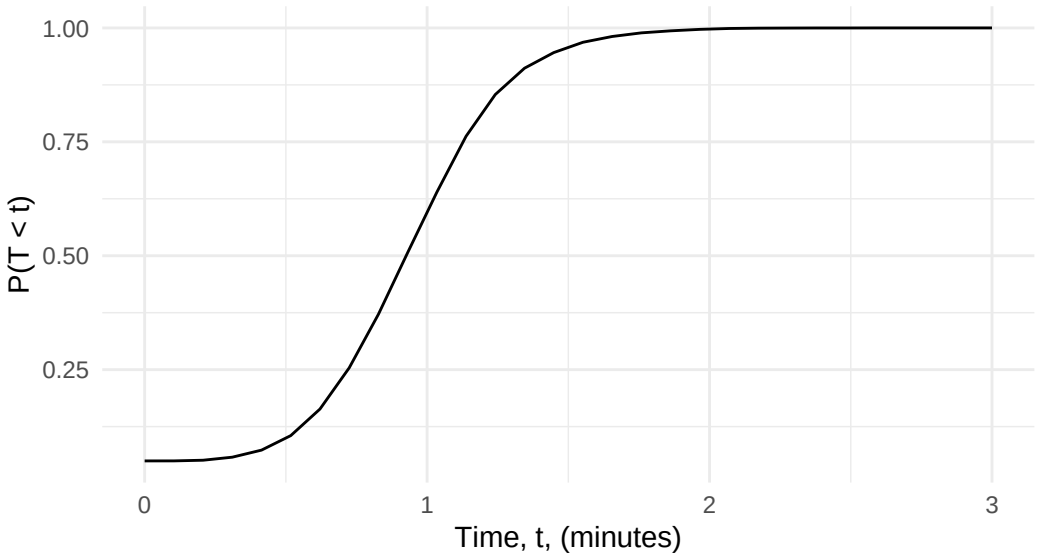

Figure 9: Empirical Customer Flow Time

7 Bonus (3 pts)

Explain why log-likelihood is used to fit distributions, including the basic underlying mathematical principles.

Grade

Question	Score	Possible
1		3
2		2
3		5
4		4
5		7
6		9
Bonus		3
Total		**30**