Strathmore
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SCHOOL OF COMPUTING AND ENGINEERING SCIENCES (SCES)

BACHELOR OF SCIENCE IN INFORMATICS AND COMPUTER SCIENCE

ICS 4106 – COMPUTER SIMULATIONS AND MODELLING

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Bank Queue Simulation Using Discrete Event Modelling

Project Description

This project simulates a single-server queuing system at a bank using discrete-event simulation (DES) for 500 customers. The simulation helps analyze customer waiting times, service durations, and the overall performance of the queue.

Assumptions:

- Customers arrive at random intervals, with inter-arrival times uniformly distributed between 1 and 8 minutes.
- Each customer is served for a period that is uniformly distributed between 1 and 6 minutes.
- Only one server is available to serve customers.
- The queue follows a FIFO (First-In, First-Out) discipline.
- A total of 500 customers are simulated.

Simulation Process Description

The simulation follows a discrete-event approach:

- First, inter-arrival times and service times are generated for 500 customers using Python's **random.uniform()** function.
- Using a loop, we:
  - Calculate the arrival time of each customer by adding their inter-arrival time to the time of the previous arrival.
  - Determine the start of service (either when the customer arrives or when the server becomes available).
  - Compute the end of service, waiting time, and total time in the system.
- A pandas DataFrame stores this information for analysis.
- Key performance metrics are computed.
- Two visualizations are generated to aid in understanding the queuing behavior.

Sample Data Table

Below is a preview of the first 5 entries from the simulation dataset:

Customer	Inter Arrival Time	Service Time	Arrival Time	Service Start Time	Service End Time	Waiting Time	Time In System
1	6.48	4.90	6.48	6.48	11.38	0.00	4.90
2	4.35	1.32	10.83	11.38	12.71	0.55	1.88
3	1.20	4.34	12.03	12.71	17.05	0.68	5.02
4	1.67	1.01	13.70	17.05	18.06	3.35	4.36
5	4.33	5.07	18.03	18.06	23.12	0.03	5.09

The Values are rounded for readability. The full data is available in the CSV.

Performance Metrics

From the simulation output:

- Average Waiting Time: 2.03 minutes
- Average Service Time: 3.52 minutes
- Average Time in System: 5.55 minutes
- Maximum Waiting Time: 16.71 minutes
- Total Simulation Time: 2298.46 minutes
- Percentage of Customers Who Waited: 54.40%

These metrics give a good summary of the efficiency of the queue under the given conditions.

Visualizations

Figure 1: Time in System vs. Waiting Time (per Customer)

This line chart shows the waiting time and total time in the system for each customer.

Peaks occur due to bursts in arrivals or long service times.

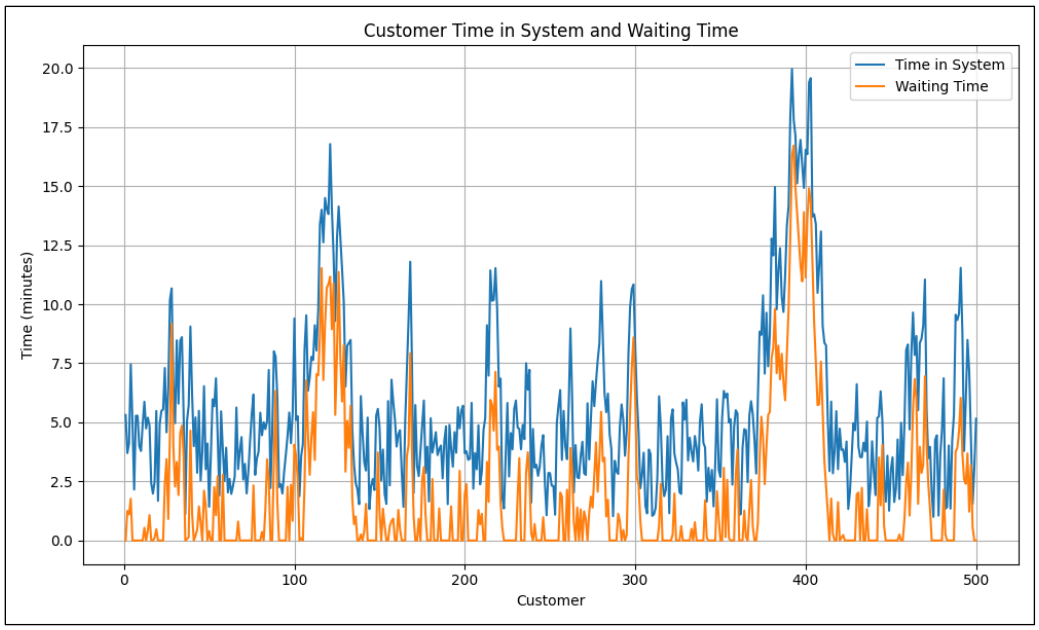
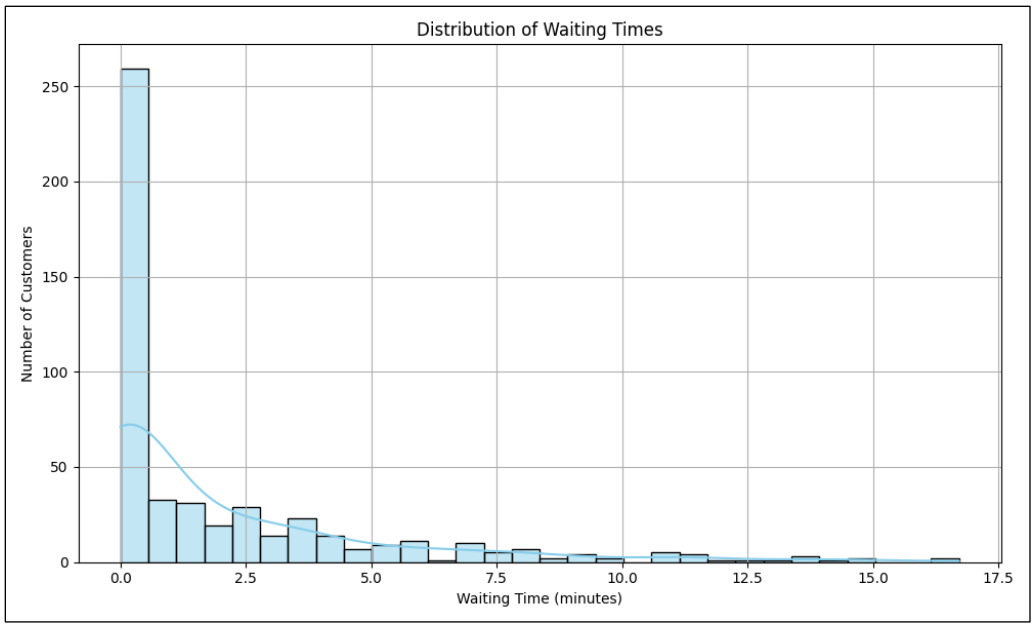


Figure 2: Distribution of Waiting Times

This histogram shows that most customers waited very little, often under 2 minutes, but a few experienced much longer wait times, especially during congestion spikes.



Interpretation

Queue Efficiency:
A single server was able to handle over 500 customers with only 2 minutes average waiting time, which is efficient for most banking scenarios.

Congestion Points:
Spikes in waiting time and system time indicate temporary overload, possibly due to closely spaced arrivals or unusually long service durations.

Improvements:
While the system is stable, adding a second server during peak periods could reduce maximum waiting times and ensure smoother operations.

Conclusion

The simulation effectively models a single-server queuing system using discrete-event simulation in Python. The generated statistics and visualizations provide insights into customer wait times, system load, and overall performance. The results suggest a well-performing system with some room for optimization during high-load moments.

Github link - https://github.com/Mutinda-Mark/bank-queue-simulation