# Simulation Report – M/M/1 Queue System

Project Title: ATM Queue Simulation Using M/M/1 Queuing Model

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Course: Simulation & Modeling

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## 1. Project Description

This project simulates an M/M/1 queuing system for an ATM using discrete-event simulation in Java. Random numbers were generated via the Linear Congruential Method (LCM), tested for statistical quality, and used to model customer arrivals and service durations over time.

## 2. Setup of Simulation

- Random Number Generator: Linear Congruential Method

- Number of Uniform Numbers: 50 for interarrivals and 50 for services

- Distributions Used: Exponential distribution for both interarrival and service

- Values of λ:

-λ for arrival: 0.5

-μ for service: 1.0

- Simulation Time: Total time required to serve 100 customers

## 3. Summary of Results

|  |  |
| --- | --- |
| Metric | Value |
| Mean Arrival Rate (λ) | ~0.5000 |
| Mean Service Rate (μ) | ~1.0000 |
| Server Utilization (U) | ~48.23% |
| Mean Number in System (N) | ~1.002 |
| Average Time in System (R) | ~2.003 |
| System Throughput (X) | ~0.4977 |

**Uniformity Test:**

The numbers exhibited a nice distribution across the 10 bins, implying that the uniformity is acceptable.

**Independence Test:**

The Pearson correlation coefficients were:

- Interarrival: -0.1183

- Service: -0.1221

These values imply that, though weak, some correlation exists. Hence, the random numbers produced were mostly independent.

## 4. Evaluation of the System

The M/M/1 queue simulation works as expected:

- The system remains stable, with μ = 1.0 being greater than λ = 0.5.

- The server is utilized at less than 100%, and hence, the system is not overloaded.

- The expected time spent in the system by customers is about 2.003 units, consistent with M/M/1 theory:

R = 1 / (μ - λ) = 1 / (1 - 0.5) = 2

- The output file contains a very detailed list of events based on customers and the key performance metrics and hence satisfies all the requirements of this project.

## 5. Recommendations for Improvement

1. Independence Test Improvement: Consider graphical solutions (scatter plot of Ui vs Ui+1) or autocorrelation analyses for better validation of independence.

2. Visualization: A useful addition might be time-series graphs and bar charts (e.g., waiting times, queue lengths).

3. Multi-server (M/M/c): Consider extending the simulation to an M/M/c model (multiple servers), which better reflects real-world banking environments with multiple ATMs serving customers concurrently.

4. Real-Time Animation (Optional): A GUI or an animation can be created through JavaFX wherein the progress in the queue can be monitored dynamically.

5. Variance Analysis: Perform multiple batches of simulations and analyze performance with respect to different values of λ and μ to see its sensitivity.

## 6. Conclusion

This simulation project successfully demonstrates the behavior of a single-server (M/M/1) queuing system. The results align with theoretical expectations, and the simulation is a useful tool for understanding queue dynamics, server utilization, and performance metrics.  
With some enhancements for analysis and visualization, this simulator could be expanded into a more comprehensive queuing system modeling tool.