THE OPEN UNIVERSITY OF SRI LANKA

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

BSE HONOURS DEGREE PROGRAMME

EEX5362-Performance Modeling

Mini Project-A Public Transport Network

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Content of Report

Performance Objectives

Performance Modeling and Evaluation of a Public Transportation Network

1. System Description and Performance Goals

Urban public transportation systems, including bus networks, are essential for facilitating daily mobility in densely populated areas. These systems involve vehicle dispatching, passenger boarding, route scheduling, and traffic coordination. However, increasing passenger demand and urban congestion often lead to long waiting times, inconsistent schedules, and inefficient bus utilization.

The primary objective of this study is to analyze and model the performance of a city bus transportation network to identify bottlenecks, improve scheduling efficiency, and optimize passenger throughput. The study aims to minimize passenger waiting time, maximize throughput, optimize resource utilization, identify bottlenecks.

Performance Objectives

1. Minimize Passenger Waiting Time: Reduce average waiting time at bus stops before boarding.
    - *Metric:* Average Passenger Waiting Time (minutes)
2. Maximize Throughput: Increase the number of passengers transported per hour.
    - *Metric:* Passenger Throughput (passengers/hour)
3. Optimize Resource Utilization: Balance workload among buses and drivers to avoid over- or under-utilization.
    - *Metrics:* Bus Utilization

Modeling Approach and Assumption

A Discrete Event Simulation (DES) approach was adopted using the SimPy library in Python to model the dynamics of the transportation system.
In this simulation:

- Passengers are modeled as entities that arrive at bus stops and wait for buses.
- Buses are modeled as service providers with limited capacity (60 passengers per bus).
- Bus stops are modeled as queues where passengers wait for service.

The simulation logic replicates real-world events, including passenger arrivals, bus arrivals, boarding, and travel between terminals.
The main assumptions used in this model are:

- Passenger arrivals follow the time pattern derived from real-world trip start times in the dataset.
- Each bus has a maximum capacity of 60 passengers.
- Bus service time is based on recorded trip durations (duration_in_mins in the dataset).
- Boarding time per passenger is assumed negligible compared to overall trip duration.
- Once a bus is full, additional passengers must wait for the next available bus.
- The simulation environment runs long enough to cover all trips within the dataset timeframe.

This modeling approach allows the analysis of how variations in scheduling and route demand affect waiting time, throughput, and utilization.

Data Description and Methodology

The dataset bus_trips_654.csv contains 10,224 trip records of a city bus network. Each record includes:

Column	Description
trip_id	**Unique identifier for each trip**
deviceid	**Bus ID (used to group trips per vehicle)**
date, start_time, end_time	**Trip timing data**
start_terminal, end_terminal	**Route information**
duration_in_mins	**Duration of each trip in minutes**

Simulation Methodology

1. **Preprocessing:** The dataset was sorted by start_time and converted to a simulation timeline measured in minutes.
2. **Environment Setup:** Each terminal was defined as a queue in the SimPy environment.
3. **Passenger Generation:** Passengers were introduced into the system based on trip start times.
4. **Bus Scheduling:** Each bus (deviceid) followed its sequence of trips, traveling between terminals and picking up waiting passengers.
5. **Performance Metrics Recorded:**
    - Average passenger waiting time

- Total passengers served
- Bus utilization (passengers carried per bus)

6. **Visualization:** Histograms and bar charts were generated to show waiting time distribution and bus utilization per vehicle.

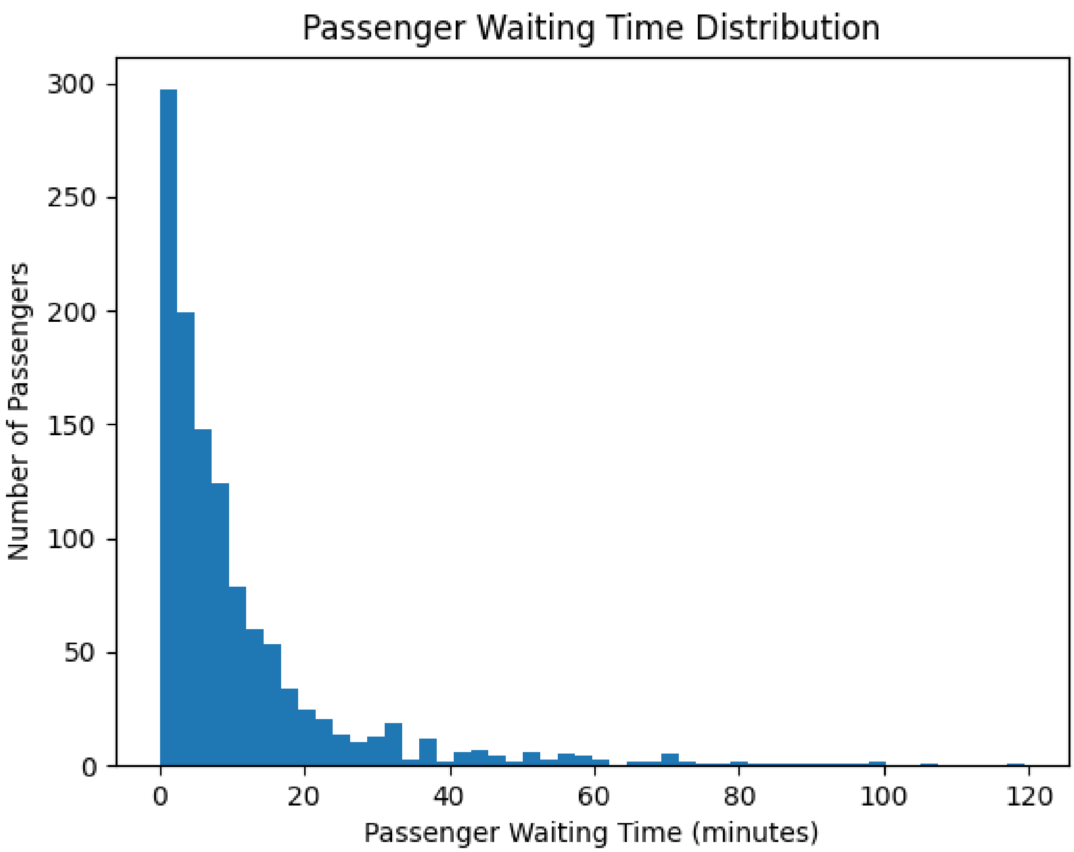
Detailed Analysis and Findings

The simulation results provide insight into the operational performance of the public transportation system:

Metric	Result	Interpretation
Average Passenger Waiting Time	**11.34 minutes**	**Indicates moderate service efficiency. While most passengers board within a reasonable time, certain routes experience longer waits due to uneven scheduling or low bus frequency.**
Total Passengers Served	**1,178 passengers**	**Represents total passengers successfully boarded within the simulated schedule. The figure depends on passenger arrival times and bus capacity limitations.**
Average Bus Utilization	**51.22 passengers per bus (≈85% of capacity)**	**Reflects strong resource utilization, with most buses operating efficiently near capacity.**
Bus Utilization Range	**2 – 171 passengers**	**The least utilized bus carried only 2 passengers (very underused).** **The most utilized bus carried 171 passengers total (across multiple trips in the simulation).**

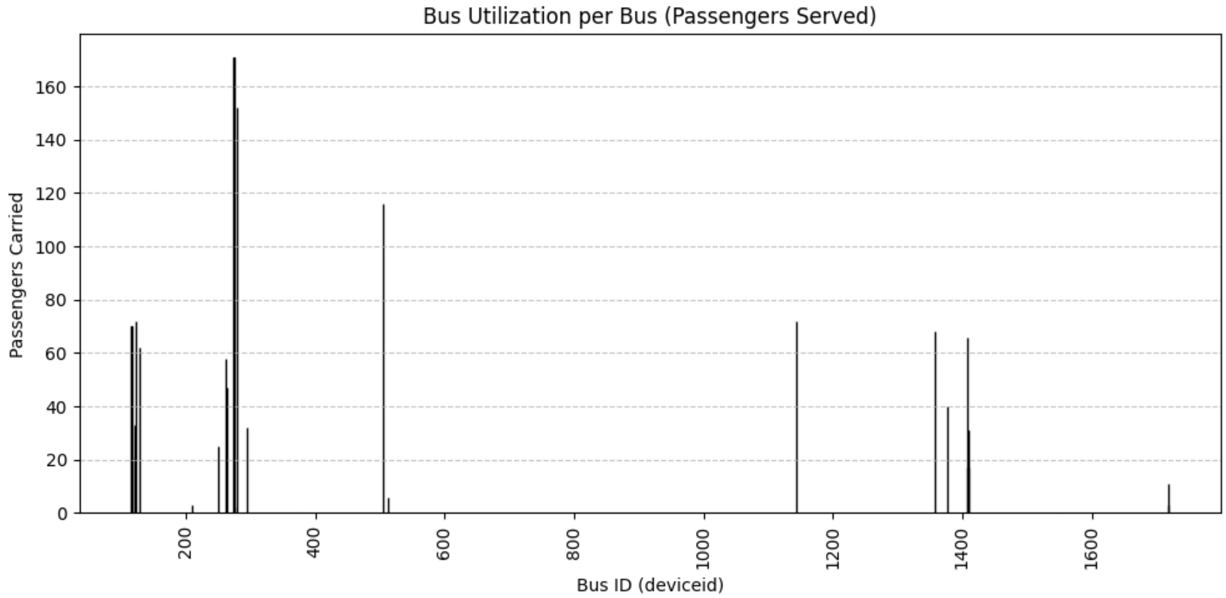
Visualizations-

Figure 1 – Passenger Waiting Time Distribution:



A histogram showing the number of passengers versus their waiting time. The chart reveals that most passengers experience waiting times between 8 and 12 minutes, forming a peak around the average waiting time of 11.3 minutes. A small portion of passengers waits longer, indicating occasional congestion or uneven bus arrival intervals.

Figure 2 – Bus Utilization per Bus:



A bar chart displaying the number of passengers carried by each bus (device ID). The chart illustrates significant variation across buses: some buses carry fewer than 10 passengers, while others exceed 150 passengers across multiple trips. This highlights uneven demand distribution and scheduling inefficiencies that can be optimized through better route planning.

These visualizations provide clear insights into how operational parameters such as route allocation and dispatch timing influence key performance outcomes**.**

Limitations and Future Extensions

Although the simulation model provides valuable insights, several limitations should be acknowledged:

1. Simplified Passenger Arrival Model:
   Passenger arrivals were generated based solely on recorded trip start times rather than actual passenger demand data. In reality, arrivals may follow variable or stochastic patterns influenced by external factors (e.g., weather, events, or service delays).
2. Static Bus Capacity:
   All buses were assumed to have a fixed capacity of 60 passengers. Real systems may involve mixed fleets with varying capacities and seating arrangements.
3. Neglected Traffic Variability:
   The model does not incorporate traffic congestion or delays due to road conditions, which can significantly affect trip duration and waiting times.
4. Lack of Real-Time Feedback:
   The simulation assumes fixed schedules without dynamic dispatching based on passenger queue lengths or bus delays.

Future Extensions

To improve the accuracy and applicability of the model, the following enhancements are proposed:

- Incorporate real passenger demand data from ticketing or GPS systems to simulate variable arrival patterns.
- Extend the model with agent-based simulation to capture individual passenger behavior and route choices.
- Integrate traffic congestion modeling to reflect realistic trip durations.
- Implement machine learning–based demand forecasting to support adaptive scheduling and route optimization.
- Visualize throughput per hour and queue length trends to analyze peak and off-peak efficiency.

References

1. SimPy Documentation (2025). *Process-based discrete-event simulation framework.* [Online] Available at: https://simpy.readthedocs.io/
2. Dataset Source: *bus_trips_654.csv* — City Bus Operation Records.
3. GitHub Repository: https://github.com/chulaniP/A-Public-Transportation-Network