THE OPEN UNIVERSITY OF SRI LANKA FACULTY OF ENGINEERING TECHNOLOGY

THE DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

EEX5362 Performance Modelling

Deliverable 01- Mini Project

Performance Modeling and Evaluation of Colombo Public Bus Transportation Network

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1. Introduction

The system selected for this performance modeling study is the Public Bus Transportation Network operating within the Colombo Metropolitan Region in Sri Lanka. This transportation system is a large-scale, complex, and dynamic network jointly managed both by public (Sri Lanka Transport Board) and private operators. The system consists of multiple routes that have several bus connections between main cities, suburbs, and town centers. Each such route comprises a sequence of stops, depots, and terminals with a fixed number of buses servicing passengers with variable intervals.

This transportation network is based on the dynamic interaction between multiple elements that include changing passenger demand, efficiency of bus scheduling, road congestion, driver supply, and capacity of buses. These interdependencies make the system ideal for performance modeling and analysis. The important measurable characteristics of the performance will be passenger waiting time, bus utilization, route throughput, and service reliability.

1. Problem Statement (High-Level Problem)

Although the most affordable and accessible means of traveling, public buses in Colombo are plagued by chronic inefficiencies, causing dissatisfaction among passengers and operational losses. The major issues include long waiting times during peak hours, unpredictability in bus arrival times, delays caused by traffic congestion, and overcrowding. All these disadvantages contribute to degraded service quality and system throughput, while increasing operational costs.

There is a pressing need for a systematic performance evaluation framework for quantifying, analyzing, and optimizing system performance. Modeling will make possible the identification of bottlenecks, evaluation of scalability under an increased load, and optimization of resource allocation to enhance reliability and efficiency.

1. Performance Objectives

Key objectives of this study are to evaluate and improve the operational performance of the Colombo bus transportation network using analytical and simulation-based modeling. The following are the measurable objectives.

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| --- | --- | --- |
| Objective | Description | Performance matric |
| Minimize Passenger Waiting Time | waiting time of passengers in major stops during peak and off-peak hours. | Average waiting time (in minutes) |
| Bottleneck Identification | Identifies critical routes, stops, or periods of time that slow down the system. | Delay Percentage per Route/Segment |
| Optimize Resource Allocation | Determine the optimal number of buses per route to balance demand and supply. | Bus utilization rate (%) |
| Assess Scalability | Simulate system behavior under increased passenger demand and extended route coverage. | Load-response curves, delay analysis |

1. Dataset

The dataset used for this research is a simulated one, representing daily bus operations. It includes temporal, spatial, and operational parameters required to model the flow of passengers, the occupancy of buses, and the adherence to timetables.

|  |  |
| --- | --- |
| Data type | Description |
| route\_id | Unique identifier for each bus route. |
| bus\_id | Unique bus registration number or fleet ID. |
| departure\_time | Scheduled time of departure from a specific stop. |
| arrival\_time | Actual time of arrival at the next stop. |
| stop\_id | Unique identifier of a bus stop or terminal. |
| passenger\_arrivals | Number of passengers waiting at a stop. |
| bus\_capacity | Maximum capacity of the bus (number of passengers). |
| current\_load | Number of passengers currently onboard. |
| travel\_time | Time taken between consecutive stops (minutes). |
| delay\_time | Difference between scheduled and actual travel time (minutes). |

1. Modeling Approach and Methodology

This research study applies two major performance modeling techniques, namely, Queueing Theory and Discrete Event Simulation (DES), to performance evaluation and analysis of the bus transportation system within Colombo City. These methods will be used for both analytical and dynamic modeling of passenger flow, service efficiency, and resource utilization across multiple routes and stops.

The passenger arrival rate, λ, is the average number of passengers arriving per unit time, whereas the service rate, μ, denotes the average number of passengers that a bus can board in one unit of time. A single bus operating at one stop can thus be modeled as an M/M/1 queue, while multiple buses serving the same stop simultaneously could be extended to an M/M/c queue model.

Average Waiting Time (Wq)

Average Queue Length (Lq)

Outputs of the DES models include key performance indicators like average passenger waiting time, bus occupancies, throughput per route, and average delay times. Such results give a realistic overview of the performance of the Colombo bus system under operational scenario variations, hence offering indications for performance optimization opportunities regarding, for instance, increasing the frequency of buses or optimization of route scheduling.

In the modeling process, several assumptions were made to keep the model simple and analytically tractable:

The passenger arrivals at each stop follow a Poisson distribution because the arrivals are random and independent over time.

1. Expected Outcomes

* Quantitative Analysis, Waiting time, throughput, utilization in clear numbers.
* Bottleneck Identification, Specific stops/routes causing delays
* Resource Optimization, Suggested number of buses per route to minimize idle time
* Scalability Insights, Performance under increased demand scenarios
* Visualization, Graphs for decision-making: Bar charts, heatmaps, queue curves.

1. Limitations and Future Extensions

Limitations

* Traffic variability not fully captured in real-time scenarios
* Passenger behavior (e.g., missing buses) simplified
* External events (accidents, breakdowns) not included

Future Extensions

* Integration with real-time GPS and traffic data for live simulation
* Predictive modeling using machine learning for demand forecasting
* Optimization of multi-route interactions and scheduling

1. Git Repository

<https://github.com/umayanga23/colombo-bus-performance-model.git>