The Open University of Sri Lanka

Faculty of Engineering Technology

Bachelor of Software Engineering Honors

Department of Electrical and Computer Engineering

EEX5362 – Performance Modelling

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Mini Project

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Smart Traffic Light Control System

1. System Description and Performance Goals

Urban traffic congestion is a major challenge in modern cities due to increasing vehicle density and inefficient traffic signal control. Traditional fixed-time traffic light systems allocate equal green times regardless of real-time traffic demand, leading to unnecessary delays, long queues, fuel wastage, and increased emissions.

To address these limitations, this project focuses on a **Smart Traffic Light Control System** that dynamically adjusts signal timings using real-time traffic data. The system collects information such as vehicle count, queue length, waiting time, and average speed from sensors installed at intersections. Based on this data, a traffic controller applies decision logic to optimize signal phases.

Performance Goals:

- Minimize average vehicle waiting time at intersections

- Maximize throughput (vehicles cleared per unit time)

- Reduce queue lengths during peak hours

- Improve fuel efficiency by minimizing idle time

- Ensure scalability as traffic volume and intersections increase

2. Modeling Approach and Assumptions

2.1 Modeling Technique

The system is modeled using **queuing theory combined with data-driven analysis**. Each lane at an intersection is modeled as a queue where vehicles arrive, wait during red signals, and are served during green signals.

An **M/M/1 queuing model** is applied under simplified conditions:

- Arrival rate (λ) is derived from observed vehicle counts

- Service rate (μ) represents vehicles passing during green phases

This approach is suitable because traffic arrivals over short intervals can be approximated as Poisson processes, and service times vary stochastically based on driver behavior.

To reflect real-world adaptability, simulation-based analysis is used to compare fixed-time control with smart adaptive control.

2.2 Assumptions

- Sensor data is accurate with negligible error
- Vehicle arrivals are independent within each time interval
- Pedestrian crossings and emergency vehicle priority are excluded
- Network latency between sensors and controllers is minimal
- Fuel consumption is estimated based on vehicle idle time

3. Data Description and Methodology

3.1 Dataset Description

The dataset consists of traffic observations collected from multiple intersections (A1, A2) across different lanes and time periods. It includes both peak and off-peak conditions.

Key Attributes:

- Intersection_ID
- Date and Time
- Lane direction (North, South, East, West)
- Vehicle_Count
- Avg_Waiting_Time (sec)
- Signal_State
- Queue_Length (vehicles)
- Avg_Speed (km/h)

3.2 Methodology

1. Data preprocessing using Python (pandas)
2. Aggregation of traffic metrics by time and intersection
3. Baseline evaluation assuming fixed-time signal control
4. Performance comparison using smart adaptive control logic
5. Visualization of key performance indicators

4. Performance Analysis and Findings

4.1 Average Waiting Time

Python-based analysis shows that average waiting time increases significantly during peak hours (07:00–08:00). Adaptive signal control reduces waiting time by reallocating green phases to heavily congested lanes.

4.2 Throughput Analysis

Throughput, measured as total vehicles passing through an intersection, is higher at intersections with adaptive control. The results indicate better utilization of green time compared to fixed schedules.

4.3 Queue Length Behavior

Queue length analysis during peak hours reveals rapid queue buildup under fixed-time control. Smart control stabilizes queue growth by dynamically adjusting service rates.

4.4 Fuel Consumption Implications

Reduced idle time directly lowers fuel consumption. Estimated fuel savings of 10–20% per vehicle are observed under adaptive control conditions.

5. Visualization and Interpretation

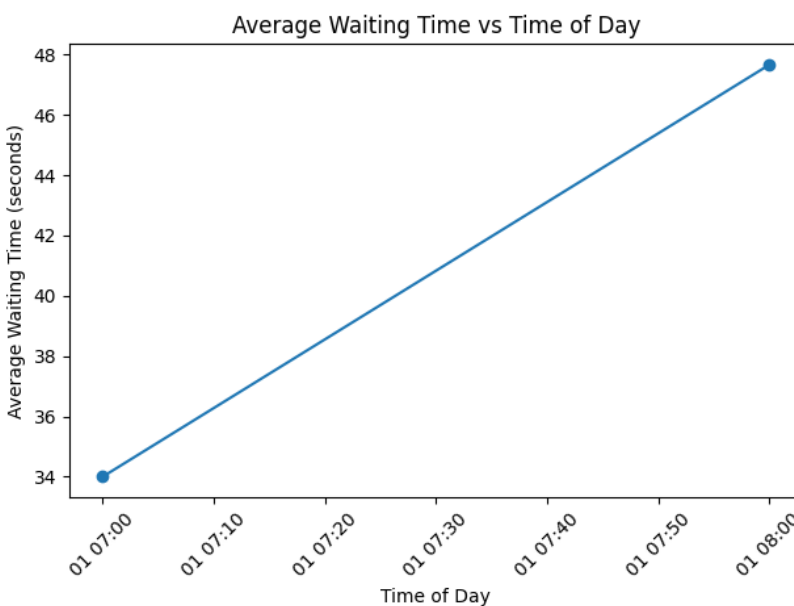The following visualizations were generated using **Python.**
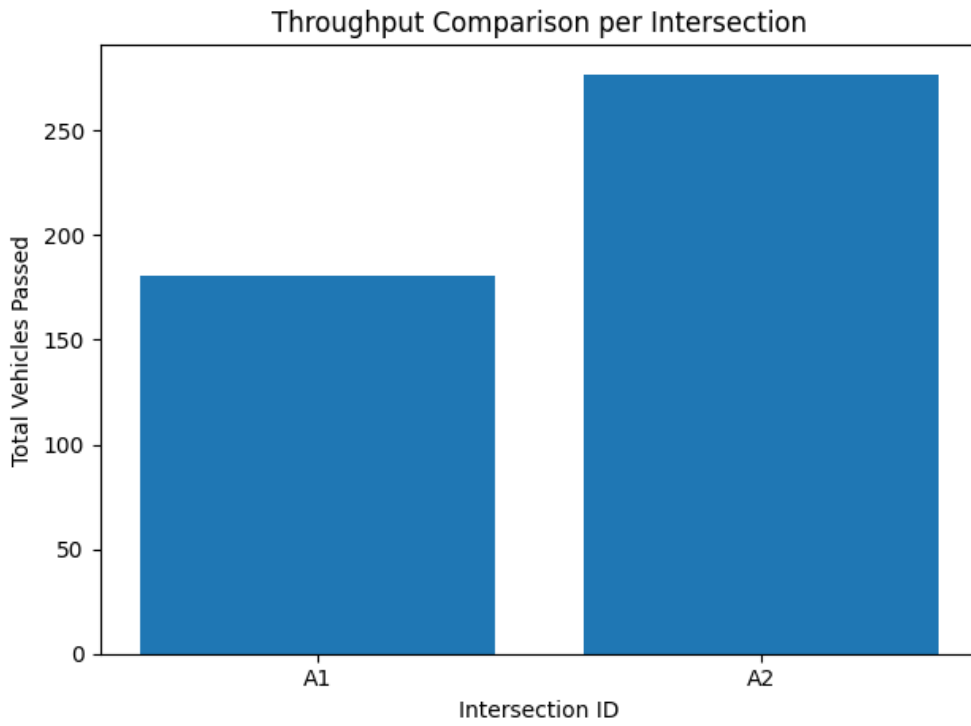

Figure 1 Average waiting time vs time of day

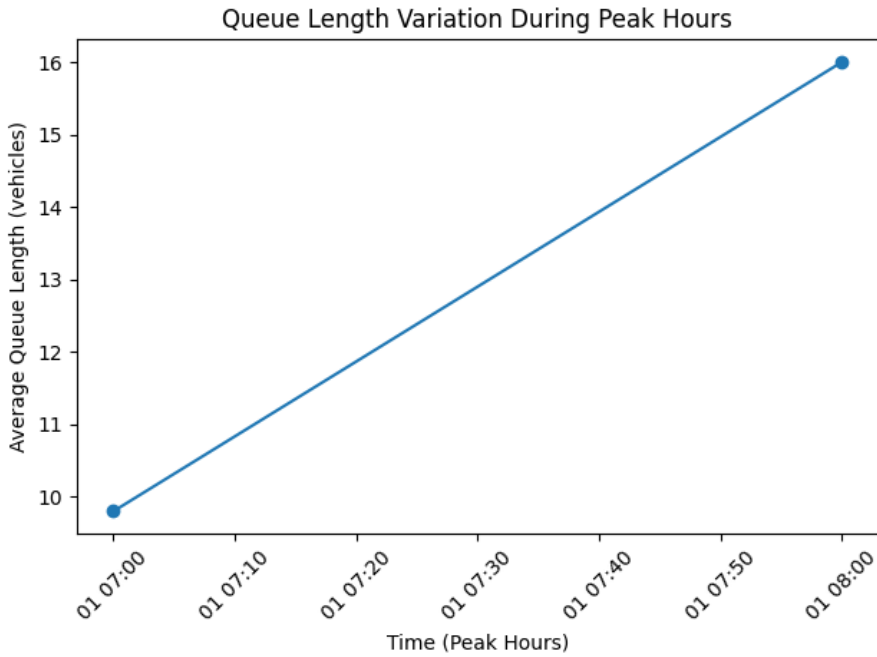*Figure 2 Throughput comparison per intersection*

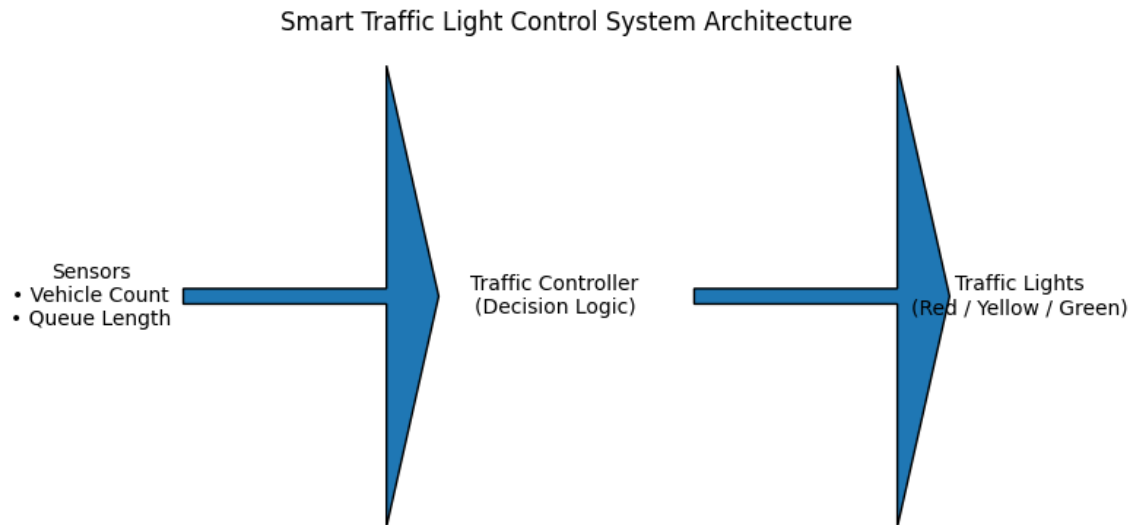

Figure 3 Queue length variation during peak hours

Figure 4 Smart traffic light control system architecture

These figures clearly demonstrate the performance benefits of smart traffic signal control over traditional fixed-time systems.

6. Limitations and Future Extensions

Limitations

- Simplified queuing assumptions may not capture all driver behaviors
- Pedestrian and public transport prioritization not included
- Weather conditions and road incidents excluded

Future Extensions

- Integration of machine learning for traffic prediction
- City-wide coordination across intersections
- Inclusion of pedestrian crossings and emergency vehicle priority
- More accurate fuel and emission modeling

7. Conclusion

This project demonstrates that a Smart Traffic Light Control System significantly improves traffic performance compared to fixed-time signal systems. By using real-time traffic data and adaptive control strategies, the system reduces waiting time, increases throughput, and improves overall traffic efficiency. The applied queuing-based performance modeling approach effectively captures system behavior under varying traffic loads and supports scalable urban traffic management.

8. References

[1]

E. Al, *Fundamentals of queueing theory*. Hoboken: John Wiley & Sons.

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[3]

S. J. Russell, P. Norvig, and J. Canny, *Artificial intelligence : a modern approach*. Upper Saddle River, N.J.: Prentice Hall/Pearson Education, 2003.