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Complex System Identification

The identified complex system is Multi-lane Highway Toll Plaza.

Multi-lane Highway Toll Plaza

The toll plaza system is a very important item in modern transportation, specifically on highways. This is a control point for collecting tolls while ensuring a smooth flow of traffic. But, during peak time, traffic congestion, long queues, increasing waiting times, and reduced throughput can occur due to inefficient booth management.

This system is characterized by variable service times at toll booths and random vehicle arrivals. The crucial challenge here is to minimize queues and waiting times while ensuring efficient collection of tolls by allocating limited resources to meet dynamic demand.

Factors that affect the complexity of the system

* Random Arrivals

Vehicle arrival is not constant. This can lead to unexpected and unpredictable bursts of traffic.

* Time-Varying Demand

The arrival times change throughout the day. Different strategies should be used handle peak and off-peak hour vehicles.

* Queue Dynamics

Vehicles maybe stagnated in one lane when there are other lanes with less queue length. Vehicles also might be restricted to certain lanes due to the payment method.

* Heterogeneous Servers

Toll booths efficiency might vary as Electronic Toll collection lanes process vehicles significantly faster than manual cash lanes.

Performance Objectives

1. Minimize average vehicle wait time

The primary goal is to minimize the waiting time of vehicles in queues.

The current average waiting time of a vehicle will be measured and set a target of less than 90 seconds (for example) will be set during peak hours.

The average wait time can be also reduced by optimal booth allocation and scheduling.

1. Maximize system throughput

The toll plaza should be a able to handle and process the incoming flow of vehicles without having traffic congestion.

Set a target of having a throughput of >= 95% (for example) of the arrival rate to prevent a backlog.

1. Achieve optimal resource allocation

A balanced workload distribution should be ensured across all lanes to avoid over utilization or under utilization of toll booths.

In order to achieve cost and performance equilibrium, we target to maintain all the toll booths (manual and ETC) at 75-80% of full utilization during the peak hours. This means that resources are used effectively and there is no over-crowding.

1. Identify and eliminate bottlenecks

Identify components that limit the overall performance of the system, and optimize their operation.

1. Scalability Analysis

Ensure the system can handle peak volume conditions by analyzing system performance when traffic volume increases.