Dynamic Pricing for Urban Parking Lots

Prepared by: Sneha Biswas

Date: 7 July 2025

1. Introduction

Urban parking lots often suffer from demand-supply imbalance, leading to congestion, underutilization, or overpriced spots. This project aims to implement a real-time dynamic pricing model using Pathway that adjusts parking prices based on demand fluctuations.

2. Dataset Overview

The dataset includes three columns: Timestamp, Occupancy, and Capacity. We preprocess the data by converting the date and time into a unified timestamp and sorting it chronologically for accurate simulation.

3. Demand Function

The demand function used is: price = 10 + (max_occupancy - min_occupancy) / capacity. This reflects that larger fluctuations in occupancy during the day will lead to higher dynamic pricing.

4. Assumptions

- Daily demand variation impacts pricing.

- Capacity remains fairly stable.

- Prices update every 24 hours using a tumbling window.

- Competition or external factors are not considered in this version.

Model 1: Daily Demand Aggregation Pricing

This model calculates a dynamic price once per day based on the difference between the maximum and minimum occupancy levels. It uses a tumbling window of 24 hours. The price is calculated using the formula:

price = 10 + (max_occupancy - min_occupancy) / capacity

This helps adjust pricing based on how much occupancy fluctuates in a day.

Model 2: Demand-Sensitive Pricing with Contextual Features

This model enhances pricing by incorporating queue length and special day effects. It uses the following demand-based formula:

demand_score = [ALPHA * (occupancy / capacity) + BETA * (queue / 10)] * (1 + special_day * GAMMA)

price = BASE_PRICE * (1 + demand_score)

Weights: ALPHA=3.0, BETA=0.5, GAMMA=2.0, BASE_PRICE=10.0
It increases prices during higher queue lengths and on special days.

Model 3: Enhanced Pricing with Traffic Conditions

This model adds traffic condition as an additional multiplier to Model 2. Traffic levels are mapped to floats and factored in:

raffic_boost = 1 + (traffic_level * DELTA)
price = BASE_PRICE * (1 + demand_score) * traffic_boost

Weights: DELTA=2.0
This allows for higher pricing during high congestion periods near the parking area, making it the most context-aware model.

7. Visualizations

The Bokeh chart shows the daily price calculated from demand variations. Points and line charts visualize how price changes over time.

8. Conclusion and Future Work

The dynamic pricing model demonstrates how real-time data can be used to adjust parking prices effectively. Future improvements can include pricing based on competition, location-based differentiation, and inclusion of traffic data or nearby events.