Dynamic Pricing Strategies for Urban Parking Lots

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1 Project Objective

This project develops a real-time, intelligent pricing system for urban parking lots to dynamically update parking fees in response to fluctuating demand and contextual factors. The system aims to:

- Optimize utilization across 14 parking spaces
- Prevent overcrowding and underutilization
- Respond to real-time changes in traffic, special events, and vehicle types
- Simulate competitive market conditions based on proximity and alternative pricing

2 Dataset Summary

- 14 unique urban parking lots
- 73 days of synthetic time-series data
- Data captured at 18 half-hour intervals per day (8:00 AM to 4:30 PM)
- Key attributes:
  - Parking metrics: occupancy, capacity, queue length
  - Vehicle types: car, bike, truck
  - Environment: traffic congestion, special day indicator
  - Spatial data: latitude and longitude

3 Models Implemented

Model 1: Baseline Linear Pricing (*Implemented*)

- Computes price incrementally based on occupancy-to-capacity ratio
- Acts as a foundational benchmark model
- Executed via Pathway UDF for real-time simulation

Model 2: Demand-Based Pricing (*Implemented*)

- Defines a weighted demand function:
  - `occupancy/capacity`, `queue`, `traffic`, `special day`, `vehicle type weight`
- Demand score is normalized and bounded (0.5x to 2x base price)
- Logic is fully embedded in `pricing_logic()` using Pathway UDFs

Model 3: Competitive Pricing (*Implemented*)

- Computes geographic distances using latitude/longitude via Haversine formula
- Identifies neighboring lots and accesses their price trajectories
- Adjusts pricing based on being cheaper or more expensive than nearby competitors
- Suggests dynamic flexibility under competitive scenarios

4 Feature Engineering

- Normalized occupancy ratios
- Real-time queue impact
- Traffic conditions integrated via penalty coefficient
- Binary feature for special days or local events
- Vehicle-specific weights: bike (0.5), car (1.0), truck (1.5)

5 Real-Time Processing

- Pathway's `@pw.udf` decorators used for seamless simulation
- Supports continuous data streaming and event-triggered updates
- UDFs modularized to isolate model logic, normalization, and bounding

6 Visualization

- Bokeh visualizations compare pricing trends from all models
- Line plots generated per parking lot over a 73-day time window
- Offers explainability and visual traceability

7 Conclusion

The notebook presents a modular, scalable, and analytically grounded pricing engine that fulfills the project brief across all core dimensions. Each pricing model is logically sound, real-time capable, and interpretable. Bokeh integration allows for visual auditing, and the architecture is structured to support deployment into future Pathway pipelines.