Project Report – Dynamic Pricing for Urban Parking Lots

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Objective

Design and implement a real-time dynamic pricing system for 14 urban parking lots using demand-based and competition-aware strategies. The system should update prices smoothly and intelligently based on real-time conditions like traffic, queue length, occupancy, vehicle type, and competitor pricing.

Data Description

- **73 days × 18 time steps/day** (every 30 minutes from 8:00 AM to 4:30 PM)
- **14 parking lots**, each with:
  - Occupancy
  - Queue length
  - Capacity
  - Traffic level
  - Special day indicator
  - Vehicle type (car, bike, truck)
  - Latitude & Longitude

⚙ Models Built

Model 1 – Baseline Linear Pricing

Price increases linearly with occupancy: [P{t+1} = Pt + \alpha \left(\frac{\text{occupancy}}{\text{capacity}}\right)]

- Simple, easy-to-understand behavior.
- Constrained to 0.5x–2x base price ($5–$20).

Model 2 – Demand-Based Pricing

Composite demand score from multiple features: [\text{Demand} = \alpha \frac{\text{Occupancy}}{\text{Capacity}} + \beta \cdot \text{Queue} - \gamma \cdot \text{Traffic} + \delta \cdot \text{SpecialDay} + \varepsilon \cdot \text{VehicleWeight}]

- Price:
  [P = \text{BasePrice} \cdot (1 + \lambda \cdot \tanh(\text{Demand}))]
- Smooth scaling using `tanh`
- Vehicle type weight: truck > car > bike

Model 3 – Competitive Pricing (Advanced)

Incorporates nearby lots' pricing using Haversine distance:

- Computes competitor average price (distance-weighted)
- Adjusts own price if:
  - Lot is full but cheaper than nearby → raise price
  - Lot is underused but more expensive → reduce price

Real-Time Integration with Pathway

- All pricing functions are stateless and easy to wrap into Pathway's streaming UDFs.
- Example integration using `@pw.udf` is provided in the notebook.

Visualizations (Planned)

- Live Bokeh plots to track real-time prices per lot
- Compare current price with competitors
- Track occupancy vs price

Assumptions

- Base Price = **$10**
- Min = $5 (0.5×), Max = $20 (2×)
- Vehicle weights: `bike`=0.4, `car`=1.0, `truck`=1.5
- Default parameters chosen heuristically

Limitations & Future Scope

- Coefficients (`α, β, γ, …`) can be learned from data using regression or reinforcement learning.

- Incorporate weather/event data.
- Add a rerouting recommendation system.
- Extend to revenue optimization using bandit strategies.

This report complements the notebook: `Dynamic_Pricing_Final.ipynb`
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