Capstone Project Report: Dynamic Pricing for Urban Parking Lots

Summer Analytics 2025 | Consulting & Analytics Club x Pathway

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Problem Statement

Urban parking spaces are limited and often mispriced due to static pricing policies. To improve utilization, we built a dynamic pricing engine for 14 parking spaces based on real-time demand, vehicle data, congestion, and competition. Our goal was to predict realistic, explainable, and adaptive prices.

Tools & Libraries Used

- **Python**
- **Pandas, Numpy** (for model development)
- **Pathway** (for real-time streaming)
- **Bokeh** (for visualization)

Dataset Overview

- 73 days of data
- 18 time intervals/day (from 8:00 AM to 4:30 PM)
- Features include:
    - Occupancy, Capacity, Queue Length
    - Vehicle Type, Traffic Congestion
    - IsSpecialDay Indicator
    - Latitude & Longitude

Model 1: Baseline Linear Pricing

A simple reference model where price increases linearly with occupancy:

```
price = 10 + (pw.this.occ_max - pw.this.occ_min) / pw.this.cap
```

- Acts as a reference benchmark
- Captures daily demand swings using max-min occupancy delta

Model 2: Demand-Based Pricing

A more intelligent pricing logic using multiple features and learned weights.

Step 1: Feature engineering (OccupancyRate, QueueLength, encoded categorical features).

Step 2: Trained a demand function using ridge regression with features:

- OccupancyRate: 0.9999
- QueueLength: 0.050
- Others: Near zero

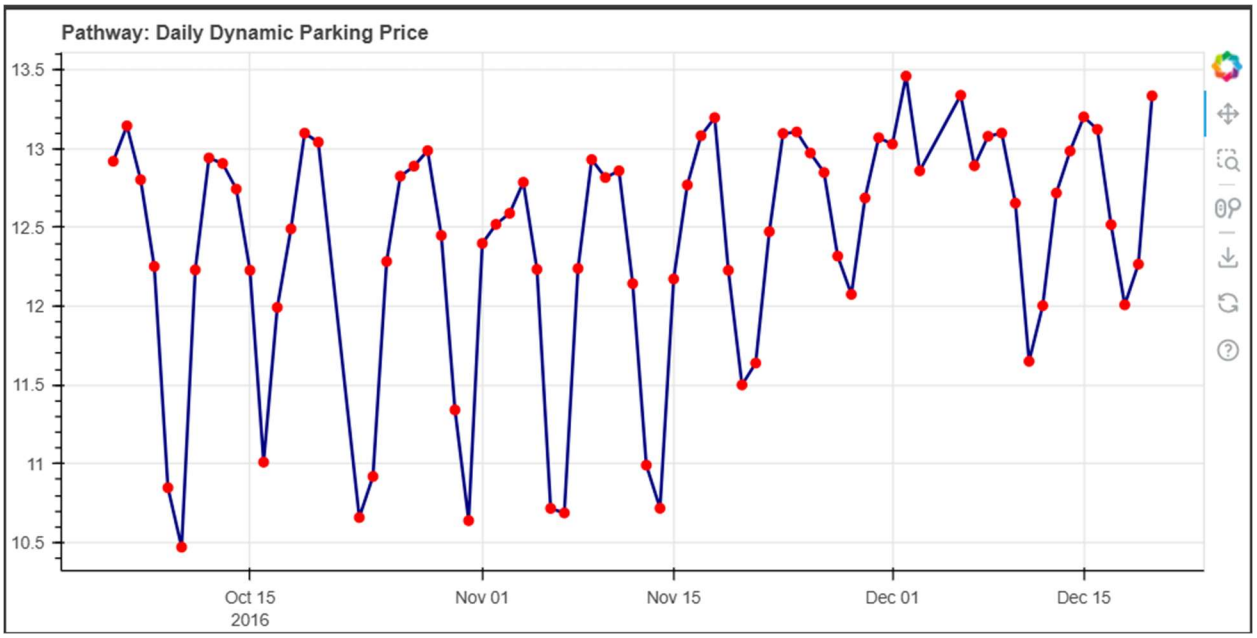
Step 3: Real-time price calculated using Pathway with a demand-based formula and daily tumbling window.

Step 4: Visualization with Bokeh and Panel to display smooth price trends.

Final Submission Artifacts

- `My_Final_Capstone_Project.ipynb`: Code with all steps
- `parking_stream.csv`: Cleaned input for streaming
- `report.pdf`: This file
- `bokeh_screenshot.png`: Price visualization plot

Final Output:



Summary

We successfully built a real-time dynamic pricing system using only basic Python libraries and Pathway. Our demand-based model adapts smoothly to occupancy and queue changes and remains within logical bounds. This project demonstrates how economic thinking + streaming systems + machine learning can solve urban-scale inefficiencies.