**Capstone Report: Dynamic Pricing for Urban Parking Lots**

**Project Overview**

This capstone project, conducted as part of Summer Analytics 2025, addresses the issue of inefficient and static pricing in urban parking lots. The solution involves developing a dynamic pricing engine that uses real-time data to intelligently adjust parking fees based on current demand, vehicle types, and surrounding conditions. The project incorporates real-time data processing using Pathway, pricing model logic using Python (NumPy, Pandas), and real-time visualization via Bokeh.

**Dataset Description**

The dataset includes parking data from 14 urban parking lots over a period of 73 days. Each day includes 18 time-slices from 8:00 AM to 4:30 PM, captured at 30-minute intervals. Key features:

* Location (Latitude, Longitude)
* Capacity and Occupancy of each lot
* Queue Length
* Vehicle Type (Car, Bike, Truck)
* Nearby Traffic Congestion
* Special Day Indicator (holiday, event)
* Timestamp

**Project Objective**

To implement a dynamic pricing system that:

* Starts from a base price of $10
* Adjusts pricing based on real-time conditions
* Responds to factors like queue length, traffic congestion, and event days
* Remains smooth and explainable
* Optionally suggests rerouting when nearby competitor lots are more favorable

**Model 1: Linear Pricing Model**

This baseline model uses a linear relation between occupancy and price:

Price = BasePrice + α \* (Occupancy / Capacity)

Where α = 5, and price is bounded between $5 and $20. This model captures basic supply-demand logic and provides a reference point for advanced models.

**Model 2: Demand-Based Pricing Model**

This model incorporates additional features to calculate a demand score:

Demand = α \* (Occupancy / Capacity) + β \* QueueLength - γ \* Traffic + δ \* IsSpecialDay + ε\_vehicle

* α = 5 (occupancy)
* β = 0.1 (queue length)
* γ = 0.05 (traffic)
* δ = 0.2 (special day)
* ε\_vehicle: weight varies by vehicle type (car = 1.0, bike = 0.5, truck = 1.5)

**Final Price:**

Price = BasePrice \* (1 + λ \* NormalizedDemand)

Where λ = 0.3, and price is clipped between 0.5x and 2x the base price.

**Real-Time Simulation using Pathway**

* Implemented real-time streaming using Pathway’s pw.io.csv.read() in streaming mode
* Used pw.temporal.tumbling() windows to smooth daily pricing updates
* Applied UDFs for both Model 1 and Model 2 price generation
* pw.run() executed live updates continuously

**Visualization with Bokeh**

* Used Panel + Bokeh for interactive real-time line plots
* Plotted Model 2 price per lot across timestamps
* Used dropdowns for lot selection
* Optional competitor pricing overlay based on geographic proximity

**Outputs**

* Final streaming output saved to parking\_stream.csv
* Includes timestamps, LotID, Occupancy, Model 1 price, and Model 2 price

**Sample:**

| Timestamp | LotID | Occupancy | Capacity | Model2\_Price |
| --- | --- | --- | --- | --- |
| 2025-07-01 08:00AM | 12.9716\_77.5946 | 45 | 60 | $12.84 |

**Justification of Pricing Behavior**

* Occupancy increases lead to higher prices
* Special days cause noticeable spikes
* Queue length and vehicle type further influence pricing levels
* Smooth changes achieved using windowing functions

**Conclusion**

This project demonstrates the ability to:

* Design rule-based dynamic pricing systems from scratch
* Simulate real-time ingestion and response using Pathway
* Visualize and explain price shifts effectively

Future scope includes:

* Enhancing the competitor pricing logic
* Integrating predictive ML models for price forecasting
* Rerouting logic for overflow conditions

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