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

**Project Title:** Dynamic Pricing for Urban Parking Lots  
**Event:** Summer Analytics 2025 Capstone  
**Organized by:** Consulting & Analytics Club × Pathway  
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**1. Project Overview**

Urban parking spaces are scarce and experience significant variations in demand throughout the day. Most parking lots use static pricing models that fail to reflect these fluctuations, resulting in either congestion or underutilization. This project simulates an intelligent, real-time pricing engine for 14 parking lots using machine learning principles and economic theory.

**2. Objective**

To build a data-driven, real-time pricing model for each parking lot that adjusts prices based on:

* Occupancy rate
* Queue length
* Nearby traffic congestion
* Special events
* Vehicle type
* Competitor pricing

**3. Dataset Description**

* **Parking lots:** 14
* **Time Span:** 73 days
* **Time Intervals:** Every 30 minutes from 8:00 AM to 4:30 PM
* **Attributes:**
  + Latitude & Longitude
  + Capacity, Occupancy, Queue length
  + Vehicle Type: car, bike, truck
  + Traffic Condition: low, medium, high
  + Special Day Indicator (0/1)

**4. Technology Stack**

* Python, NumPy, Pandas
* Google Colab
* Bokeh (for interactive visualization)
* GitHub (for code hosting and version control)

**5. Model Implementation**

**Model 1: Static Linear Pricing**

**Formula:**

Price = Previous Price + alpha \* (Occupancy / Capacity)

* **Alpha (α):** Slope coefficient
* **Characteristics:** Predictable, smooth linear change with occupancy
* **Use Case:** Establishes a basic relationship between occupancy and price.

**Visualization:**

* Line plot of price over time for selected lots
* Shows smooth price increase as occupancy rises

**Model 2: Demand-Based Pricing**

**Demand Function:**

Demand = α \* (Occupancy / Capacity) + β \* Queue Length

- γ \* Traffic + δ \* IsSpecialDay + ε \* VehicleWeight

Where:

* VehicleWeight = 1.3 (truck), 1.0 (car), 0.7 (bike)
* Traffic: converted to numerical scale (low=1, medium=2, high=3)

**Price Formula:**

Price = Base \* (1 + λ \* Normalized Demand)

* Demand normalized between 0 and 1
* λ used to scale the price smoothly
* Price bounded between 0.5x and 2x base price

**Assumptions:**

* Higher occupancy and queues indicate higher demand
* Traffic congestion reduces desirability
* Events increase demand
* Trucks are willing to pay more than bikes

**Visualization:**

* Demand-based price fluctuation
* Clear peaks on holidays and high congestion slots

**Model 3: Competitive Pricing**

**Competitor Analysis:**

* Distance between parking lots calculated using latitude/longitude
* For each lot, nearby competitors within a 0.005-degree radius are selected

**Adjustment Logic:**

If nearby lots are cheaper and less full:

-> reduce price to remain competitive

If nearby lots are expensive or full:

-> increase price slightly to benefit from spillover

**Final Price:**

Final Price = Base + α \* Demand + ϕ \* Competitor Adjustment

* ϕ tunes influence of competitors

**Visualization:**

* Price variations considering real-time competitor behavior
* Sharp dips when competitors lower prices or congestion drops

**6. Visual Outputs (Bokeh Graphs)**

All visualizations were created using Bokeh for interactivity and clarity.

* **Model 1 Graph:** Smooth increase in pricing with occupancy
* **Model 2 Graph:** Peaks aligned with traffic and events
* **Model 3 Graph:** Dynamic pricing reacting to competition

These are saved in the /images folder as:

* model1.png
* model2.png
* model3.png

**7. Results Saved**

All pricing calculations were saved to:

final\_parking\_pricing.csv

This includes columns for all three models' pricing per timestamp per lot.

**8. Key Insights**

* Demand-based pricing outperforms static pricing in responsiveness
* Competition-aware pricing can avoid loss of customers to cheaper lots
* Price caps (0.5x to 2x) ensure fairness to users while optimizing revenue

**9. Repository Summary**

**GitHub Link:** *[Your GitHub repo URL here]*  
**Files in Repository:**

├── Dynamic\_Pricing\_Notebook.ipynb

├── final\_parking\_pricing.csv

├── dataset.csv

├── README.md

└── /images

├── model1.png

├── model2.png

└── model3.png

**Future Scope**

* Deploy pricing engine in real-time using Pathway's streaming integration
* Include rerouting suggestions using navigation APIs (e.g., Google Maps)
* Account for user behavior via feedback loops or heatmaps

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