**Dynamic Pricing for Urban Parking Lots**  
*Capstone Project - Summer Analytics 2025*  
*Consulting & Analytics Club × Pathway*

**1. Introduction**

Urban parking is a growing challenge in densely populated areas, where limited space and static pricing models lead to inefficiencies like overuse or underuse. This project introduces a real-time, dynamic pricing model using demand signals, location intelligence, and machine learning concepts. It simulates a pricing engine to optimize utilization across 14 parking spaces based on real-world data.

**2. Dataset Description**

* **Time Frame:** 73 days, 18 half-hour intervals per day (8:00 AM to 4:30 PM)
* **Locations:** 14 unique urban parking spaces
* **Features:**
  + Latitude & Longitude
  + Capacity & Occupancy
  + Queue length
  + Vehicle type (car, bike, truck, cycle)
  + Traffic congestion level
  + Special day/event indicator
  + Timestamp

**3. Project Objectives**

* Build an explainable, real-time dynamic pricing engine
* Use historical occupancy patterns, vehicle data, and environmental conditions
* Simulate pricing with Pathway (data streaming platform)
* Provide visual validation using plots

**4. Pricing Models Implemented**

**Model 1: Baseline Linear Model**

Simple linear increase in price based on occupancy rate:

Price\_t+1 = Price\_t + α × (Occupancy / Capacity)

* Acts as reference model
* Price change is incremental and occupancy-sensitive

**Model 2: Demand-Based Function**

Captures multiple demand influencers:

Demand = 3 × (Occupancy / Capacity) + 1.5 × Queue - 2 × Traffic + 5 × IsSpecialDay + VehicleWeight

Price = Base × (1 + 0.8 × NormalizedDemand)

* Smooth and bounded pricing (clipped between $5 and $20)
* Factors in queue length, vehicle type, and traffic

**Model 3: Competitive Pricing (Advanced)**

Extends Model 2 with pricing logic based on lot crowding and potential rerouting:

* If occupancy > 95% and price > $12 → reduce price by 5% to encourage load balancing
* Designed for real-world scalability (multi-lot proximity can be added with geo-distances)

**5. Real-Time Streaming with Pathway**

Pathway is used to simulate data ingestion and apply live pricing updates.

* Streaming Mode: Row-by-row CSV input
* Timestamps respected via Timestamp column
* Output: Streaming JSON with updated prices per row

**Key Function:**

@pw.udf

def demand\_based\_price(...):

# Uses occupancy, queue, traffic, special day, vehicle type to compute normalized demand

return clipped price between 5 and 20

**6. Results and Visualizations**

A time-series line plot comparing all models:

* Model 1 shows a stair-step linear rise
* Model 2 is smoother and reacts to multiple signals
* Model 3 slightly adjusts Model 2 based on overcapacity

**Insights:**

* Dynamic pricing can prevent overcrowding without overpricing
* Traffic congestion and event awareness make pricing more robust

**7. Conclusion**

This pricing engine combines basic economic theory with real-time analytics. It adapts to demand, smooths user experience, and increases operational efficiency for parking administrators.

**Benefits:**

* Better space utilization
* Event-sensitive responsiveness
* Expandable to city-wide network

**Future Scope:**

* Integrate real-time maps and payment APIs
* Multi-lot rerouting suggestions using geolocation
* Learning models to predict demand trends

**8. Team & Tools**

* **Tools Used:** Python, Pandas, NumPy, Matplotlib, Pathway, Bokeh
* **Environment:** Google Colab
* **Submitted by:** Sakshi Bhardwaj
* **Institution:** Noida Institute Of Engineering and Technology