Dynamic Pricing for Urban Parking Lots

Capstone Project of Summer Analytics 2025 hosted by Consulting & Analytics Club × Pathway

Introduction

This presentation discusses the implementation of a dynamic pricing system for urban parking lots. It aims to address the challenges of static pricing, which can lead to either underuse or overcrowding. The objective is to maximize space utilization and establish equitable pricing based on real-time demand factors.

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Dataset Overview

Data was collected from 14 parking spots over 73 days.
Each day includes 18 time points with 30-minute intervals from 8:00 AM to 4:30 PM.
Key features include Parking Lot ID, Latitude, Longitude, Occupancy, Capacity, Queue Length, Nearby Traffic Conditions, Special Day Indicator, and Vehicle Type.

Feature Engineering

Occupancy rate calculated as Occupancy divided by Capacity.
Queue Normalization scales queue length between 0 and 1.
Traffic Encoding uses a numeric scale for traffic levels: low (1), medium (2), high (3).
Vehicle weighting: Cars are weighted at 1.0; Bikes at 0.5.
Datetime parsing combines date and time into a usable timestamp.

Pricing Models

- Model 1: Baseline Linear Model
- The Baseline Linear Model serves as a fundamental tool in the pricing framework, enabling operators to quantify their pricing strategies based on historical data and trends.
- This model not only establishes a clear pricing structure but also aids in customer expectations, as consumers can easily anticipate changes in parking fees based on occupancy rates.

- Model 2: Demand-Based Price Function
- In the Demand Based Pricing model, various data points are analyzed, including seasonal trends, local events, and even traffic patterns, which collectively influence consumer demand and thus pricing strategies.

- To maximize profit, this model may introduce peak pricing during high-demand hours, while offering discounts during off-peak times to encourage usage when demand is lower.

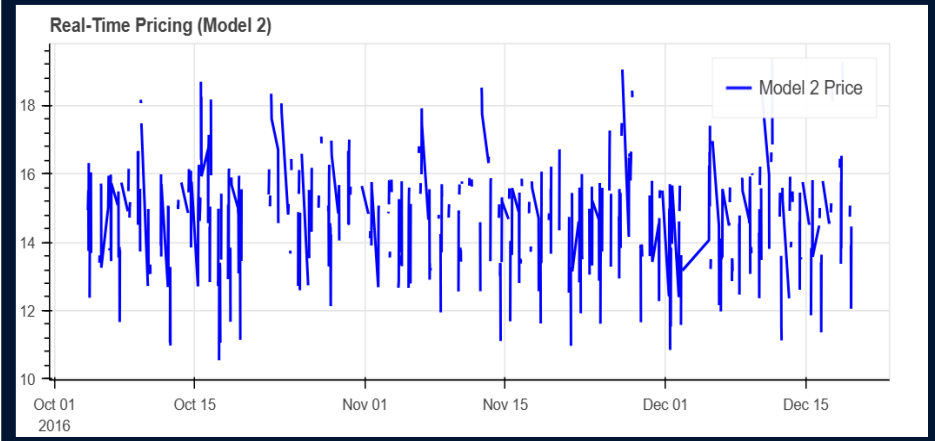
- Model 3 : Competitive Pricing Mode
- The Competitive Pricing Model not only monitors nearby parking rates but also analyzes occupancy levels and customer behavior to refine its pricing approach, keeping prices competitive.
- With these dynamic pricing strategies, operators can implement strategic marketing campaigns to attract customers, such as targeted advertisements or loyalty rewards for frequent users.

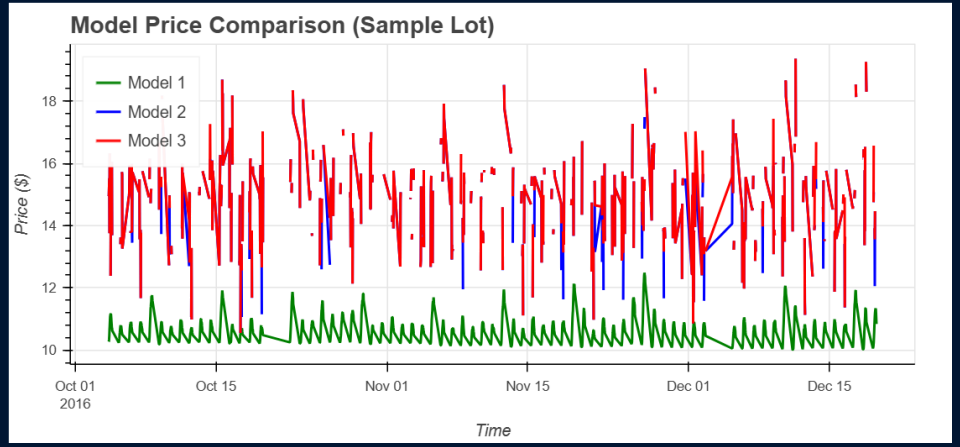
Real-Time Simulations

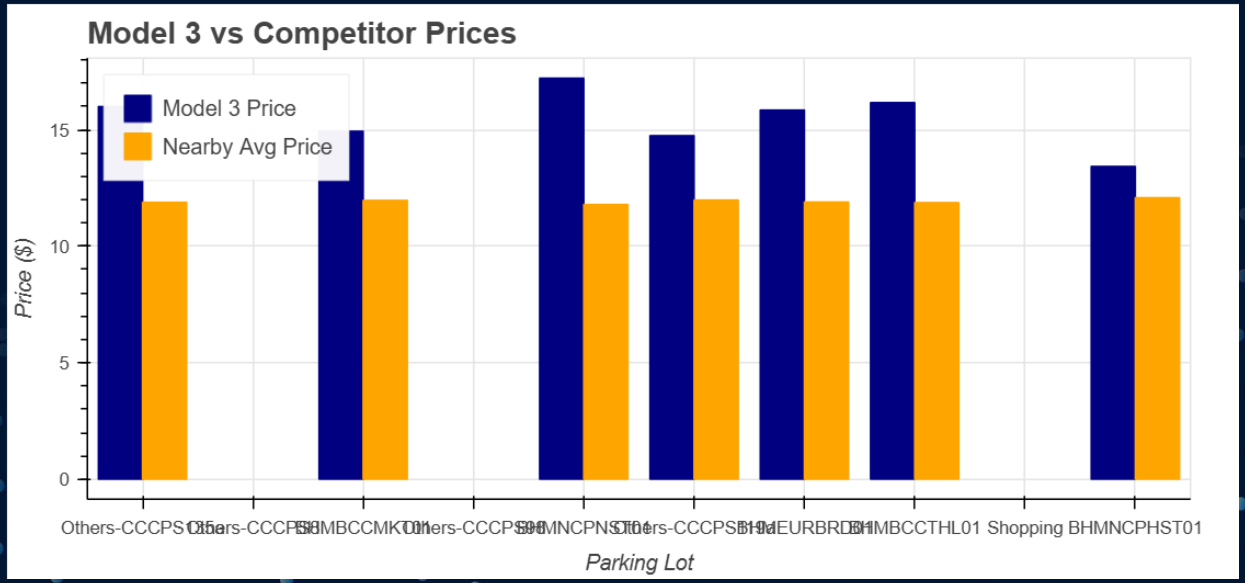
Pathway was employed to simulate real-time data streaming.
Row-by-row data streaming ensures the order of timestamps is preserved.
A user-defined function was developed to calculate prices in real time using Pathway's streaming logic.

Visualization

Time-Series Plots illustrate pricing trends for each model.
Comparison Charts display performance between models 1, 2, and 3.
Competitor Bars allow evaluation of one’s prices against those of adjacent lots simultaneously.


Real-Time Pricing (Model 2)
Model 2 Price
18
16
14
12
10
Oct 01
2016
Oct 15
Nov 01
Nov 15
Dec 01
Dec 15


Model Price Comparison (Sample Lot)
Model 1
Model 2
Model 3
Price ($)
18
16
14
12
10
Oct 01
2016
Oct 15
Nov 01
Nov 15
Dec 01
Dec 15
Time


Model 3 vs Competitor Prices
Model 3 Price
Nearby Avg Price
Price ($)
15
10
5
0
Others-CCCPS135
BHMBCCMKT01
Others-CCCPS98
BHMNCPNST01
Others-CCCPS194
BHMBCCTHL01
Shopping BHMNCPHST01
Parking Lot

Assumptions

Demand weights (α, β, etc.) were selected based on feature relevance.
The Special Day can be marked as either 1 (yes) or 0 (no).
Vehicle types were categorized into two groups for analysis.

Conclusion

The project successfully demonstrates a dynamic pricing system that effectively responds to changing market conditions and competition. It ensures price fairness and stability while providing a scalable framework for practical implementation.

Thank you!

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