Dynamic Pricing for Urban Parking Lots

```
!pip install pathway bokeh --quiet # This cell may take a few seconds to execute.
```

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ERROR: pip's dependency resolver does not currently take into account all the package
bigframes 2.8.0 requires google-cloud-bigquery[bqstorage,pandas]>=3.31.0, but you hav
```

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import datetime
from datetime import datetime
import pathway as pw
import bokeh.plotting
import panel as pn
```

```
url = "https://drive.google.com/uc?id=1D479FLjp9aO3Mg8g6Lpj9oRViWacurA6"
```

```
df = pd.read_csv(url)
df
```

```
# You can find the sample dataset here: https://drive.google.com/file/d/1D479FLjp9aO3Mg8g
```

	Unnamed: 0	SystemCodeNumber	Capacity	Occupancy	LastUpdatedDate	LastUpdatedTi
0	0	BHMBCCMKT01	577	61	04-10-2016	07:59:
1	1	BHMBCCMKT01	577	64	04-10-2016	08:25:
2	2	BHMBCCMKT01	577	80	04-10-2016	08:59:
3	3	BHMBCCMKT01	577	107	04-10-2016	09:32:
4	4	BHMBCCMKT01	577	150	04-10-2016	09:59:
...	...	...	...	...	...	
1307	1307	BHMBCCMKT01	577	309	19-12-2016	14:30:
1308	1308	BHMBCCMKT01	577	300	19-12-2016	15:03:
1309	1309	BHMBCCMKT01	577	274	19-12-2016	15:29:
1310	1310	BHMBCCMKT01	577	230	19-12-2016	16:03:
1311	1311	BHMBCCMKT01	577	193	19-12-2016	16:30:

1312 rows × 12 columns

Preprocessing the Data

```
# Combine the 'LastUpdatedDate' and 'LastUpdatedTime' columns into a single datetime colu
df['Timestamp'] = pd.to_datetime(df['LastUpdatedDate'] + ' ' + df['LastUpdatedTime'],
                                  format='%d-%m-%Y %H:%M:%S')

# Sort the DataFrame by the new 'Timestamp' column and reset the index
df = df.sort_values('Timestamp').reset_index(drop=True)
```

```
# Save the selected columns to a CSV file for streaming or downstream processing
df[["Timestamp", "Occupancy", "Capacity"]].to_csv("parking_stream.csv", index=False)

# Note: Only three features are used here for simplicity.
# Participants are expected to incorporate additional relevant features in their models.
```

```
# Define the schema for the streaming data using Pathway
# This schema specifies the expected structure of each data row in the stream

class ParkingSchema(pw.Schema):
    Timestamp: str   # Timestamp of the observation (should ideally be in ISO format)
    Occupancy: int   # Number of occupied parking spots
    Capacity: int    # Total parking capacity at the location



# Load the data as a simulated stream using Pathway's replay_csv function
# This replays the CSV data at a controlled input rate to mimic real-time streaming
# input_rate=1000 means approximately 1000 rows per second will be ingested into the stre

data = pw.demo.replay_csv("parking_stream.csv", schema=ParkingSchema, input_rate=1000)


# Define the datetime format to parse the 'Timestamp' column
fmt = "%Y-%m-%d %H:%M:%S"

# Add new columns to the data stream:
# - 't' contains the parsed full datetime
# - 'day' extracts the date part and resets the time to midnight (useful for day-level ag
data_with_time = data.with_columns(
    t = data.Timestamp.dt.strptime(fmt),
    day = data.Timestamp.dt.strptime(fmt).dt.strftime("%Y-%m-%dT00:00:00")
)
```

Model 1 - Baseline Linear Model

```
# STEP 2: Your Capstone Code Starts Here
import pathway as pw
from pathway.io.csv import read, write

# Define your schema (modern version uses Python types)
class ParkingSchema(pw.Schema):
    Timestamp: str
    Occupancy: int
    Capacity: int

# STEP 4: Load the CSV as a stream (replace with your real file if needed)
source = read(
    "parking_stream.csv",  # your CSV file
    schema=ParkingSchema,
    mode="streaming",       # treat as real-time stream
    autocommit_duration_ms=1000,
)

# STEP 5: Model 1 Pricing Logic (baseline)
@pw.udf
def model1_price(occupancy, capacity):
    base_price = 10
    base_price = 10
    alpha = 0.2
    price = base_price + alpha * (occupancy / capacity)
    return round(min(max(price, 5), 20), 2)  # clamp price between $5 and $20

# STEP 6: Apply pricing
result = source.select(
    Timestamp = source.Timestamp,
    Occupancy = source.Occupancy,
    Capacity = source.Capacity,
    Price = model1_price(source.Occupancy, source.Capacity)
)

# STEP 7: Write to output CSV
write(result, "final_prices.csv")

# STEP 8: Execute
pw.run()
```

```
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```

```
import pandas as pd
import matplotlib.pyplot as plt

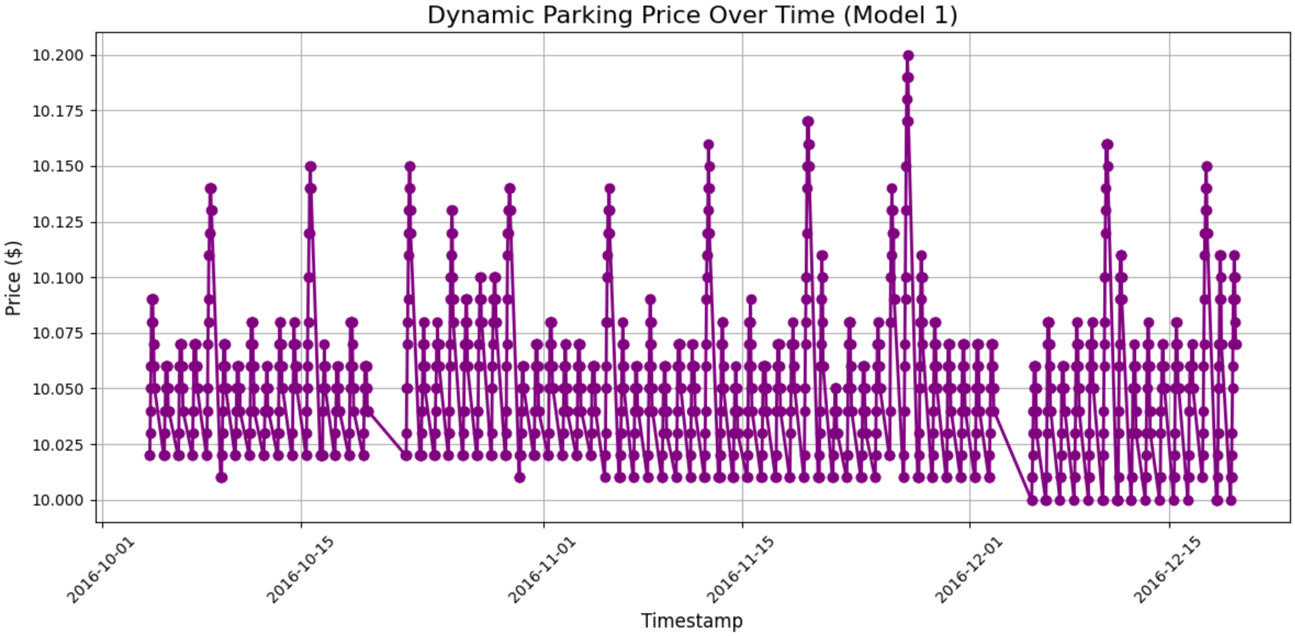
# Load the CSV that was generated earlier
df = pd.read_csv("final_prices.csv")

# Convert Timestamp to datetime (if not already)
```

```
df["Timestamp"] = pd.to_datetime(df["Timestamp"])

# Sort by Timestamp for plotting
df = df.sort_values("Timestamp")

# Plotting
plt.figure(figsize=(12, 6))
plt.plot(df["Timestamp"], df["Price"], marker="o", color="purple", linewidth=2)
plt.title("Dynamic Parking Price Over Time (Model 1)", fontsize=16)
plt.xlabel("Timestamp", fontsize=12)
plt.ylabel("Price ($)", fontsize=12)
plt.grid(True)
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



Model 2: Demand-Based Price Function

Model 2 - Demand-Based Price Function

```
import pandas as pd
import random

df = pd.read_csv("parking_stream.csv")

# Fill with sample data
df["QueueLength"] = [random.randint(0, 5) for _ in range(len(df))]
df["Traffic"] = [round(random.uniform(0.2, 1.0), 2) for _ in range(len(df))]
df["IsSpecialDay"] = [random.choice([0, 1]) for _ in range(len(df))]
df["VehicleType"] = [random.choice(["car", "bike", "truck"]) for _ in range(len(df))]

# Overwrite CSV
df.to_csv("parking_stream.csv", index=False)
```

```
    /usr/local/lib/python3.11/dist-packages/pathway/internals/graph_runner/__init__.py
```

```
# ✅ Step 1: Clean Model 2 Implementation
import pathway as pw
from pathway.io.csv import read, write

# Define schema for extended CSV
class ParkingSchema(pw.Schema):
    Timestamp: str
    Occupancy: int
    Capacity: int
    QueueLength: int
    Traffic: float
    IsSpecialDay: int
    VehicleType: str

# Stream data from the prepared CSV
source = read(
    "parking_stream.csv",
    schema=ParkingSchema,
    mode="streaming",
    autocommit_duration_ms=1000,
)

# Vehicle type weights
vehicle_weights = {
    "car": 1.0,
    "bike": 0.5,
    "truck": 1.5
}

# Model 2 Pricing Logic
@pw.udf
def model2_price(occupancy, capacity, queue, traffic, special, vehicle):
```

```
def model2_price(occupancy, capacity, queue, traffic, special, vehicle):
    alpha, beta, gamma, delta, epsilon = 0.4, 0.3, 0.2, 0.2, 0.5
    base_price = 10.0

    if capacity == 0:
        return base_price

    vt_weight = vehicle_weights.get(vehicle.lower(), 1.0)

    demand = (
        alpha * (occupancy / capacity) +
        beta * queue -
        gamma * traffic +
        delta * special +
        epsilon * vt_weight
    )

    price = base_price * (1 + 0.1 * demand)
    return round(min(max(price, 5), 20), 2)  # Clamp between $5 and $20

# Generate result table
result = source.select(
    Timestamp=source.Timestamp,
    Occupancy=source.Occupancy,
    Capacity=source.Capacity,
    Price=model2_price(
        source.Occupancy,
        source.Capacity,
        source.QueueLength,
        source.Traffic,
        source.IsSpecialDay,
        source.VehicleType,
    )
)

# Export to CSV
write(result, "final_prices.csv")

# Execute pipeline
pw.run()
```

```
                                     PATHWAY PROGRESS DASHBOARD

                       no.                                                latency
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between the time when the c
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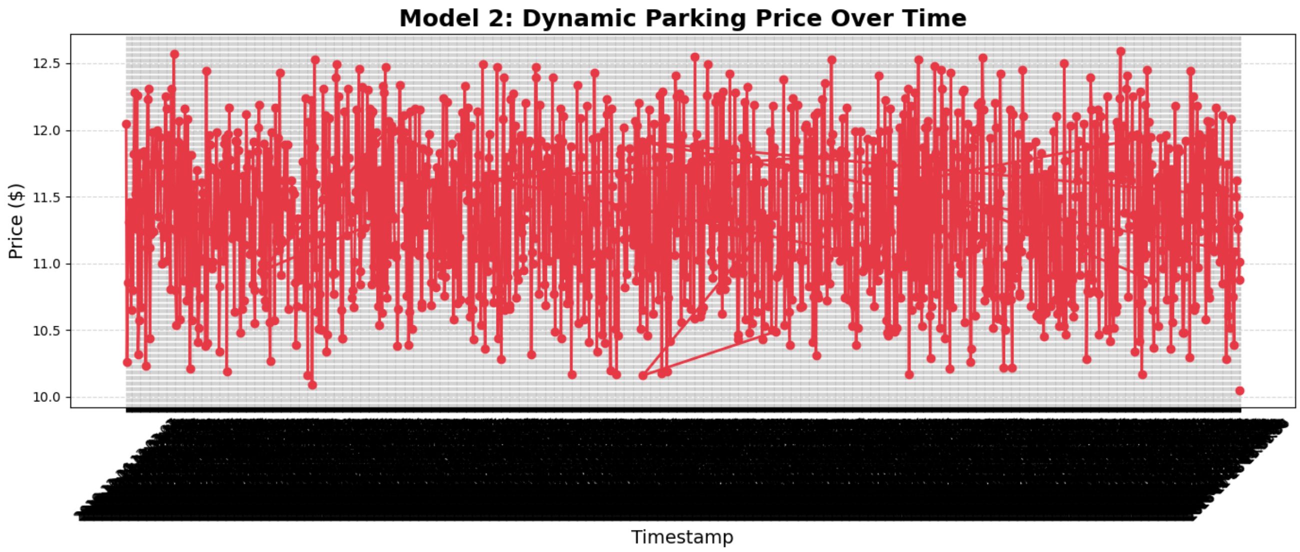
```
import matplotlib.pyplot as plt

plt.figure(figsize=(14, 6))
plt.plot(df["Timestamp"], df["Price"], color="#E63946", marker="o", linewidth=2)

plt.title("Model 2: Dynamic Parking Price Over Time", fontsize=18, fontweight='bold')
plt.xlabel("Timestamp", fontsize=14)
plt.ylabel("Price ($)", fontsize=14)

plt.grid(True, linestyle='--', alpha=0.5)
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```


Model 2: Dynamic Parking Price Over Time
Price ($)
Timestamp