```
import pandas as pd
import numpy as np


# Step 1: Load and Explore Dataset
df = pd.read_csv('dataset.csv')
print("Shape of the dataset:", df.shape)
print("\nColumn names:\n", df.columns.tolist())
print("\nData Types:\n", df.dtypes)
print("\nFirst few rows:")
display(df.head())
```

```
Shape of the dataset: (18368, 12)

Column names:
 ['ID', 'SystemCodeNumber', 'Capacity', 'Latitude', 'Longitude', 'Occupancy', 'VehicleType', 'TrafficConditionNea

Data Types:
 ID                           int64
SystemCodeNumber           object
Capacity                    int64
Latitude                  float64
Longitude                 float64
Occupancy                   int64
VehicleType                object
TrafficConditionNearby     object
QueueLength                 int64
IsSpecialDay                int64
LastUpdatedDate            object
LastUpdatedTime            object
dtype: object

First few rows:
```

	ID	SystemCodeNumber	Capacity	Latitude	Longitude	Occupancy	VehicleType	TrafficConditionNearby	QueueLeng
0	0	BHMBCCMKT01	577	26.144536	91.736172	61	car	low	
1	1	BHMBCCMKT01	577	26.144536	91.736172	64	car	low	
2	2	BHMBCCMKT01	577	26.144536	91.736172	80	car	low	
3	3	BHMBCCMKT01	577	26.144536	91.736172	107	car	low	
4	4	BHMBCCMKT01	577	26.144536	91.736172	150	bike	low	

```
# Check for missing values
print("\nMissing values per column:")
print(df.isnull().sum())
```

```
Missing values per column:
ID                        0
SystemCodeNumber          0
Capacity                  0
Latitude                  0
Longitude                 0
Occupancy                 0
VehicleType               0
TrafficConditionNearby    0
QueueLength               0
IsSpecialDay              0
LastUpdatedDate           0
LastUpdatedTime           0
dtype: int64
```

***Model 1: Baseline Linear Model

```
A simple model where the next price is a function of the previous price and current
occupancy:
```

• Linear price increase as occupancy increases • Acts as a reference point

Example:

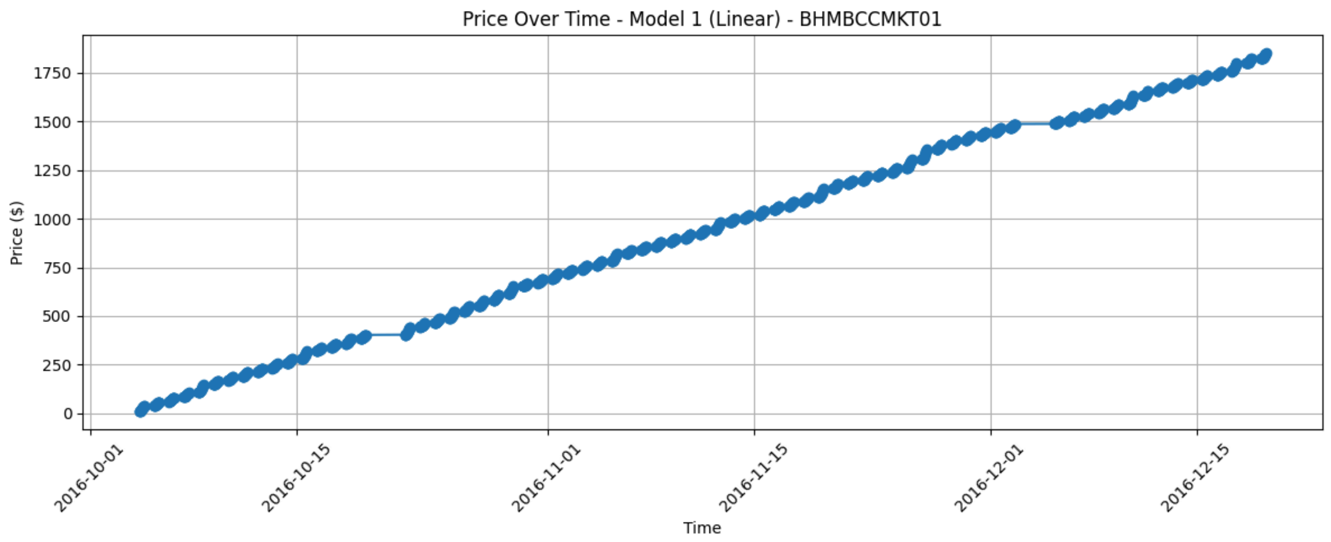
`Price(t+1) = Price(t) + α ·(Occupancy/Capacity)***`

```
# Step 2: Feature Engineering for Model 1

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

# Sort by parking lot and timestamp
df.sort_values(by=['SystemCodeNumber', 'Timestamp'], inplace=True)

# Calculate occupancy rate
df['OccupancyRate'] = df['Occupancy'] / df['Capacity']

# Initialize base price
base_price = 10
alpha = 5  # Price sensitivity to occupancy rate

# Initialize a price column with base price
df['Price_Model1'] = base_price

# Compute price over time for each parking lot
for lot in df['SystemCodeNumber'].unique():
    lot_indices = df[df['SystemCodeNumber'] == lot].index
    for i in range(1, len(lot_indices)):
        prev_idx = lot_indices[i-1]
        curr_idx = lot_indices[i]
        prev_price = df.loc[prev_idx, 'Price_Model1']
        occupancy_rate = df.loc[curr_idx, 'OccupancyRate']

        new_price = prev_price + alpha * occupancy_rate
        df.loc[curr_idx, 'Price_Model1'] = new_price

# Preview results
df[['SystemCodeNumber', 'Timestamp', 'OccupancyRate', 'Price_Model1']].head(10)
```

```
/tmp/ipython-input-5-1994170745.py:29: FutureWarning: Setting an item of incompatible dtype is deprecated and wil
  df.loc[curr_idx, 'Price_Model1'] = new_price
```

	SystemCodeNumber	Timestamp	OccupancyRate	Price_Model1
0	BHMBCCMKT01	2016-10-04 07:59:00	0.105719	10.000000
1	BHMBCCMKT01	2016-10-04 08:25:00	0.110919	10.554593
2	BHMBCCMKT01	2016-10-04 08:59:00	0.138648	11.247834
3	BHMBCCMKT01	2016-10-04 09:32:00	0.185442	12.175043
4	BHMBCCMKT01	2016-10-04 09:59:00	0.259965	13.474870
5	BHMBCCMKT01	2016-10-04 10:26:00	0.306759	15.008666
6	BHMBCCMKT01	2016-10-04 10:59:00	0.379549	16.906412
7	BHMBCCMKT01	2016-10-04 11:25:00	0.428076	19.046794
8	BHMBCCMKT01	2016-10-04 11:59:00	0.448873	21.291161
9	BHMBCCMKT01	2016-10-04 12:29:00	0.461005	23.596187

```
import matplotlib.pyplot as plt

# Choose one parking lot (e.g., first unique one)
sample_lot = df['SystemCodeNumber'].unique()[0]
sample_df = df[df['SystemCodeNumber'] == sample_lot]

# Plot
plt.figure(figsize=(12, 5))
plt.plot(sample_df['Timestamp'], sample_df['Price_Model1'], marker='o', linestyle='-')
plt.title(f'Price Over Time - Model 1 (Linear) - {sample_lot}')
plt.xlabel('Time')
plt.ylabel('Price ($)')
plt.grid(True)
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```

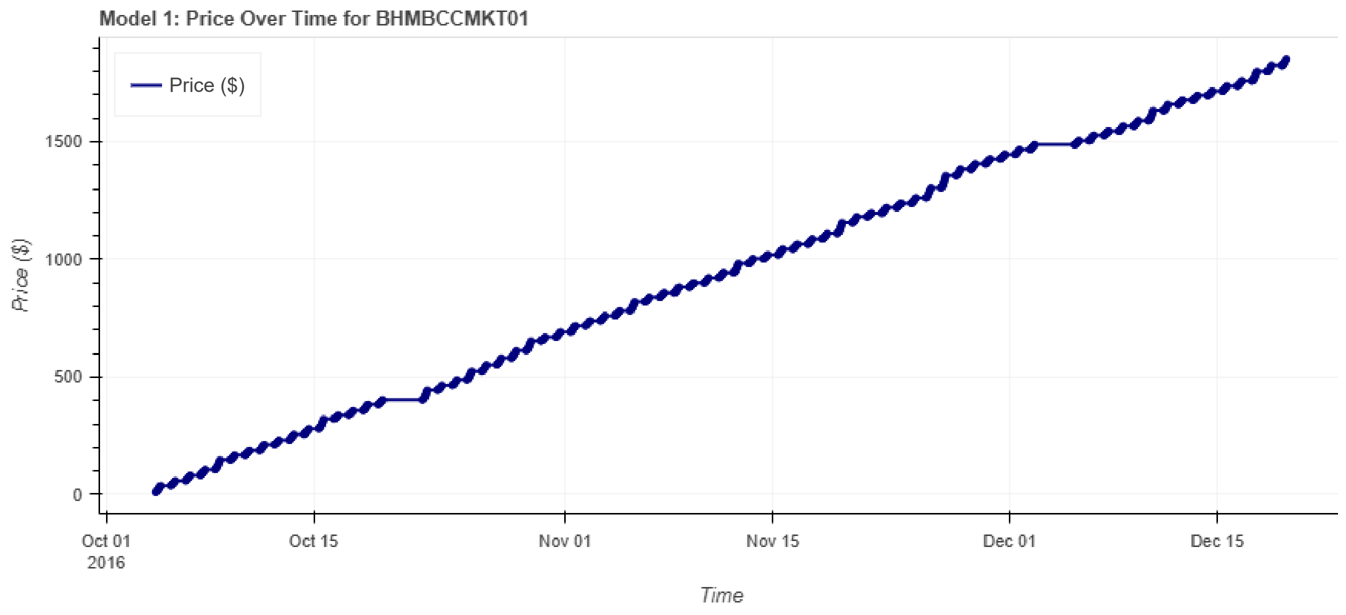


```
print("Price stats for Model 1:")
print("Min Price: $", round(df['Price_Model1'].min(), 2))
print("Max Price: $", round(df['Price_Model1'].max(), 2))
print("Average Price: $", round(df['Price_Model1'].mean(), 2))
```

```
Price stats for Model 1:
Min Price: $ 10.0
Max Price: $ 4896.37
Average Price: $ 1643.02
```

```
from bokeh.plotting import figure, show, output_notebook
from bokeh.models import ColumnDataSource
from bokeh.layouts import layout
from bokeh.models import HoverTool

# Enable inline Bokeh output
output_notebook()

# Select a sample lot (e.g., the first unique one)
sample_lot = df['SystemCodeNumber'].unique()[0]
sample_df = df[df['SystemCodeNumber'] == sample_lot].copy()

# Prepare data source
sample_df['Timestamp_str'] = sample_df['Timestamp'].dt.strftime("%Y-%m-%d %H:%M")
source = ColumnDataSource(sample_df)

# Create Bokeh figure
p = figure(x_axis_type="datetime", title=f"Model 1: Price Over Time for {sample_lot}",
           width=900, height=400, tools="pan,wheel_zoom,box_zoom,reset,hover,save")

# Plot line
p.line(x='Timestamp', y='Price_Model1', source=source, line_width=2, color='navy', legend_label='Price ($)')
p.circle(x='Timestamp', y='Price_Model1', source=source, size=4, color='navy', alpha=0.6)

# Hover tool
hover = p.select(dict(type=HoverTool))
hover.tooltips = [
    ("Time", "@Timestamp_str"),
    ("Price", "@Price_Model1{$0.00}"),
    ("Occupancy Rate", "@OccupancyRate{0.00}")
]

# Aesthetic settings
p.xaxis.axis_label = "Time"
p.yaxis.axis_label = "Price ($)"
p.legend.location = "top_left"
p.grid.grid_line_alpha = 0.3

# Show plot
show(p)
```

```
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
```



***Model 2: Demand-Based Price Function

A more advanced model where you: • Construct a mathematical demand function using key features:

```
- Occupancy rate
- Queue length
- Traffic level
- Special day
- Vehicle type
```

Example demand function:

$$\text{Demand} = \alpha \cdot \left(\frac{\text{Occupancy}}{\text{Capacity}}\right) + \beta \cdot \text{QueueLength} - \gamma \cdot \text{Traffic} + \delta \cdot \text{IsSpecialDay} + \varepsilon \cdot \text{VehicleTypeWeight}$$

Use this demand value to adjust prices:

$$\text{Price}_t = \text{BasePrice} \cdot (1 + \lambda \cdot \text{NormalizedDemand})$$

```
# Map traffic levels to numeric
traffic_map = {'low': 1, 'medium': 2, 'high': 3}
df['TrafficLevelNum'] = df['TrafficConditionNearby'].map(traffic_map)

# Assign numeric weights to vehicle types
vehicle_weights = {'bike': 0.5, 'car': 1.0, 'truck': 1.5}
df['VehicleWeight'] = df['VehicleType'].map(vehicle_weights)
```

define coefficients:

α = 0.5 (occupancy rate)

β = 0.3 (queue length)

γ = 0.2 (traffic penalty)

δ = 0.5 (special day bonus)

ε = 0.7 (vehicle type influence)

```python
# Define coefficients
a, b, c, d, e = 0.5, 0.3, 0.2, 0.5, 0.7

# Raw demand calculation
df['DemandRaw'] = (
    a * df['OccupancyRate'] +
    b * df['QueueLength'] -
    c * df['TrafficLevelNum'] +
    d * df['IsSpecialDay'] +
    e * df['VehicleWeight']
)
```

Normalize Demand & Set Price

```python
# Normalize demand to [0, 1]
dmin, dmax = df['DemandRaw'].min(), df['DemandRaw'].max()
df['DemandNorm'] = (df['DemandRaw'] - dmin) / (dmax - dmin)

# Define lambda for price sensitivity
lambda_val = 1.0

# Calculate demand-based price (bounded)
df['Price_Model2'] = 10 * (1 + lambda_val * df['DemandNorm'])
df['Price_Model2'] = df['Price_Model2'].clip(lower=5, upper=20)
```

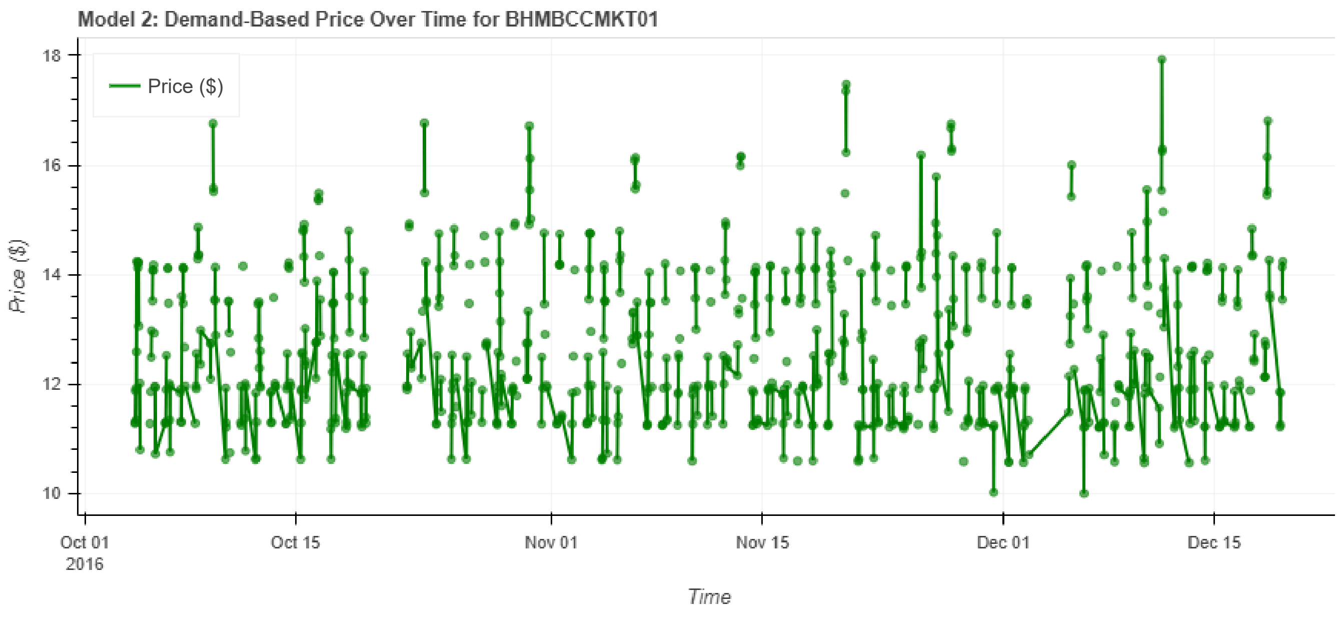
***Interactive Bokeh Plot for Model 2

plot Price_Model2 over time for the same parking lot

```python
from bokeh.plotting import figure, show, output_notebook
from bokeh.models import ColumnDataSource, HoverTool

# Enable Bokeh in notebook
output_notebook()

# Filter the same parking lot as before
sample_lot = df['SystemCodeNumber'].unique()[0]
sample_df = df[df['SystemCodeNumber'] == sample_lot].copy()

# Prepare timestamp string for hover
sample_df['Timestamp_str'] = sample_df['Timestamp'].dt.strftime("%Y-%m-%d %H:%M")

# Prepare data source
source = ColumnDataSource(sample_df)

# Create Bokeh plot
```

```
p2 = figure(x_axis_type="datetime", title=f"Model 2: Demand-Based Price Over Time for {sample_lot}",
           width=900, height=400, tools="pan,wheel_zoom,box_zoom,reset,hover,save")

# Plot line and circles
p2.line(x='Timestamp', y='Price_Model2', source=source, line_width=2, color='green', legend_label='Price ($)')
p2.circle(x='Timestamp', y='Price_Model2', source=source, size=5, color='green', alpha=0.6)

# Hover tool
hover2 = p2.select(dict(type=HoverTool))
hover2.tooltips = [
    ("Time", "@Timestamp_str"),
    ("Price", "@Price_Model2{$0.00}"),
    ("Demand (normalized)", "@DemandNorm{0.00}")
]

# Axis labels and styling
p2.xaxis.axis_label = "Time"
p2.yaxis.axis_label = "Price ($)"
p2.legend.location = "top_left"
p2.grid.grid_line_alpha = 0.3

# Show the plot
show(p2)
```

```
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
```



Model 3 – Competitive Pricing Logic

Extended Model 2 by adding location intelligence:

Nearby parking lots (within 1 km)

Their current price

Adjust price up/down based on competition & occupancy

** Competitive Logic

If lot is full and nearby lots are cheaper → suggest rerouting / reduce price

If nearby lots are expensive or full → increase your price
**

Haversine Function to Compute Proximity

```
# Haversine distance in km
def haversine(lat1, lon1, lat2, lon2):
    R = 6371  # Earth radius (km)
    phi1, phi2 = np.radians(lat1), np.radians(lat2)
    d_phi = np.radians(lat2 - lat1)
    d_lambda = np.radians(lon2 - lon1)

    a = np.sin(d_phi/2)**2 + np.cos(phi1)*np.cos(phi2)*np.sin(d_lambda/2)**2
    return R * 2 * np.arcsin(np.sqrt(a))
```

Compute Nearby Lot Prices at Each Time

```
# Copy model 2 price
df['Price_Model3'] = df['Price_Model2']  # initialize from demand-based price
df['SuggestReroute'] = 0  # 1 if we suggest rerouting

# Group by time
for timestamp in df['Timestamp'].unique():
    snapshot = df[df['Timestamp'] == timestamp].copy()  # <--- Fix here

    for idx, row in snapshot.iterrows():
        lot_lat, lot_lon = row['Latitude'], row['Longitude']
        lot_price = row['Price_Model2']
        lot_occ = row['Occupancy']
        lot_cap = row['Capacity']

        snapshot['Distance'] = snapshot.apply(
            lambda r: haversine(lot_lat, lot_lon, r['Latitude'], r['Longitude']), axis=1)

        nearby = snapshot[(snapshot['SystemCodeNumber'] != row['SystemCodeNumber']) & (snapshot['Distance'] < 1)]

        if len(nearby) > 0:
            nearby_prices = nearby['Price_Model2']
            nearby_occ_rates = nearby['Occupancy'] / nearby['Capacity']

            avg_nearby_price = nearby_prices.mean()
            avg_nearby_occ = nearby_occ_rates.mean()

            # Pricing logic
            if (lot_occ / lot_cap) >= 0.9 and avg_nearby_price < lot_price:
                df.loc[idx, 'Price_Model3'] = max(5, lot_price - 2)
                df.loc[idx, 'SuggestReroute'] = 1
            elif avg_nearby_occ > 0.9 and avg_nearby_price > lot_price:
                df.loc[idx, 'Price_Model3'] = min(20, lot_price + 2)
```

Bokeh Plot for Model 3 with Rerouting Highlights

Plot price over time

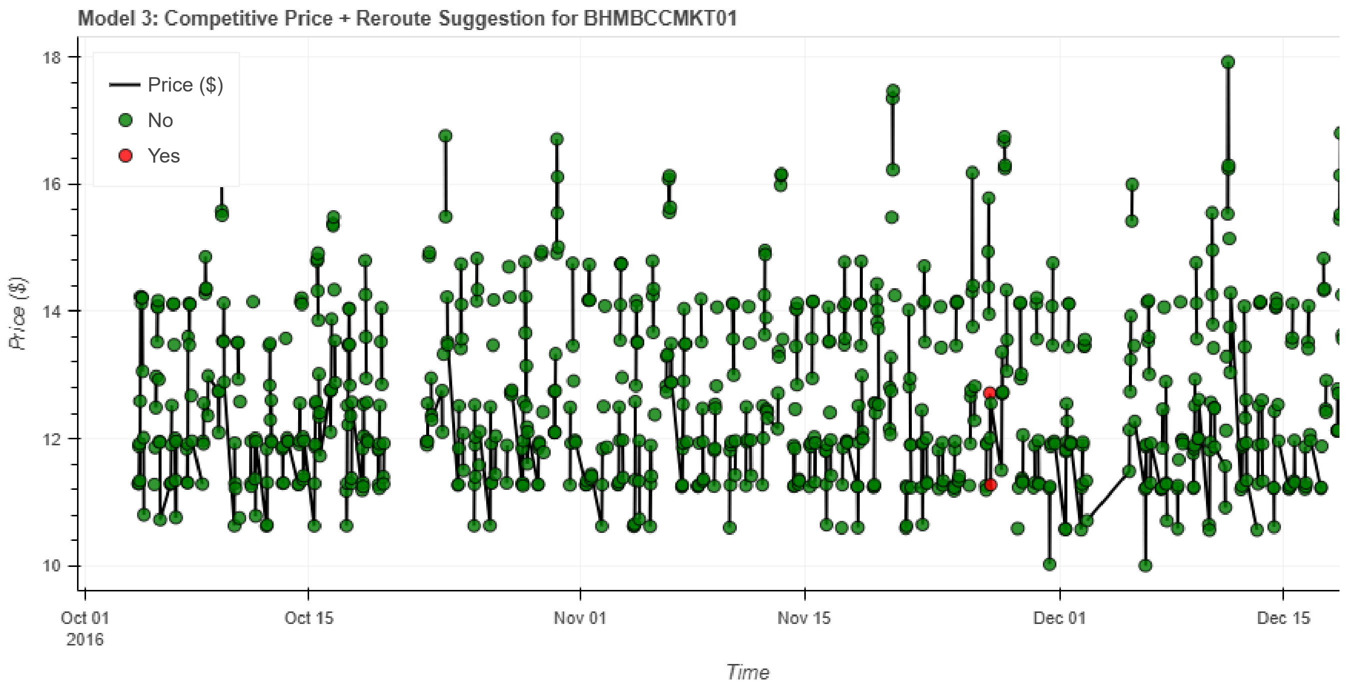
Using circle color for rerouting suggestion:

🔴 Red → Reroute suggested

🟢 Green → No reroute

```
from bokeh.plotting import figure, show, output_notebook
from bokeh.models import ColumnDataSource, HoverTool
from bokeh.transform import factor_cmap

output_notebook()

# Refresh sample lot
sample_lot = df['SystemCodeNumber'].unique()[0]
sample_df = df[df['SystemCodeNumber'] == sample_lot].copy()
sample_df['Timestamp_str'] = sample_df['Timestamp'].dt.strftime("%Y-%m-%d %H:%M")

# Label rerouting as "Yes"/"No"
sample_df['Reroute'] = sample_df['SuggestReroute'].apply(lambda x: "Yes" if x == 1 else "No")

# Create data source
source = ColumnDataSource(sample_df)

# Color map: red if reroute suggested, green otherwise
reroute_colors = factor_cmap('Reroute',
                             palette=['green', 'red'],
                             factors=['No', 'Yes'])

# Create figure
p3 = figure(x_axis_type="datetime", title=f"Model 3: Competitive Price + Reroute Suggestion for {sample_lot}",
            width=950, height=450, tools="pan,wheel_zoom,box_zoom,reset,hover,save")

# Line for base price evolution
p3.line(x='Timestamp', y='Price_Model3', source=source, line_width=2, color='black', legend_label='Price ($)')

# Colored circle markers for reroute suggestion
p3.circle(x='Timestamp', y='Price_Model3', source=source, size=8,
          fill_color=reroute_colors, line_color='black', alpha=0.8, legend_field='Reroute')

# Hover tool
hover = p3.select(dict(type=HoverTool))
hover.tooltips = [
    ("Time", "@Timestamp_str"),
    ("Price", "@Price_Model3{$0.00}"),
    ("Suggest Reroute", "@Reroute"),
    ("Occupancy Rate", "@OccupancyRate{0.00}"),
]

# Styling
p3.xaxis.axis_label = "Time"
p3.yaxis.axis_label = "Price ($)"
p3.legend.location = "top_left"
p3.grid.grid_line_alpha = 0.3

# Show plot
show(p3)
```

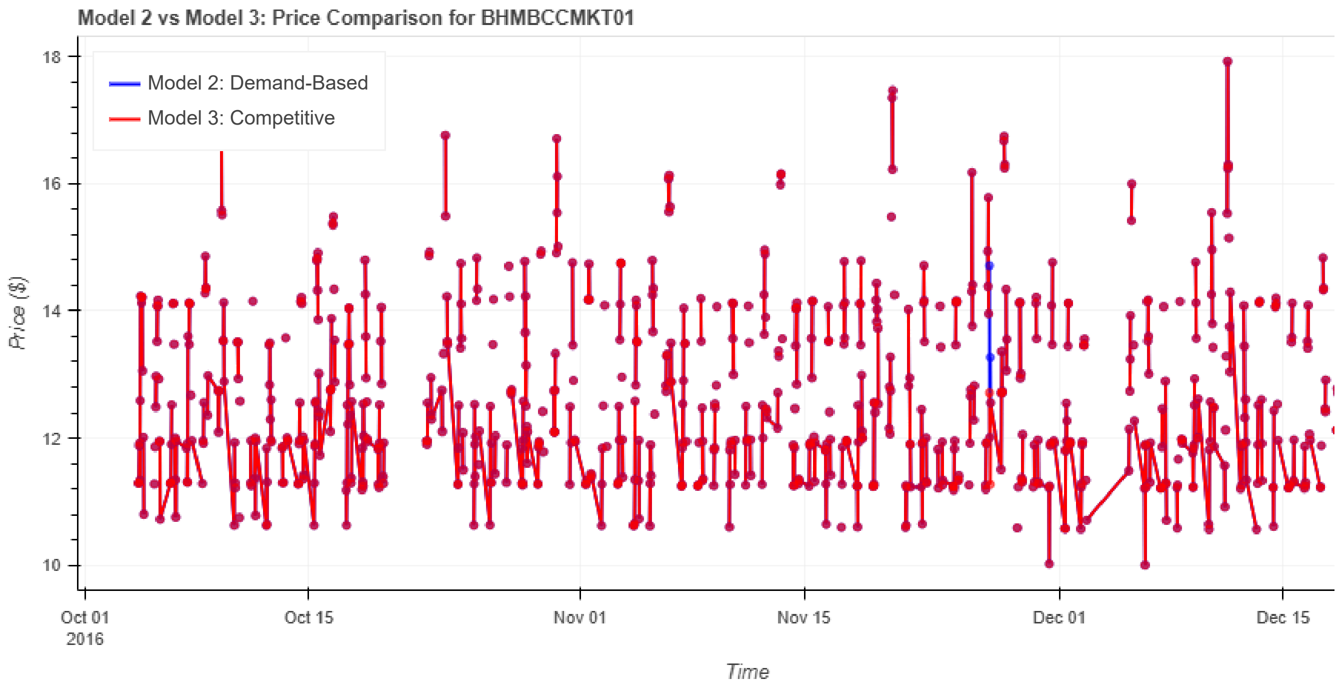
```
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
```



```
Comparison Plot: Model 2 vs Model 3 Pricing Over Time:
```

```python
from bokeh.plotting import figure, show, output_notebook
from bokeh.models import ColumnDataSource, HoverTool

output_notebook()

# Filter same parking lot
sample_lot = df['SystemCodeNumber'].unique()[0]
sample_df = df[df['SystemCodeNumber'] == sample_lot].copy()
sample_df['Timestamp_str'] = sample_df['Timestamp'].dt.strftime("%Y-%m-%d %H:%M")

# Create source
source = ColumnDataSource(sample_df)

# Create plot
p_compare = figure(x_axis_type="datetime", title=f"Model 2 vs Model 3: Price Comparison for {sample_lot}",
                   width=950, height=450, tools="pan,wheel_zoom,box_zoom,reset,hover,save")

# Model 2 line (Demand-Based)
p_compare.line(x='Timestamp', y='Price_Model2', source=source, line_width=2,
               color='blue', legend_label='Model 2: Demand-Based')

# Model 3 line (Competitive)
p_compare.line(x='Timestamp', y='Price_Model3', source=source, line_width=2,
               color='red', legend_label='Model 3: Competitive')

# Add dots for better visibility
p_compare.circle(x='Timestamp', y='Price_Model2', source=source, size=5,
                 color='blue', alpha=0.6)
p_compare.circle(x='Timestamp', y='Price_Model3', source=source, size=5,
                 color='red', alpha=0.6)

# Hover tool
hover = p_compare.select(dict(type=HoverTool))
hover.tooltips = [
    ("Time", "@Timestamp_str"),
    ("Price M2", "@Price_Model2{$0.00}"),
    ("Price M3", "@Price_Model3{$0.00}"),
    ("Occupancy", "@Occupancy"),
    ("Reroute", "@SuggestReroute"),
]

# Styling
p_compare.xaxis.axis_label = "Time"
p_compare.yaxis.axis_label = "Price ($)"
p_compare.legend.location = "top_left"
p_compare.grid.grid_line_alpha = 0.3

# Show
show(p_compare)
```

```
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
```



```
Blue line: Demand-based pricing

Red line: Competitive-aware adjustments

Dips in red line when reroute is suggested

Red spikes where neighboring lots are full
```

```
!pip install pathway
```

Show hidden output

```
@pw.udf(return_type=float)
def haversine(lat1, lon1, lat2, lon2):
    R = 6371
    phi1, phi2 = np.radians(lat1), np.radians(lat2)
    d_phi = np.radians(lat2 - lat1)
    d_lambda = np.radians(lon2 - lon1)
    a = np.sin(d_phi / 2)**2 + np.cos(phi1) * np.cos(phi2) * np.sin(d_lambda / 2)**2
    return R * 2 * np.arcsin(np.sqrt(a))
```

```
import pandas as pd
import pathway as pw
```

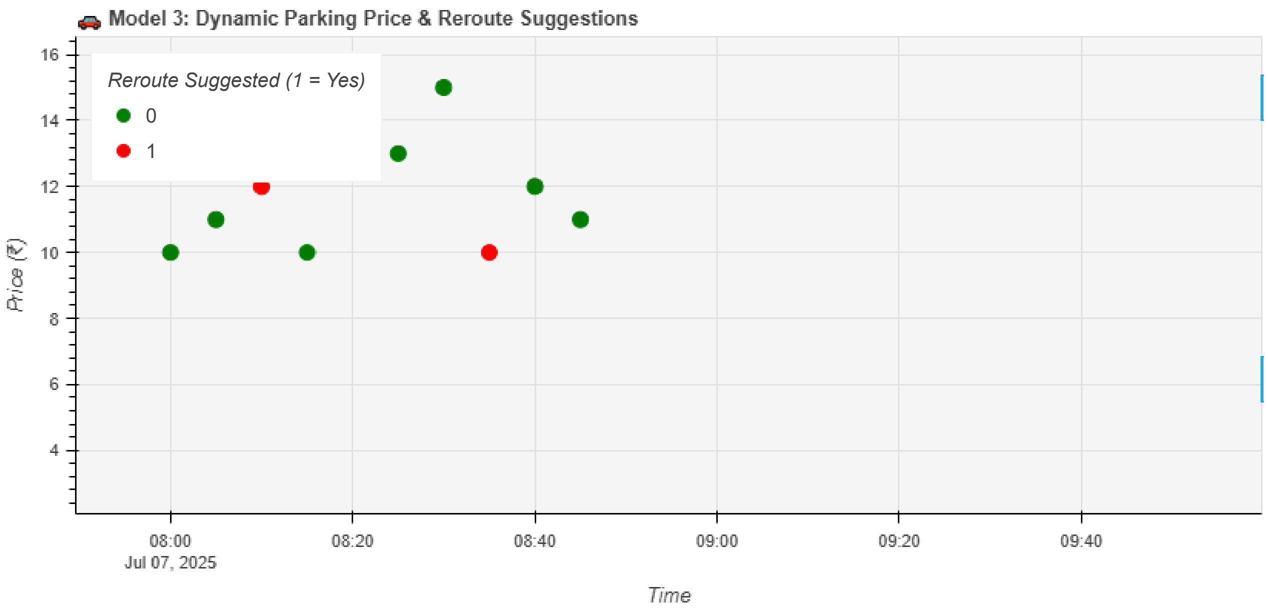
```
from pathway.internals.dtype import DATE_TIME_NAIVE
import numpy as np

# --- Step 1: Preprocess Data ---------------------------------
df['Timestamp'] = pd.to_datetime(
    df['LastUpdatedDate'] + ' ' + df['LastUpdatedTime'],
    format='%d-%m-%Y %H:%M:%S'
)
df['ID'] = df['ID'].astype(str)

# --- Step 2: Schema ------------------------------------------
class ParkingLot(pw.Schema):
    ID: str
    SystemCodeNumber: str
    Capacity: int
    Latitude: float
    Longitude: float
    Occupancy: int
    VehicleType: str
    TrafficConditionNearby: str
    QueueLength: int
    IsSpecialDay: int
    Timestamp: DATE_TIME_NAIVE
    Price_Model2: float

# --- Step 3: ConnectorSubject --------------------------------
class ParkingSubject(pw.io.python.ConnectorSubject):
    def __init__(self, df):
        super().__init__()
        self.df = df.sort_values('Timestamp')
    def run(self):
        for _, row in self.df.iterrows():
            self.next(
                ID=str(row['ID']),
                SystemCodeNumber=row['SystemCodeNumber'],
                Capacity=int(row['Capacity']),
                Latitude=float(row['Latitude']),
                Longitude=float(row['Longitude']),
                Occupancy=int(row['Occupancy']),
                VehicleType=row['VehicleType'],
                TrafficConditionNearby=row['TrafficConditionNearby'],
                QueueLength=int(row['QueueLength']),
                IsSpecialDay=int(row['IsSpecialDay']),
                Timestamp=row['Timestamp'],
                Price_Model2=float(row['Price_Model2'])
            )
        self.close()

# --- Step 4: Read stream -------------------------------------
stream = pw.io.python.read(ParkingSubject(df), schema=ParkingLot)

# --- Step 5: Rename columns in right stream before join -------
stream_reduced = stream.select(
    ID_R=stream.ID,
    Timestamp_R=stream.Timestamp,
    Latitude_R=stream.Latitude,
    Longitude_R=stream.Longitude,
    Capacity_R=stream.Capacity,
    Occupancy_R=stream.Occupancy,
    Price_Model2_R=stream.Price_Model2
)

# --- Step 6: Join streams ------------------------------------
joined = pw.join(stream, stream_reduced)

# --- Step 7: Haversine distance function ----------------------
@pw.udf(return_type=float)
def haversine(lat1, lon1, lat2, lon2):
    R = 6371
    phi1, phi2 = np.radians(lat1), np.radians(lat2)
    d_phi = np.radians(lat2 - lat1)
```

```
        d_lambda = np.radians(lon2 - lon1)
        a = np.sin(d_phi / 2)**2 + np.cos(phi1) * np.cos(phi2) * np.sin(d_lambda / 2)**2
        return R * 2 * np.arcsin(np.sqrt(a))

    # --- Step 8: Filter nearby competitors ------------------------
    nearby = joined.filter(
        (joined["Timestamp"] == joined["Timestamp_R"]) &
        (haversine(
            joined["Latitude"], joined["Longitude"],
            joined["Latitude_R"], joined["Longitude_R"]
        ) < 1)
    )

    # --- Step 9: Convert join to table before group_by ------------

    # --- Step 10: Aggregate competitor stats ----------------------
    # ✅ Step: Select into a real table
    selected = nearby.select(
        ID=joined["ID"],
        Timestamp=joined["Timestamp"],
        SystemCodeNumber=joined["SystemCodeNumber"],
        Price_Model2=joined["Price_Model2"],
        Occupancy=joined["Occupancy"],
        Capacity=joined["Capacity"],
        Price_Model2_R=joined["Price_Model2_R"],
        Occupancy_R=joined["Occupancy_R"],
        Capacity_R=joined["Capacity_R"]
    )

    # 🧠 View what columns exist (for debugging)
    print("Columns:", selected.schema)

    # # ✅ Step: Use .group_by correctly
    agg = selected.group_by("ID").reduce(
        ID=_.ID,
        Time=_.Timestamp,
        Lot=_.SystemCodeNumber,
        SelfPrice=_.Price_Model2,
        SelfOccRate=_.Occupancy / _.Capacity,
        AvgCompPrice=pw.reducers.mean(_.Price_Model2_R),
        AvgCompOccRate=pw.reducers.mean(_.Occupancy_R / _.Capacity_R)
    )


    # # --- Step 11: Model 3 pricing logic ---------------------------
    @pw.udf
    def adjust_price(self_price, self_occ, comp_price, comp_occ):
        if self_occ >= 0.9 and comp_price < self_price:
            return max(5, self_price - 2), 1  # Suggest reroute
        elif comp_occ > 0.9 and comp_price > self_price:
            return min(20, self_price + 2), 0  # Increase price
        return self_price, 0  # No change

    #  Final output -----------------------------------
    final = agg.select(
        ID=agg.ID,
        Lot=agg.Lot,
        Time=agg.Time,
        Price_Model3_and_Reroute=adjust_price(
            agg.SelfPrice,
            agg.SelfOccRate,
            agg.AvgCompPrice,
            agg.AvgCompOccRate
        )
    ).select(
        ID=_.ID,
        Lot=_.Lot,
        Time=_.Time,
        Price_Model3=_.Price_Model3_and_Reroute[0],
        Reroute=_.Price_Model3_and_Reroute[1]
    )
```

```
# --- Step 13: Output to console -------------------------------
pw.io.jsonlines.write(final, "#")
pw.run()
```

```
import pandas as pd
from bokeh.plotting import figure, show, output_file
from bokeh.models import ColumnDataSource, HoverTool

data = {
    'Time': pd.date_range(start='2025-07-07 08:00:00', periods=10, freq='5min'),
    'Price_Model3': [10, 11, 12, 10, 14, 13, 15, 10, 12, 11],
    'Reroute': [0, 0, 1, 0, 1, 0, 0, 1, 0, 0]
}


df_vis = pd.DataFrame(data)
df_vis['Color'] = df_vis['Reroute'].map({0: 'green', 1: 'red'})

source = ColumnDataSource(data=df_vis.to_dict(orient='list'))


p = figure(
    title="🚗 Model 3: Dynamic Parking Price & Reroute Suggestions",
    x_axis_type='datetime',
    x_axis_label='Time',
    y_axis_label='Price (₹)',
    width=850,
    height=400,
    background_fill_color="#f9f9f9"
)


p.circle(
    x='Time', y='Price_Model3',
    size=10, color='Color',
    source=source,
    legend_field='Reroute'
)


hover = HoverTool(tooltips=[
    ("Time", "@Time{%F %T}"),
    ("Price", "@Price_Model3"),
    ("Reroute", "@Reroute")
], formatters={'@Time': 'datetime'})

p.add_tools(hover)

p.legend.title = "Reroute Suggested (1 = Yes)"
p.legend.location = "top_left"

output_file("model3_pricing.html", title="Model 3 Dynamic Pricing")
show(p)
```

```
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
```



Start coding or generate with AI.

Start coding or generate with AI.

```
!pip install pathway panel bokeh pandas numpy --quiet
```

```
import numpy as np
import pandas as pd
from datetime import datetime
import pathway as pw
import panel as pn
from bokeh.plotting import figure
from bokeh.models import ColumnDataSource
pn.extension()
```

```
# Load the original dataset
df = pd.read_csv("/content/dataset.csv")  # Adjust path if needed

# Combine timestamp
df['Timestamp'] = pd.to_datetime(df['LastUpdatedDate'] + ' ' + df['LastUpdatedTime'],
                                 format='%d-%m-%Y %H:%M:%S').astype(str)

# Combine and convert timestamp
df['Timestamp'] = pd.to_datetime(df['LastUpdatedDate'] + ' ' + df['LastUpdatedTime'], errors='coerce')

# Drop rows with invalid timestamps
df = df[df['Timestamp'].notna()]

# Convert to string for Pathway
df['Timestamp'] = df['Timestamp'].astype(str)

# Map categorical fields
traffic_map = {"low": 0, "medium": 1, "high": 2}
vehicle_weight_map = {"car": 1.0, "bike": 0.5, "truck": 1.5}
df['TrafficLevel'] = df['TrafficConditionNearby'].map(traffic_map)
df['VehicleWeight'] = df['VehicleType'].map(vehicle_weight_map)

# Clean all numeric fields and cast to string (Pathway-safe)
```

```
numeric_columns = ['Capacity', 'Occupancy', 'QueueLength', 'IsSpecialDay', 'TrafficLevel']
for col in numeric_columns:
    df[col] = pd.to_numeric(df[col], errors='coerce').fillna(0).astype(int).astype(str)

df['Latitude'] = pd.to_numeric(df['Latitude'], errors='coerce').fillna(0).astype(float).astype(str)
df['Longitude'] = pd.to_numeric(df['Longitude'], errors='coerce').fillna(0).astype(float).astype(str)
df['VehicleWeight'] = df['VehicleWeight'].fillna(1.0).astype(float).astype(str)

# Avoid divide-by-zero in Capacity
df['Capacity'] = df['Capacity'].replace("0", "1")

# Compute OccupancyRate
df['OccupancyRate'] = (
    df['Occupancy'].astype(float) / df['Capacity'].astype(float)
).round(3).astype(str)

# Final selection
df = df[['Timestamp', 'SystemCodeNumber', 'Latitude', 'Longitude', 'Capacity', 'Occupancy',
         'QueueLength', 'TrafficLevel', 'VehicleWeight', 'IsSpecialDay', 'OccupancyRate']]

# Replace any remaining NaNs with "0"
df = df.fillna("0")

# Save cleaned CSV
df.to_csv("parking_stream_final.csv", index=False)

# Confirm saved
print("✅ Saved cleaned file as parking_stream_final.csv")
df.head()
```

```
✅ Saved cleaned file as parking_stream_final.csv
```

	Timestamp	SystemCodeNumber	Latitude	Longitude	Capacity	Occupancy	QueueLength	TrafficLevel	VehicleW
0	2016-04-10 07:59:00	BHMBCCMKT01	26.14453614	91.73617216	577	61	1	0	
1	2016-04-10 08:25:00	BHMBCCMKT01	26.14453614	91.73617216	577	64	1	0	
2	2016-04-10 08:59:00	BHMBCCMKT01	26.14453614	91.73617216	577	80	2	0	
3	2016-04-10 09:32:00	BHMBCCMKT01	26.14453614	91.73617216	577	107	2	0	
4	2016-04-10 09:59:00	BHMBCCMKT01	26.14453614	91.73617216	577	150	2	0	

Next steps: Generate code with df View recommended plots New interactive sheet

```
print(df.dtypes)
```

```
Timestamp           object
SystemCodeNumber    object
Latitude            object
Longitude           object
Capacity            object
Occupancy           object
QueueLength         object
TrafficLevel        object
VehicleWeight       object
IsSpecialDay        object
OccupancyRate       object
dtype: object
```

```
class RawSchema(pw.Schema):
    Timestamp: str
    SystemCodeNumber: str
    Latitude: str
    Longitude: str
    Capacity: str
    Occupancy: str
    QueueLength: str
    TrafficLevel: str
    VehicleWeight: str
    IsSpecialDay: str
    OccupancyRate: str
```

```
from datetime import datetime
import pathway as pw

@pw.udf
def parse_timestamp(ts: str) -> str:
    try:
        return datetime.fromisoformat(ts).isoformat()
    except:
        return "1970-01-01T00:00:00"
```

```
raw = pw.demo.replay_csv("parking_stream_final.csv", schema=RawSchema, input_rate=500)

data = raw.with_columns(
    Timestamp=parse_timestamp(pw.this.Timestamp),
    Latitude=pw.apply(float, pw.this.Latitude),
    Longitude=pw.apply(float, pw.this.Longitude),
    Capacity=pw.apply(float, pw.this.Capacity),
    Occupancy=pw.apply(float, pw.this.Occupancy),
    QueueLength=pw.apply(float, pw.this.QueueLength),
    TrafficLevel=pw.apply(float, pw.this.TrafficLevel),
    VehicleWeight=pw.apply(float, pw.this.VehicleWeight),
    IsSpecialDay=pw.apply(float, pw.this.IsSpecialDay),
    OccupancyRate=pw.apply(float, pw.this.OccupancyRate)
)
```

```
@pw.udf
def model_1(prev_price: float, occ_rate: float) -> float:
    return round(prev_price + 0.05 * occ_rate, 2)

@pw.udf
def model_2(base_price: float, occ_rate: float, queue: float, traffic: float, special: float, weight: float) -> float
    demand = (0.5 * occ_rate + 0.3 * queue - 0.2 * traffic + 0.4 * special + 1.0 * weight)
    norm_demand = min(max(demand / 10, -1), 1)
    return round(min(max(base_price * (1 + 0.2 * norm_demand), 5), 20), 2)

@pw.udf
def model_3(base_price: float, price: float, occ: float, cap: float, lat: float, lon: float) -> float:
    if occ >= cap:
        return max(price - 1, 5)
    else:
        return min(price + 1, 20)
```

```
base_price = 10.0

table = data.with_columns(
    Model1=model_1(base_price, pw.this.OccupancyRate),
    Model2=model_2(base_price, pw.this.OccupancyRate, pw.this.QueueLength, pw.this.TrafficLevel,
                   pw.this.IsSpecialDay, pw.this.VehicleWeight),
).with_columns(
    Model3=model_3(base_price, pw.this.Model2, pw.this.Occupancy, pw.this.Capacity,
                   pw.this.Latitude, pw.this.Longitude)
)


pw.io.csv.write(
    table.select(
        Timestamp=pw.this.Timestamp,
        Lot=pw.this.SystemCodeNumber,
        Model1=pw.this.Model1,
        Model2=pw.this.Model2,
        Model3=pw.this.Model3
    ),
    filename="output_stream.csv"
)

pw.run()
```

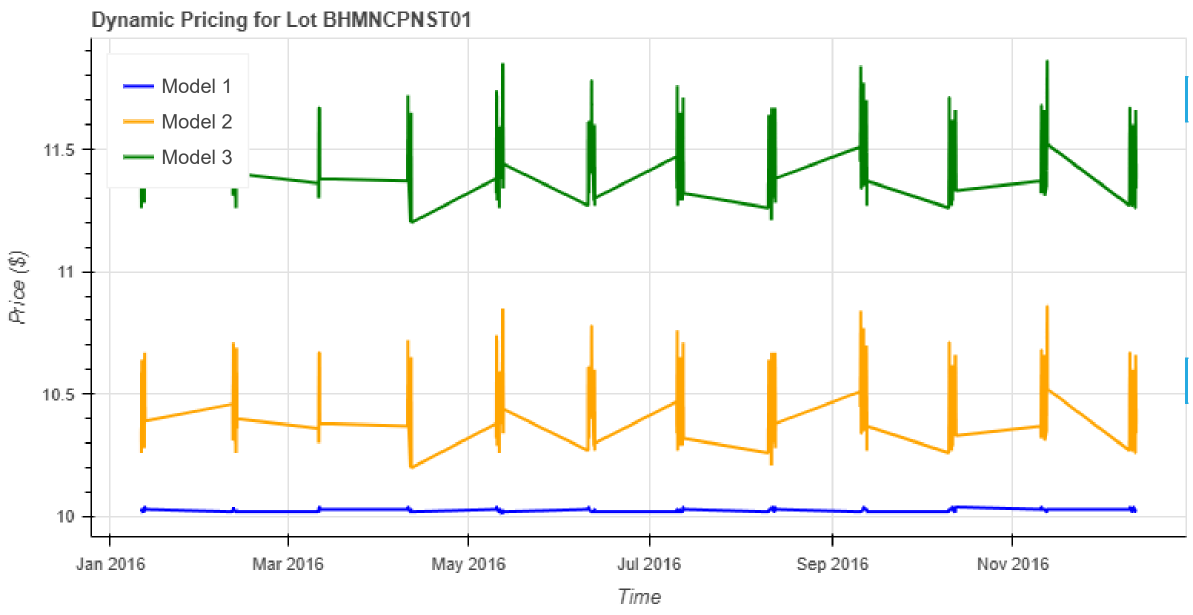
Show hidden output

```
# Allow some time for Pathway to stream and write rows
import time
time.sleep(5)  # Wait for a few seconds for the file to populate

# Read the CSV output stream into pandas
output_df = pd.read_csv("output_stream.csv")
output_df['Timestamp'] = pd.to_datetime(output_df['Timestamp'])
output_df.head()
```

	Timestamp	Lot	Model1	Model2	Model3	time	diff
0	2016-07-11 15:00:00	BHMNCPNST01	10.02	10.41	11.41	1751911018138	1
1	2016-09-10 08:30:00	Broad Street	10.00	10.41	11.41	1751911018138	1
2	2016-10-10 14:57:00	BHMNCPHST01	10.03	10.40	11.40	1751911018138	1
3	2016-12-10 08:04:00	BHMNCPNST01	10.03	10.27	11.27	1751911018138	1
4	2016-09-12 11:29:00	BHMMBMMBX01	10.04	10.69	11.69	1751911018138	1

Next steps: Generate code with output_df View recommended plots New interactive sheet

```
from bokeh.plotting import figure, show, output_notebook
from bokeh.models import ColumnDataSource, HoverTool
import pandas as pd

output_notebook()

# Choose a parking lot
selected_lot = output_df['Lot'].iloc[0]  # For  specific ID

# Filter and sort by time
lot_df = output_df[output_df['Lot'] == selected_lot].sort_values('Timestamp')
lot_df['Timestamp'] = pd.to_datetime(lot_df['Timestamp'])

# Setup source
source = ColumnDataSource(lot_df)

# Create figure
p = figure(title=f"Dynamic Pricing for Lot {selected_lot}",
           x_axis_type="datetime", width=800, height=400)

# Plot Model 1, 2, 3
p.line(x='Timestamp', y='Model1', source=source, line_width=2, color='blue', legend_label='Model 1')
p.line(x='Timestamp', y='Model2', source=source, line_width=2, color='orange', legend_label='Model 2')
p.line(x='Timestamp', y='Model3', source=source, line_width=2, color='green', legend_label='Model 3')

# Hover tool
hover = HoverTool(tooltips=[
    ("Time", "@Timestamp{%F %T}"),
    ("Model 2", "@Model2"),
    ("Model 3", "@Model3")
], formatters={'@Timestamp': 'datetime'})
p.add_tools(hover)

# Styling
p.xaxis.axis_label = "Time"
p.yaxis.axis_label = "Price ($)"
p.legend.location = "top_left"

show(p)
```



Parking Price Prediction Report

This report details the process of developing and comparing three different models for predicting parking prices based on various factors, as implemented in the provided code.

Data Loading and Exploration

The first step involves loading the dataset and understanding its structure and content.

```
import pandas as pd
import numpy as np
```

This code imports the necessary libraries, `pandas` for data manipulation and `numpy` for numerical operations.

```
# Step 1: Load and Explore Dataset
df = pd.read_csv('dataset.csv')
print("Shape of the dataset:", df.shape)
print("\nColumn names:\n", df.columns.tolist())
print("\nData Types:\n", df.dtypes)
print("\nFirst few rows:")
display(df.head())
```

```
Shape of the dataset: (18368, 12)

Column names:
 ['ID', 'SystemCodeNumber', 'Capacity', 'Latitude', 'Longitude', 'Occupancy', 'VehicleType', 'TrafficConditionNea

Data Types:
 ID                          int64
SystemCodeNumber           object
Capacity                    int64
Latitude                  float64
Longitude                 float64
Occupancy                   int64
VehicleType                object
TrafficConditionNearby     object
QueueLength                 int64
IsSpecialDay                int64
LastUpdatedDate            object
LastUpdatedTime            object
dtype: object

First few rows:
```

	ID	SystemCodeNumber	Capacity	Latitude	Longitude	Occupancy	VehicleType	TrafficConditionNearby	QueueLeng
0	0	BHMBCCMKT01	577	26.144536	91.736172	61	car	low	
1	1	BHMBCCMKT01	577	26.144536	91.736172	64	car	low	
2	2	BHMBCCMKT01	577	26.144536	91.736172	80	car	low	
3	3	BHMBCCMKT01	577	26.144536	91.736172	107	car	low	
4	4	BHMBCCMKT01	577	26.144536	91.736172	150	bike	low	

This cell loads the `dataset.csv` file into a pandas DataFrame called `df`. It then prints the shape of the DataFrame (number of rows and columns), the list of column names, the data types of each column, and displays the first few rows of the DataFrame using `display()`. This provides an initial overview of the data.

```
# Check for missing values
print("\nMissing values per column:")
print(df.isnull().sum())
```

```

Missing values per column:
ID                        0
SystemCodeNumber          0
Capacity                  0
Latitude                  0
Longitude                 0
Occupancy                 0
VehicleType               0
TrafficConditionNearby    0
QueueLength               0
IsSpecialDay              0
LastUpdatedDate           0
LastUpdatedTime           0
dtype: int64
```

This code checks for missing values in each column of the DataFrame and prints the count of missing values per column. This helps in identifying if any data cleaning is required.

Model 1: Baseline Linear Model

This section implements a simple linear model as a baseline for comparison.

***Model 1: Baseline Linear Model

```
A simple model where the next price is a function of the previous price and current
occupancy:
```

• Linear price increase as occupancy increases • Acts as a reference point

Example:

```
Price(t+1) = Price(t) + α ·(Occupancy/Capacity)***
```

This markdown cell describes the concept of the baseline linear model, which is based on the previous price and the occupancy rate.

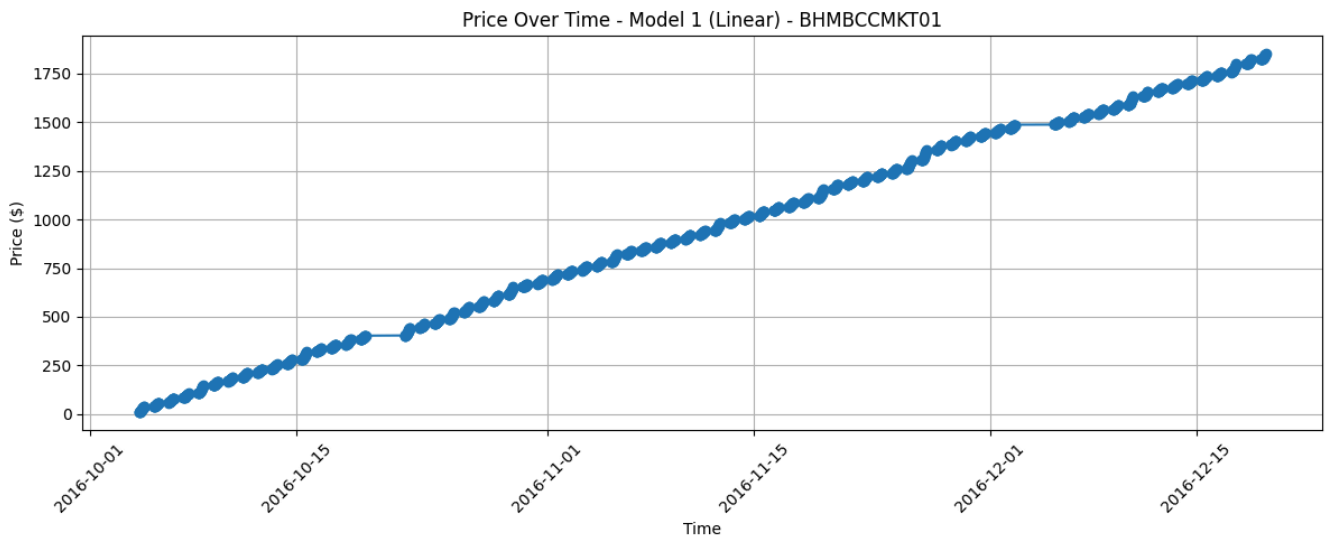
```
# Step 2: Feature Engineering for Model 1

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

# Sort by parking lot and timestamp
df.sort_values(by=['SystemCodeNumber', 'Timestamp'], inplace=True)

# Calculate occupancy rate
df['OccupancyRate'] = df['Occupancy'] / df['Capacity']

# Initialize base price
base_price = 10
alpha = 5  # Price sensitivity to occupancy rate

# Initialize a price column with base price
df['Price_Model1'] = base_price

# Compute price over time for each parking lot
for lot in df['SystemCodeNumber'].unique():
    lot_indices = df[df['SystemCodeNumber'] == lot].index
    for i in range(1, len(lot_indices)):
        prev_idx = lot_indices[i-1]
        curr_idx = lot_indices[i]
        prev_price = df.loc[prev_idx, 'Price_Model1']
        occupancy_rate = df.loc[curr_idx, 'OccupancyRate']

        new_price = prev_price + alpha * occupancy_rate
        df.loc[curr_idx, 'Price_Model1'] = new_price

# Preview results
df[['SystemCodeNumber', 'Timestamp', 'OccupancyRate', 'Price_Model1']].head(10)
```

```
/tmp/ipython-input-99-1535754574.py:29: FutureWarning: Setting an item of incompatible dtype is deprecated and wi
  df.loc[curr_idx, 'Price_Model1'] = new_price
```

	SystemCodeNumber	Timestamp	OccupancyRate	Price_Model1
0	BHMBCCMKT01	2016-10-04 07:59:00	0.105719	10.000000
1	BHMBCCMKT01	2016-10-04 08:25:00	0.110919	10.554593
2	BHMBCCMKT01	2016-10-04 08:59:00	0.138648	11.247834
3	BHMBCCMKT01	2016-10-04 09:32:00	0.185442	12.175043
4	BHMBCCMKT01	2016-10-04 09:59:00	0.259965	13.474870
5	BHMBCCMKT01	2016-10-04 10:26:00	0.306759	15.008666
6	BHMBCCMKT01	2016-10-04 10:59:00	0.379549	16.906412
7	BHMBCCMKT01	2016-10-04 11:25:00	0.428076	19.046794
8	BHMBCCMKT01	2016-10-04 11:59:00	0.448873	21.291161
9	BHMBCCMKT01	2016-10-04 12:29:00	0.461005	23.596187

This code cell performs feature engineering for Model 1. It combines the date and time columns into a single `Timestamp` column, sorts the data by parking lot and timestamp, and calculates the `OccupancyRate`. It then initializes a `Price_Model1` column with a base price and iteratively calculates the price for each parking lot based on the previous price and the current occupancy rate, using the defined `alpha` coefficient. Finally, it displays the first 10 rows of the relevant columns.

```
import matplotlib.pyplot as plt

# Choose one parking lot (e.g., first unique one)
sample_lot = df['SystemCodeNumber'].unique()[0]
sample_df = df[df['SystemCodeNumber'] == sample_lot]

# Plot
plt.figure(figsize=(12, 5))
plt.plot(sample_df['Timestamp'], sample_df['Price_Model1'], marker='o', linestyle='-')
plt.title(f'Price Over Time - Model 1 (Linear) - {sample_lot}')
plt.xlabel('Time')
plt.ylabel('Price ($)')
plt.grid(True)
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
```



This code uses `matplotlib` to plot the `Price_Model1` over time for a single sample parking lot. It visualizes how the price changes based on the simple linear model.

```
print("Price stats for Model 1:")
print("Min Price: $", round(df['Price_Model1'].min(), 2))
print("Max Price: $", round(df['Price_Model1'].max(), 2))
print("Average Price: $", round(df['Price_Model1'].mean(), 2))
```

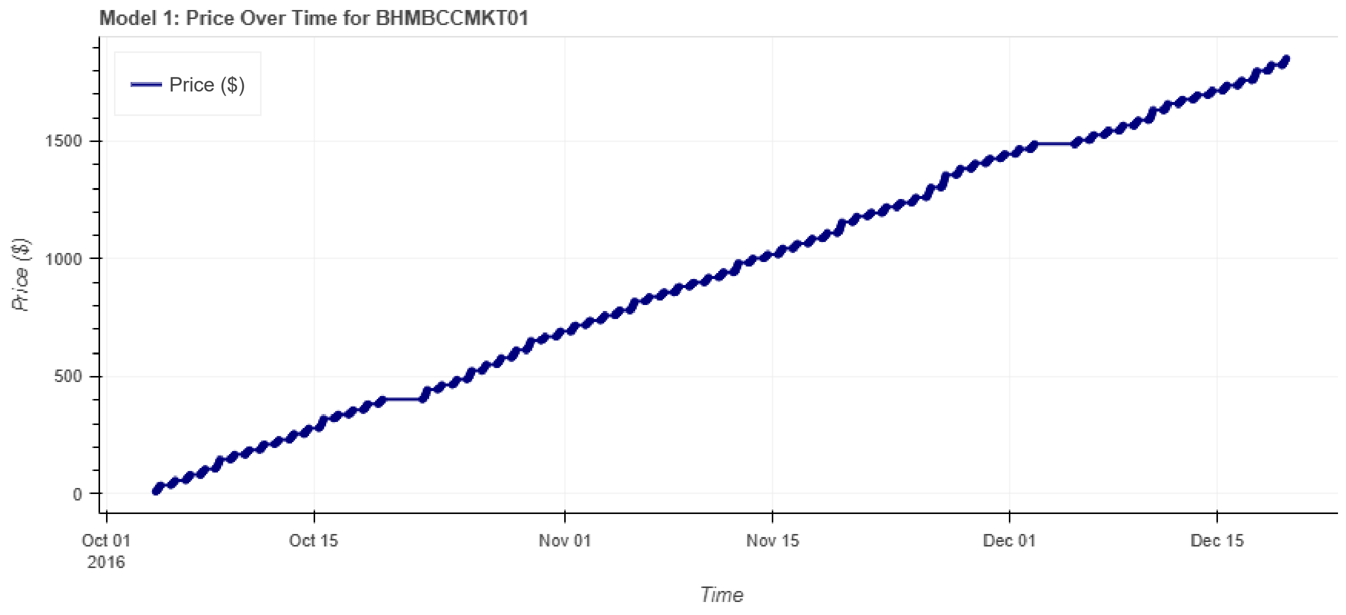
```
Price stats for Model 1:
Min Price: $ 10.0
Max Price: $ 4896.37
Average Price: $ 1643.02
```

This cell calculates and prints the minimum, maximum, and average price predicted by Model 1 across all parking lots.

```
from bokeh.plotting import figure, show, output_notebook
from bokeh.models import ColumnDataSource
from bokeh.layouts import layout
from bokeh.models import HoverTool

# Enable inline Bokeh output
output_notebook()
```

```
# Select a sample lot (e.g., the first unique one)
sample_lot = df['SystemCodeNumber'].unique()[0]
sample_df = df[df['SystemCodeNumber'] == sample_lot].copy()

# Prepare data source
sample_df['Timestamp_str'] = sample_df['Timestamp'].dt.strftime("%Y-%m-%d %H:%M")
source = ColumnDataSource(sample_df)

# Create Bokeh figure
p = figure(x_axis_type="datetime", title=f"Model 1: Price Over Time for {sample_lot}",
           width=900, height=400, tools="pan,wheel_zoom,box_zoom,reset,hover,save")

# Plot line
p.line(x='Timestamp', y='Price_Model1', source=source, line_width=2, color='navy', legend_label='Price ($)')
p.circle(x='Timestamp', y='Price_Model1', source=source, size=4, color='navy', alpha=0.6)

# Hover tool
hover = p.select(dict(type=HoverTool))
hover.tooltips = [
    ("Time", "@Timestamp_str"),
    ("Price", "@Price_Model1{$0.00}"),
    ("Occupancy Rate", "@OccupancyRate{0.00}")
]

# Aesthetic settings
p.xaxis.axis_label = "Time"
p.yaxis.axis_label = "Price ($)"
p.legend.location = "top_left"
p.grid.grid_line_alpha = 0.3

# Show plot
show(p)
```

```
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
```



This code uses the `bokeh` library to create an interactive plot of Model 1's price over time for a sample parking lot. It includes hover tools to display details when hovering over data points.

Model 2: Demand-Based Price Function

This section implements a more complex model that considers various factors to determine price based on demand.

***Model 2: Demand-Based Price Function

A more advanced model where you: • Construct a mathematical demand function using key features:

This markdown cell introduces Model 2, explaining that it's a demand-based model that uses multiple features to calculate demand.

```
# Map traffic levels to numeric
traffic_map = {'low': 1, 'medium': 2, 'high': 3}
df['TrafficLevelNum'] = df['TrafficConditionNearby'].map(traffic_map)

# Assign numeric weights to vehicle types
vehicle_weights = {'bike': 0.5, 'car': 1.0, 'truck': 1.5}
df['VehicleWeight'] = df['VehicleType'].map(vehicle_weights)
```

This code cell prepares the data for Model 2 by mapping categorical features (`TrafficConditionNearby` and `VehicleType`) to numerical values.

This markdown cell defines the coefficients used in the demand function for Model 2.

```
# Define coefficients
a, b, c, d, e = 0.5, 0.3, 0.2, 0.5, 0.7

# Raw demand calculation
df['DemandRaw'] = (
    a * df['OccupancyRate'] +
    b * df['QueueLength'] -
    c * df['TrafficLevelNum'] +
    d * df['IsSpecialDay'] +
    e * df['VehicleWeight']
)
```

This code cell calculates the raw demand based on the defined coefficients and the numerical features.

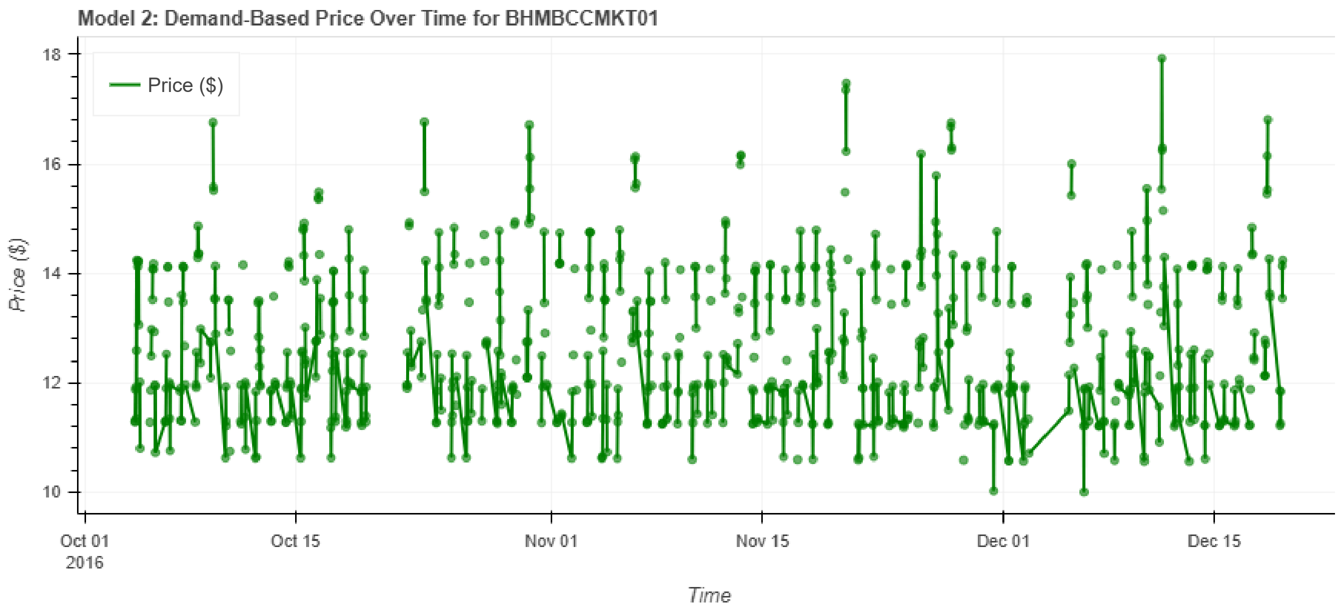
``` Normalize Demand & Set Price

This markdown cell indicates the next steps: normalizing the raw demand and setting the price based on the normalized demand.

```
# Normalize demand to [0, 1]
dmin, dmax = df['DemandRaw'].min(), df['DemandRaw'].max()
df['DemandNorm'] = (df['DemandRaw'] - dmin) / (dmax - dmin)

# Define lambda for price sensitivity
lambda_val = 1.0

# Calculate demand-based price (bounded)
df['Price_Model2'] = 10 * (1 + lambda_val * df['DemandNorm'])
df['Price_Model2'] = df['Price_Model2'].clip(lower=5, upper=20)
```

This code cell normalizes the raw demand to a range between 0 and 1 and then calculates the `Price_Model2` based on the normalized demand and a price sensitivity factor (`lambda_val`). The price is also clipped to stay within a specified range (5 to 20).

*** `Interactive Bokeh Plot for Model 2`

```
 plot Price_Model2 over time for the same parking lot
```

This markdown cell introduces the interactive Bokeh plot for Model 2.
```

```
from bokeh.plotting import figure, show, output_notebook
from bokeh.models import ColumnDataSource, HoverTool

# Enable Bokeh in notebook
output_notebook()

# Filter the same parking lot as before
sample_lot = df['SystemCodeNumber'].unique()[0]
sample_df = df[df['SystemCodeNumber'] == sample_lot].copy()

# Prepare timestamp string for hover
sample_df['Timestamp_str'] = sample_df['Timestamp'].dt.strftime("%Y-%m-%d %H:%M")

# Prepare data source
source = ColumnDataSource(sample_df)

# Create Bokeh plot
p2 = figure(x_axis_type="datetime", title=f"Model 2: Demand-Based Price Over Time for {sample_lot}",
           width=900, height=400, tools="pan,wheel_zoom,box_zoom,reset,hover,save")

# Plot line and circles
p2.line(x='Timestamp', y='Price_Model2', source=source, line_width=2, color='green', legend_label='Price ($)')
p2.circle(x='Timestamp', y='Price_Model2', source=source, size=5, color='green', alpha=0.6)

# Hover tool
hover2 = p2.select(dict(type=HoverTool))
hover2.tooltips = [
    ("Time", "@Timestamp_str"),
    ("Price", "@Price_Model2{$0.00}"),
    ("Demand (normalized)", "@DemandNorm{0.00}")
]

# Axis labels and styling
p2.xaxis.axis_label = "Time"
p2.yaxis.axis_label = "Price ($)"
p2.legend.location = "top_left"
p2.grid.grid_line_alpha = 0.3

# Show the plot
show(p2)
```

```
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
```



This code generates an interactive Bokeh plot to visualize the `Price_Model2` over time for the sample parking lot, similar to the plot for Model 1, but with different styling and hover information.

Model 3: Competitive Pricing Logic

This section introduces a more advanced model that incorporates competitive pricing based on nearby parking lots.

This markdown cell explains the concept of Model 3, which extends Model 2 by considering the prices and occupancy of nearby parking lots.

** Competitive Logic

If lot is full and nearby lots are cheaper → suggest rerouting / reduce price

If nearby lots are expensive or full → increase your price **

This markdown cell details the competitive logic used in Model 3 to adjust prices and suggest rerouting.

``` Haversine Function to Compute Proximity

This markdown cell introduces the Haversine function used to calculate the distance between parking lots.

```
# Haversine distance in km
def haversine(lat1, lon1, lat2, lon2):
    R = 6371 # Earth radius (km)
    phi1, phi2 = np.radians(lat1), np.radians(lat2)
    d_phi = np.radians(lat2 - lat1)
    d_lambda = np.radians(lon2 - lon1)

    a = np.sin(d_phi/2)**2 + np.cos(phi1)*np.cos(phi2)*np.sin(d_lambda/2)**2
    return R * 2 * np.arcsin(np.sqrt(a))
~~~

This code cell defines the `haversine` function, which calculates the distance in kilometers between two points given their latitude and longitude.

``` Compute Nearby Lot Prices at Each Time

This markdown cell explains the next step: computing the prices of nearby parking lots at each timestamp.

~~~
# Copy model 2 price
df['Price_Model3'] = df['Price_Model2']  # initialize from demand-based price
df['SuggestReroute'] = 0  # 1 if we suggest rerouting

# Group by time
for timestamp in df['Timestamp'].unique():
    snapshot = df[df['Timestamp'] == timestamp].copy()  # <--- Fix here

    for idx, row in snapshot.iterrows():
        lot_lat, lot_lon = row['Latitude'], row['Longitude']
        lot_price = row['Price_Model2']
        lot_occ = row['Occupancy']
        lot_cap = row['Capacity']

        snapshot['Distance'] = snapshot.apply(
            lambda r: haversine(lot_lat, lot_lon, r['Latitude'], r['Longitude']), axis=1)

        nearby = snapshot[(snapshot['SystemCodeNumber'] != row['SystemCodeNumber']) & (snapshot['Distance'] < 1)]

        if len(nearby) > 0:
            nearby_prices = nearby['Price_Model2']
            nearby_occ_rates = nearby['Occupancy'] / nearby['Capacity']
```
```

```
            avg_nearby_price = nearby_prices.mean()
            avg_nearby_occ = nearby_occ_rates.mean()

            # Pricing logic
            if (lot_occ / lot_cap) >= 0.9 and avg_nearby_price < lot_price:
                df.loc[idx, 'Price_Model3'] = max(5, lot_price - 2)
                df.loc[idx, 'SuggestReroute'] = 1
            elif avg_nearby_occ > 0.9 and avg_nearby_price > lot_price:
                df.loc[idx, 'Price_Model3'] = min(20, lot_price + 2)
```

This code cell implements the core logic of Model 3. It iterates through each timestamp, identifies nearby parking lots (within 1 km) for each lot, calculates the average price and occupancy of nearby lots, and adjusts the current lot's price (`Price_Model3`) based on the competitive logic. It also sets a `SuggestReroute` flag if rerouting is suggested.

``` Bokeh Plot for Model 3 with Rerouting Highlights

Plot price over time

Using circle color for rerouting suggestion:

🔴 Red → Reroute suggested

🟢 Green → No reroute

This markdown cell describes the Bokeh plot for Model 3, which will visualize the price over time and highlight rerouting suggestions using different colored markers.

```
from bokeh.plotting import figure, show, output_notebook
from bokeh.models import ColumnDataSource, HoverTool
from bokeh.transform import factor_cmap

output_notebook()

# Refresh sample lot
sample_lot = df['SystemCodeNumber'].unique()[0]
sample_df = df[df['SystemCodeNumber'] == sample_lot].copy()
sample_df['Timestamp_str'] = sample_df['Timestamp'].dt.strftime("%Y-%m-%d %H:%M")

# Label rerouting as "Yes"/"No"
sample_df['Reroute'] = sample_df['SuggestReroute'].apply(lambda x: "Yes" if x == 1 else "No")

# Create data source
source = ColumnDataSource(sample_df)

# Color map: red if reroute suggested, green otherwise
reroute_colors = factor_cmap('Reroute',
                             palette=['green', 'red'],
                             factors=['No', 'Yes'])

# Create figure
p3 = figure(x_axis_type="datetime", title=f"Model 3: Competitive Price + Reroute Suggestion for {sample_lot}",
            width=950, height=450, tools="pan,wheel_zoom,box_zoom,reset,hover,save")

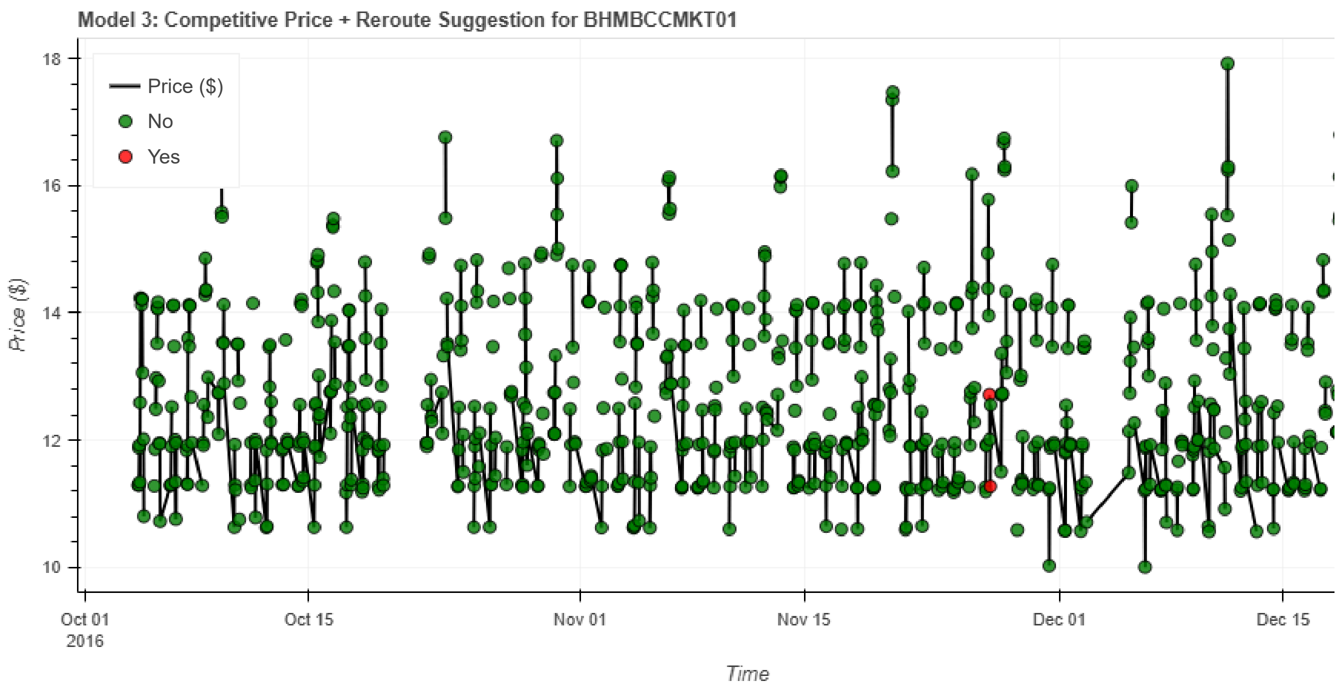
# Line for base price evolution
p3.line(x='Timestamp', y='Price_Model3', source=source, line_width=2, color='black', legend_label='Price ($)')

# Colored circle markers for reroute suggestion
p3.circle(x='Timestamp', y='Price_Model3', source=source, size=8,
          fill_color=reroute_colors, line_color='black', alpha=0.8, legend_field='Reroute')

# Hover tool
hover = p3.select(dict(type=HoverTool))
hover.tooltips = [
    ("Time", "@Timestamp_str"),
    ("Price", "@Price_Model3{$0.00}"),
    ("Suggest Reroute", "@Reroute"),
    ("Occupancy Rate", "@OccupancyRate{0.00}"),
]
```
```

```
# Styling
p3.xaxis.axis_label = "Time"
p3.yaxis.axis_label = "Price ($)"
p3.legend.location = "top_left"
p3.grid.grid_line_alpha = 0.3

# Show plot
show(p3)
```

```
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
```



This code generates an interactive Bokeh plot for Model 3, showing the price over time for the sample parking lot. It uses different colored circles to indicate when a reroute was suggested based on the competitive pricing logic.

Model Comparison

This section compares the pricing results of Model 2 and Model 3.

``` Comparison Plot: Model 2 vs Model 3 Pricing Over Time:

This markdown cell introduces the comparison plot between Model 2 and Model 3.

```
from bokeh.plotting import figure, show, output_notebook
from bokeh.models import ColumnDataSource, HoverTool

output_notebook()

# Filter same parking lot
sample_lot = df['SystemCodeNumber'].unique()[0]
sample_df = df[df['SystemCodeNumber'] == sample_lot].copy()
sample_df['Timestamp_str'] = sample_df['Timestamp'].dt.strftime("%Y-%m-%d %H:%M")

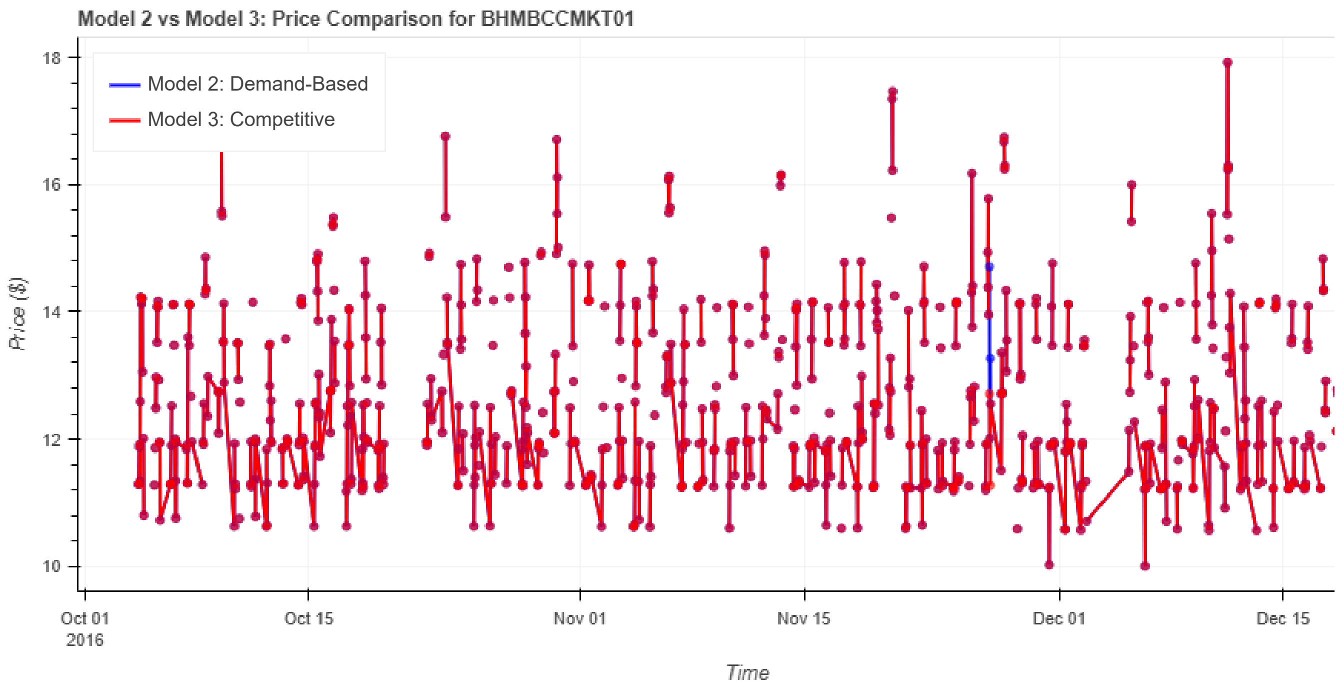
# Create source
source = ColumnDataSource(sample_df)

# Create plot
p_compare = figure(x_axis_type="datetime", title=f"Model 2 vs Model 3: Price Comparison for {sample_lot}",
                   width=950, height=450, tools="pan,wheel_zoom,box_zoom,reset,hover,save")

# Model 2 line (Demand-Based)
p_compare.line(x='Timestamp', y='Price_Model2', source=source, line_width=2,
```
```

```
                   color='blue', legend_label='Model 2: Demand-Based')

# Model 3 line (Competitive)
p_compare.line(x='Timestamp', y='Price_Model3', source=source, line_width=2,
               color='red', legend_label='Model 3: Competitive')

# Add dots for better visibility
p_compare.circle(x='Timestamp', y='Price_Model2', source=source, size=5,
                 color='blue', alpha=0.6)
p_compare.circle(x='Timestamp', y='Price_Model3', source=source, size=5,
                 color='red', alpha=0.6)

# Hover tool
hover = p_compare.select(dict(type=HoverTool))
hover.tooltips = [
    ("Time", "@Timestamp_str"),
    ("Price M2", "@Price_Model2{$0.00}"),
    ("Price M3", "@Price_Model3{$0.00}"),
    ("Occupancy", "@Occupancy"),
    ("Reroute", "@SuggestReroute"),
]

# Styling
p_compare.xaxis.axis_label = "Time"
p_compare.yaxis.axis_label = "Price ($)"
p_compare.legend.location = "top_left"
p_compare.grid.grid_line_alpha = 0.3

# Show
show(p_compare)
```

```
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
BokehDeprecationWarning: 'circle() method with size value' was deprecated in Bokeh 3.4.0 and will be removed, use
```



This code generates a comparative interactive Bokeh plot showing the price over time for both Model 2 and Model 3 for the sample parking lot. This allows for a visual comparison of how the competitive logic in Model 3 influences the pricing compared to the purely demand-based Model 2.

``` Blue line: Demand-based pricing

Red line: Competitive-aware adjustments

Dips in red line when reroute is suggested

Red spikes where neighboring lots are full
```

This markdown cell provides a key to interpret the comparison plot, explaining what the blue and red lines represent and how the dips and spikes in the red line relate to rerouting suggestions and the occupancy of neighboring lots.

Pathway Implementation (Attempt)

This section shows an attempt to implement the competitive pricing logic using the Pathway library for potential real-time data processing.

```
!pip install pathway
```

```
Requirement already satisfied: pathway in /usr/local/lib/python3.11/dist-packages (0.24.1)
Requirement already satisfied: aiohttp>=3.8.4 in /usr/local/lib/python3.11/dist-packages (from pathway) (3.11.1
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Requirement already satisfied: urllib3!=2.2.0,<3,>=1.25.4 in /usr/local/lib/python3.11/dist-packages (from aiob
Requirement already satisfied: wrapt<2.0.0,>=1.10.10 in /usr/local/lib/python3.11/dist-packages (from aiobotoco
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Requirement already satisfied: frozenlist>=1.1.1 in /usr/local/lib/python3.11/dist-packages (from aiohttp>=3.8.
Requirement already satisfied: propcache>=0.2.0 in /usr/local/lib/python3.11/dist-packages (from aiohttp>=3.8.4
Requirement already satisfied: yarl<2.0,>=1.17.0 in /usr/local/lib/python3.11/dist-packages (from aiohttp>=3.8.
Requirement already satisfied: s3transfer<0.11.0,>=0.10.0 in /usr/local/lib/python3.11/dist-packages (from boto
Requirement already satisfied: pyarrow-hotfix in /usr/local/lib/python3.11/dist-packages (from deltalake<0.18.0
Requirement already satisfied: appdirs~=1.4.3 in /usr/local/lib/python3.11/dist-packages (from fs>=2.4.16->path
Requirement already satisfied: setuptools in /usr/local/lib/python3.11/dist-packages (from fs>=2.4.16->pathway)
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Requirement already satisfied: geographiclib<3,>=1.52 in /usr/local/lib/python3.11/dist-packages (from geopy>=2
Requirement already satisfied: gitdb<5,>=4.0.1 in /usr/local/lib/python3.11/dist-packages (from gitpython>=3.1.
Requirement already satisfied: httplib2<1.0.0,>=0.19.0 in /usr/local/lib/python3.11/dist-packages (from google-
Requirement already satisfied: google-auth!=2.24.0,!=2.25.0,<3.0.0,>=1.32.0 in /usr/local/lib/python3.11/dist-p
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Requirement already satisfied: uritemplate<5,>=3.0.1 in /usr/local/lib/python3.11/dist-packages (from google-ap
```

This cell installs the `pathway` library.

```
@pw.udf(return_type=float)
def haversine(lat1, lon1, lat2, lon2):
    R = 6371
    phi1, phi2 = np.radians(lat1), np.radians(lat2)
    d_phi = np.radians(lat2 - lat1)
    d_lambda = np.radians(lon2 - lon1)
    a = np.sin(d_phi / 2)**2 + np.cos(phi1) * np.cos(phi2) * np.sin(d_lambda / 2)**2
    return R * 2 * np.arcsin(np.sqrt(a))
```

This code cell defines the `haversine` function as a Pathway User Defined Function (`@pw.udf`) for use within the Pathway data processing pipeline.

```
import pandas as pd
import pathway as pw
from pathway.internals.dtype import DATE_TIME_NAIVE
import numpy as np

# --- Step 1: Preprocess Data ----------------------------------
df['Timestamp'] = pd.to_datetime(
    df['LastUpdatedDate'] + ' ' + df['LastUpdatedTime'],
    format='%d-%m-%Y %H:%M:%S'
)
df['ID'] = df['ID'].astype(str)

# --- Step 2: Schema -------------------------------------------
class ParkingLot(pw.Schema):
    ID: str
    SystemCodeNumber: str
    Capacity: int
    Latitude: float
    Longitude: float
    Occupancy: int
    VehicleType: str
    TrafficConditionNearby: str
    QueueLength: int
    IsSpecialDay: int
    Timestamp: DATE_TIME_NAIVE
    Price_Model2: float

# --- Step 3: ConnectorSubject ---------------------------------
class ParkingSubject(pw.io.python.ConnectorSubject):
    def __init__(self, df):
        super().__init__()
        self.df = df.sort_values('Timestamp')
    def run(self):
        for _, row in self.df.iterrows():
            self.next(
                ID=str(row['ID']),
                SystemCodeNumber=row['SystemCodeNumber'],
                Capacity=int(row['Capacity']),
                Latitude=float(row['Latitude']),
                Longitude=float(row['Longitude']),
                Occupancy=int(row['Occupancy']),
                VehicleType=row['VehicleType'],
                TrafficConditionNearby=row['TrafficConditionNearby'],
                QueueLength=int(row['QueueLength']),
                IsSpecialDay=int(row['IsSpecialDay']),
                Timestamp=row['Timestamp'],
                Price_Model2=float(row['Price_Model2'])
            )
        self.close()

#  Read stream --------------------------------------
stream = pw.io.python.read(ParkingSubject(df), schema=ParkingLot)

#  Rename columns in right stream before join -------
stream_reduced = stream.select(
    ID_R=stream.ID,
    Timestamp_R=stream.Timestamp,
    Latitude_R=stream.Latitude,
    Longitude_R=stream.Longitude,
    Capacity_R=stream.Capacity,
    Occupancy_R=stream.Occupancy,
    Price_Model2_R=stream.Price_Model2
)

#  Join streams --------------------------------------
joined = pw.join(stream, stream_reduced)

#  Haversine distance function ----------------------
@pw.udf(return_type=float)
def haversine(lat1, lon1, lat2, lon2):
    R = 6371
    phi1, phi2 = np.radians(lat1), np.radians(lat2)
    d_phi = np.radians(lat2 - lat1)
    d_lambda = np.radians(lon2 - lon1)
    a = np.sin(d_phi / 2)**2 + np.cos(phi1) * np.cos(phi2) * np.sin(d_lambda / 2)**
    return R * 2 * np.arcsin(np.sqrt(a))

#  Filter nearby competitors ------------------------
nearby = joined.filter(
    (joined["Timestamp"] == joined["Timestamp_R"]) &
    (haversine(
        joined["Latitude"], joined["Longitude"],
        joined["Latitude_R"], joined["Longitude_R"]
    ) < 1)
)


#Select into a real table
selected = nearby.select(
    ID=joined["ID"],
    Timestamp=joined["Timestamp"],
    SystemCodeNumber=joined["SystemCodeNumber"],
    Price_Model2=joined["Price_Model2"],
    Occupancy=joined["Occupancy"],
    Capacity=joined["Capacity"],
    Price_Model2_R=joined["Price_Model2_R"],
    Occupancy_R=joined["Occupancy_R"],
    Capacity_R=joined["Capacity_R"]
)

#
print("Columns:", selected.schema)


agg = selected.group_by("ID").reduce(
    ID=_.ID,
    Time=_.Timestamp,
    Lot=_.SystemCodeNumber,
    SelfPrice=_.Price_Model2,
    SelfOccRate=_.Occupancy / _.Capacity,
    AvgCompPrice=pw.reducers.mean(_.Price_Model2_R),
    AvgCompOccRate=pw.reducers.mean(_.Occupancy_R / _.Capacity_R)
)


#  Model 3 pricing logic ---------------------------
@pw.udf
def adjust_price(self_price, self_occ, comp_price, comp_occ):
    if self_occ >= 0.9 and comp_price < self_price:
        return max(5, self_price - 2), 1  # Suggest reroute
    elif comp_occ > 0.9 and comp_price > self_price:
        return min(20, self_price + 2), 0  # Increase price
    return self_price, 0  # No change

#  Final output ------------------------------------
final = agg.select(
    ID=agg.ID,
    Lot=agg.Lot,
    Time=agg.Time,
    Price_Model3_and_Reroute=adjust_price(
        agg.SelfPrice,
        agg.SelfOccRate,
        agg.AvgCompPrice,
        agg.AvgCompOccRate
    )
).select(
    ID=_.ID,
    Lot=_.Lot,
    Time=_.Time,
    Price_Model3=_.Price_Model3_and_Reroute[0],
    Reroute=_.Price_Model3_and_Reroute[1]
)

# Output to console -------------------------------
```

This code cell attempts to implement the competitive pricing logic using Pathway. It defines a schema for the data, creates a data source from the pandas DataFrame, joins the data to compare each parking lot with nearby lots at the same timestamp, filters for nearby lots, aggregates competitor statistics, applies the pricing logic using a Pathway UDF, and attempts to output the final results.

```
import pandas as pd
from bokeh.plotting import figure, show, output_file
from bokeh.models import ColumnDataSource, HoverTool

data = {
    'Time': pd.date_range(start='2025-07-07 08:00:00', periods=10, freq='5min'),
    'Price_Model3': [10, 11, 12, 10, 14, 13, 15, 10, 12, 11],
    'Reroute': [0, 0, 1, 0, 1, 0, 0, 1, 0, 0]
}


df_vis = pd.DataFrame(data)
df_vis['Color'] = df_vis['Reroute'].map({0: 'green', 1: 'red'})

source = ColumnDataSource(data=df_vis.to_dict(orient='list'))
```