```
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```

Summer Anaytics Capstone Project 2025

Problem: Dynamic Pricing for Urban Parking Lots

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

Importing Data and Processing Data

```
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
```

Data Cleaning

```
df = pd.read_csv('/content/sample_data/dataset.csv')
df
```

temCodeNumber	Capacity	Latitude	Longitude	Occupancy	VehicleType	TrafficCor
BHMBCCMKT01	577	26.144536	91.736172	61	car	
BHMBCCMKT01	577	26.144536	91.736172	64	car	
BHMBCCMKT01	577	26.144536	91.736172	80	car	
BHMBCCMKT01	577	26.144536	91.736172	107	car	
BHMBCCMKT01	577	26.144536	91.736172	150	bike	
...	...	...	...	...	...	
Shopping	1920	26.150504	91.733531	1517	truck	
Shopping	1920	26.150504	91.733531	1487	car	
Shopping	1920	26.150504	91.733531	1432	cycle	
Shopping	1920	26.150504	91.733531	1321	car	
Shopping	1920	26.150504	91.733531	1180	car	

nns

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

```
df.head()
```

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

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

```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 18368 entries, 0 to 18367
Data columns (total 12 columns):
 #   Column                  Non-Null Count  Dtype
---  ------                  --------------  -----
 0   ID                      18368 non-null  int64
 1   SystemCodeNumber        18368 non-null  object
 2   Capacity                18368 non-null  int64
 3   Latitude                18368 non-null  float64
 4   Longitude               18368 non-null  float64
 5   Occupancy               18368 non-null  int64
 6   VehicleType             18368 non-null  object
 7   TrafficConditionNearby  18368 non-null  object
 8   QueueLength             18368 non-null  int64
 9   IsSpecialDay            18368 non-null  int64
 10  LastUpdatedDate         18368 non-null  object
 11  LastUpdatedTime         18368 non-null  object
```

```
dtypes: float64(2), int64(5), object(5)
memory usage: 1.7+ MB
```

```
df.isnull().sum()
```

	0
ID	0
SystemCodeNumber	0
Capacity	0
Latitude	0
Longitude	0
Occupancy	0
VehicleType	0
TrafficConditionNearby	0
QueueLength	0
IsSpecialDay	0
LastUpdatedDate	0
LastUpdatedTime	0

```
df.describe()
```

	ID	Capacity	Latitude	Longitude	Occupancy	QueueLength	IsSpecia
count	18368.000000	18368.000000	18368.000000	18368.000000	18368.000000	18368.000000	18368.00
mean	9183.500000	1605.214286	25.706547	90.751170	731.084059	4.587925	0.15
std	5302.529208	1131.153886	1.582749	3.536636	621.164982	2.580062	0.35
min	0.000000	387.000000	20.000035	78.000003	2.000000	0.000000	0.00
25%	4591.750000	577.000000	26.140048	91.727995	322.000000	2.000000	0.00
50%	9183.500000	1261.000000	26.147482	91.729511	568.000000	4.000000	0.00
75%	13775.250000	2803.000000	26.147541	91.736172	976.000000	6.000000	0.00
max	18367.000000	3883.000000	26.150504	91.740994	3499.000000	15.000000	1.00

```
df['timestamp'] = pd.to_datetime(df['LastUpdatedDate'] + ' ' + df['LastUpdatedTime'], format='%d-%m-%
```

```
df.drop(['LastUpdatedDate','LastUpdatedTime'],axis=1,inplace=True)
```

```
df = df.sort_values(by = 'timestamp')
```

```
df[['timestamp']].head()
```

	timestamp
0	2016-10-04 07:59:00
5248	2016-10-04 07:59:00
3936	2016-10-04 07:59:00
6560	2016-10-04 07:59:00
17056	2016-10-04 07:59:00

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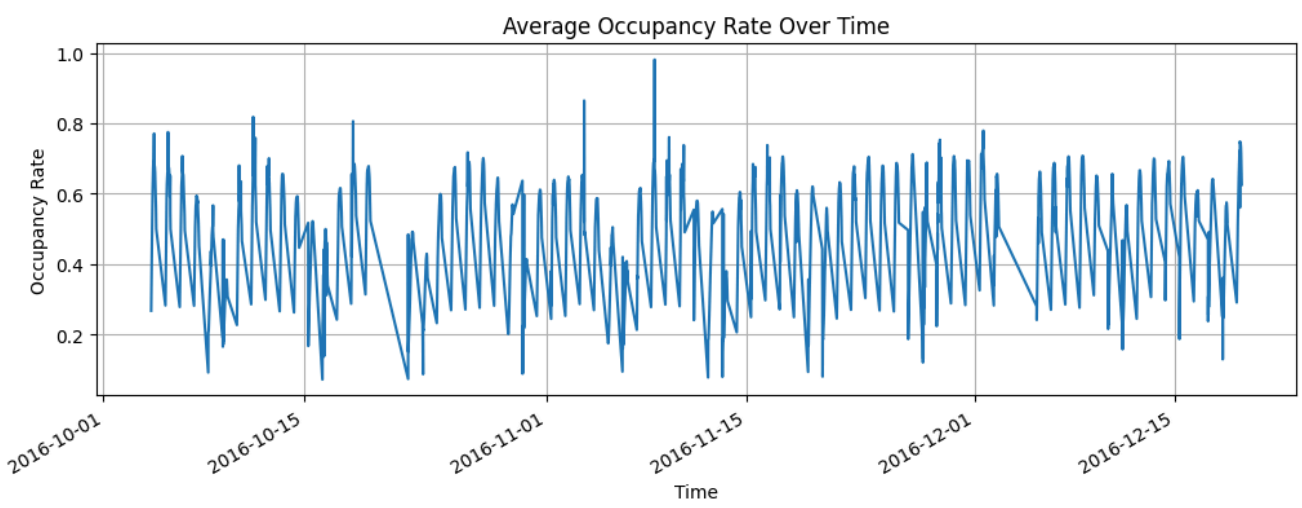
Occupancy vs Capacity

```
df['occupancy_rate'] = df['Occupancy']/df['Capacity']
df['occupancy_rate'].describe()
```

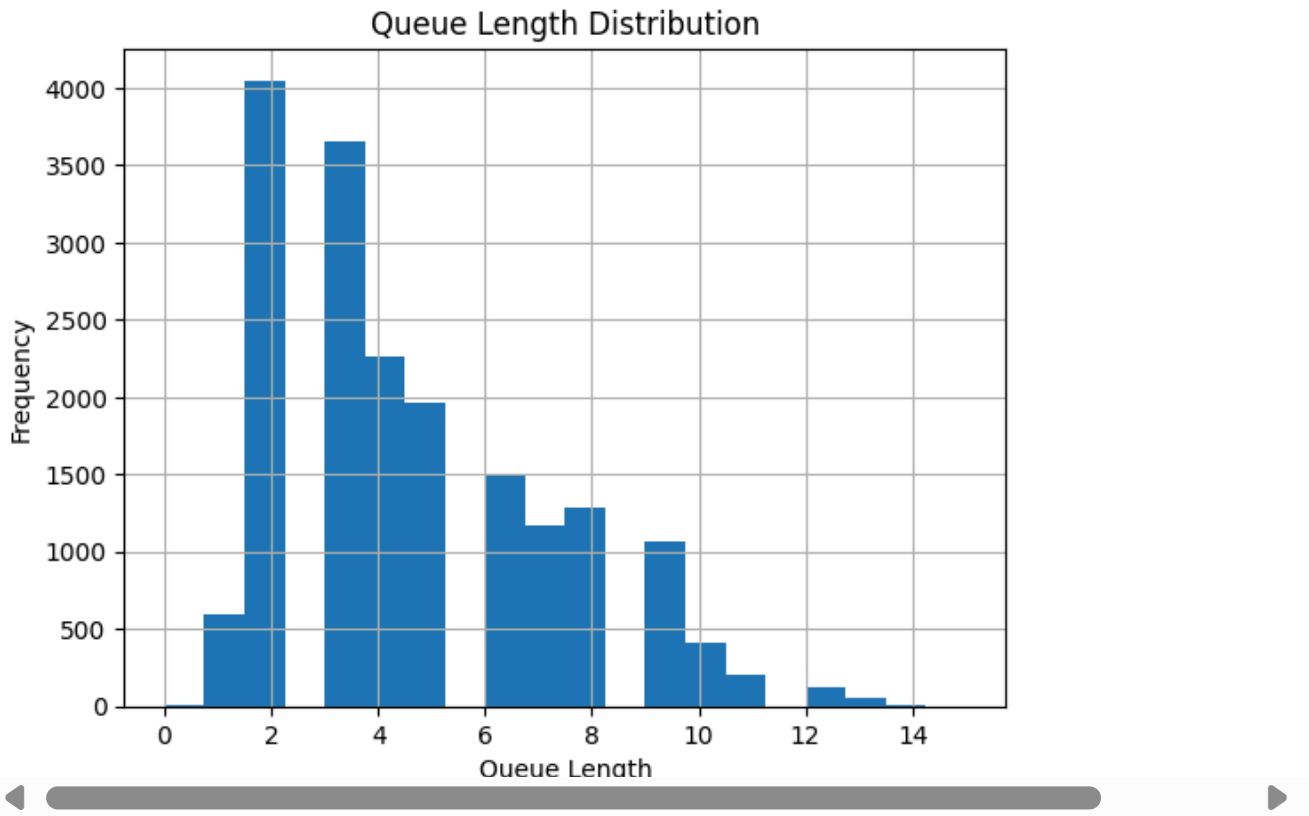
	occupancy_rate
count	18368.000000
mean	0.509119
std	0.246143
min	0.003466
25%	0.307110
50%	0.496124
75%	0.701031
max	1.041344

```
df.groupby('timestamp')['occupancy_rate'].mean().plot(figsize=(12,4))
plt.title('Average Occupancy Rate Over Time')
plt.xlabel('Time')
plt.ylabel('Occupancy Rate')
plt.grid()
plt.show()
```



Quee Lenght Distribution

```
df['QueueLength'].hist(bins=20)
plt.title('Queue Length Distribution')
plt.xlabel('Queue Length')
plt.ylabel('Frequency')
plt.show()
```

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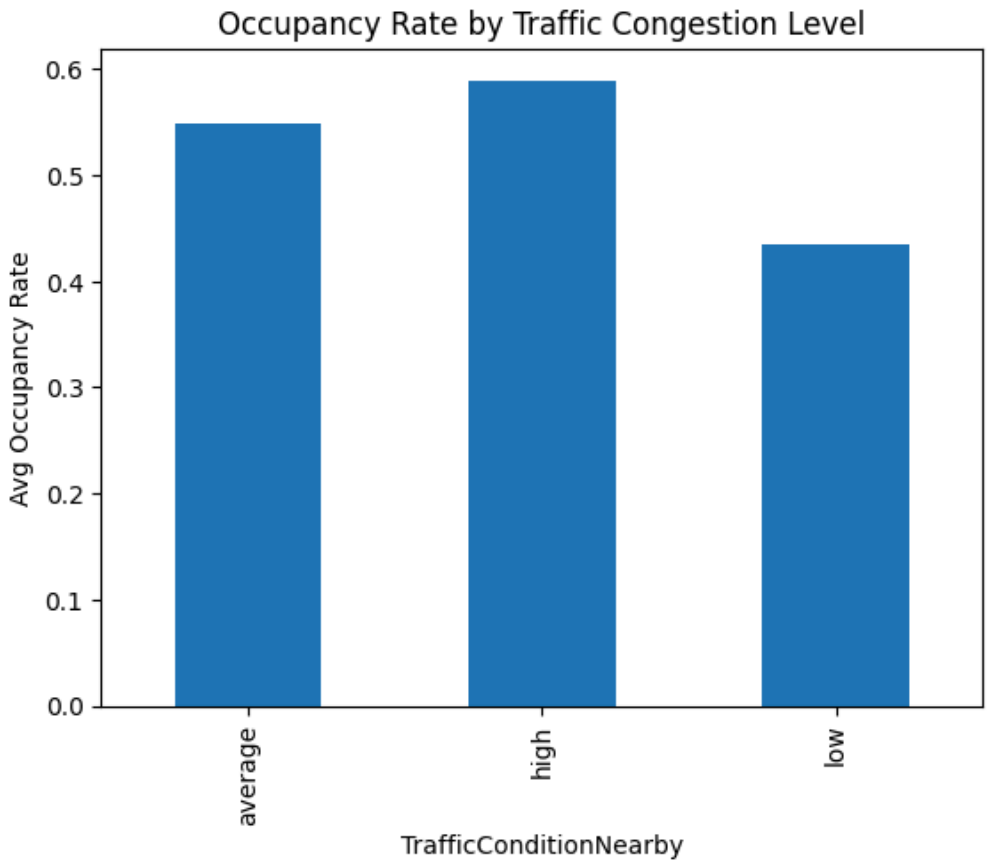
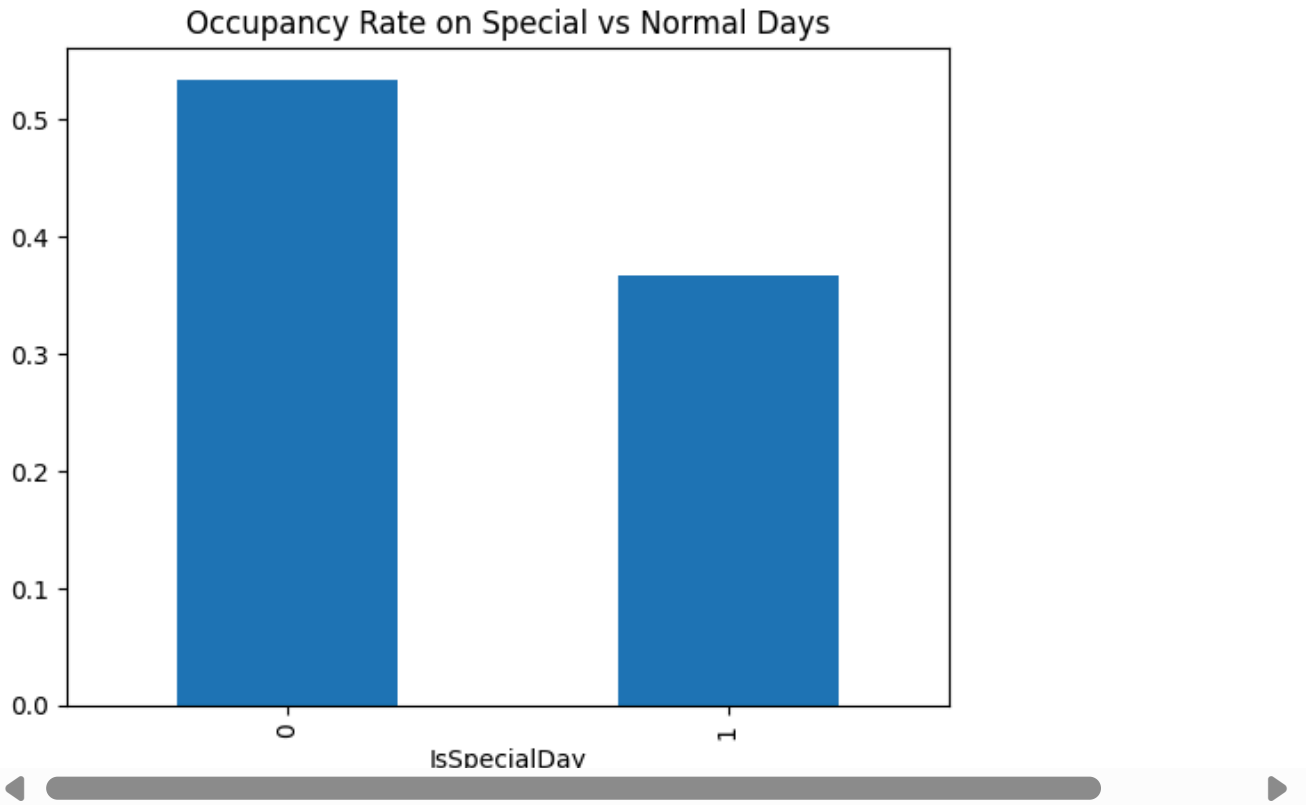
Traffic Congestion and special days

```
df.groupby('TrafficConditionNearby')['occupancy_rate'].mean().plot(kind='bar')
plt.title('Occupancy Rate by Traffic Congestion Level')
```

```
plt.ylabel('Avg Occupancy Rate')
plt.show()

df.groupby('IsSpecialDay')['occupancy_rate'].mean().plot(kind='bar')
plt.title('Occupancy Rate on Special vs Normal Days')
plt.show()
```





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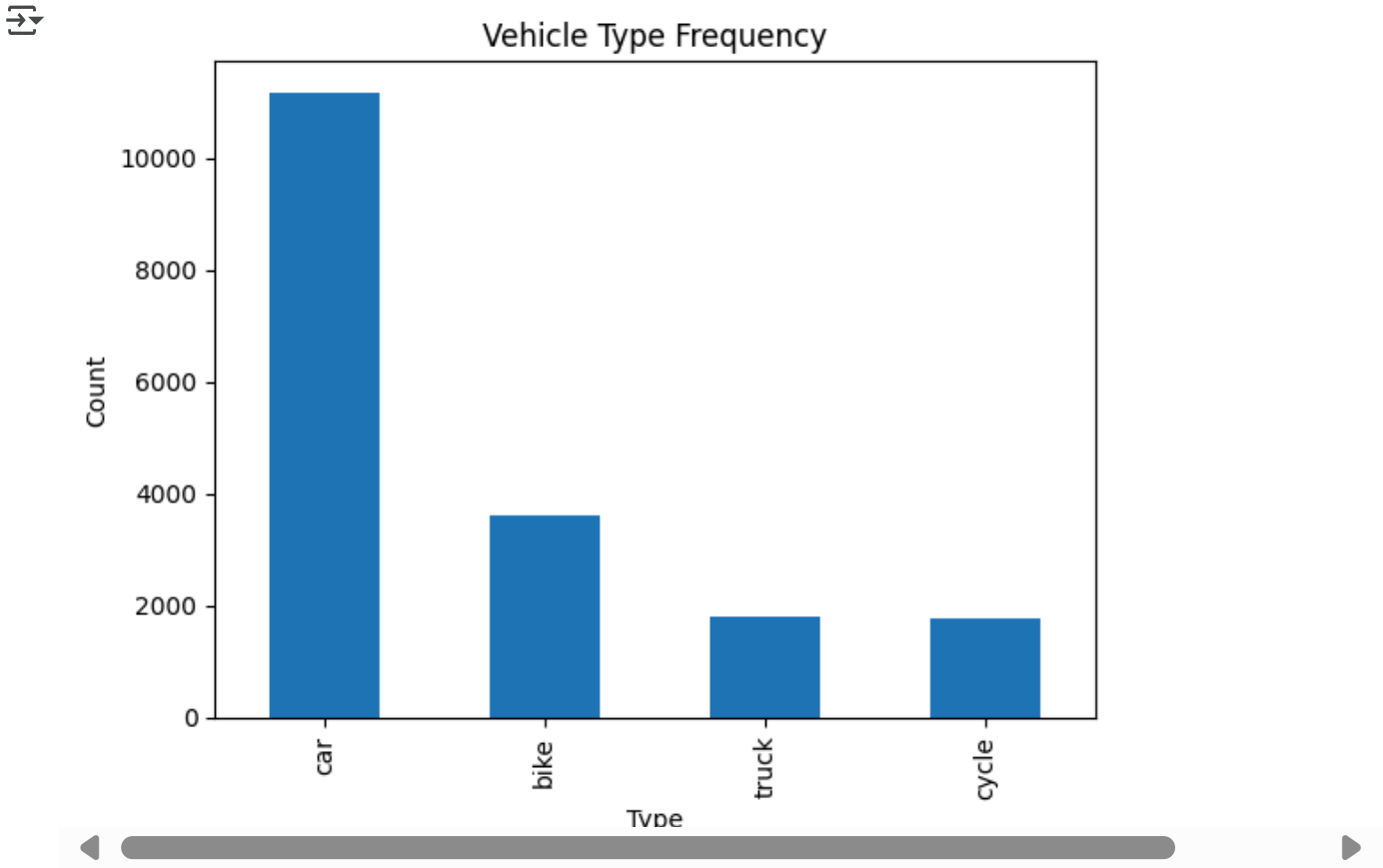
Vehical Type

```
df['VehicleType'].value_counts().plot(kind='bar')
plt.title('Vehicle Type Frequency')
plt.xlabel('Type')
plt.ylabel('Count')
plt.show()
```



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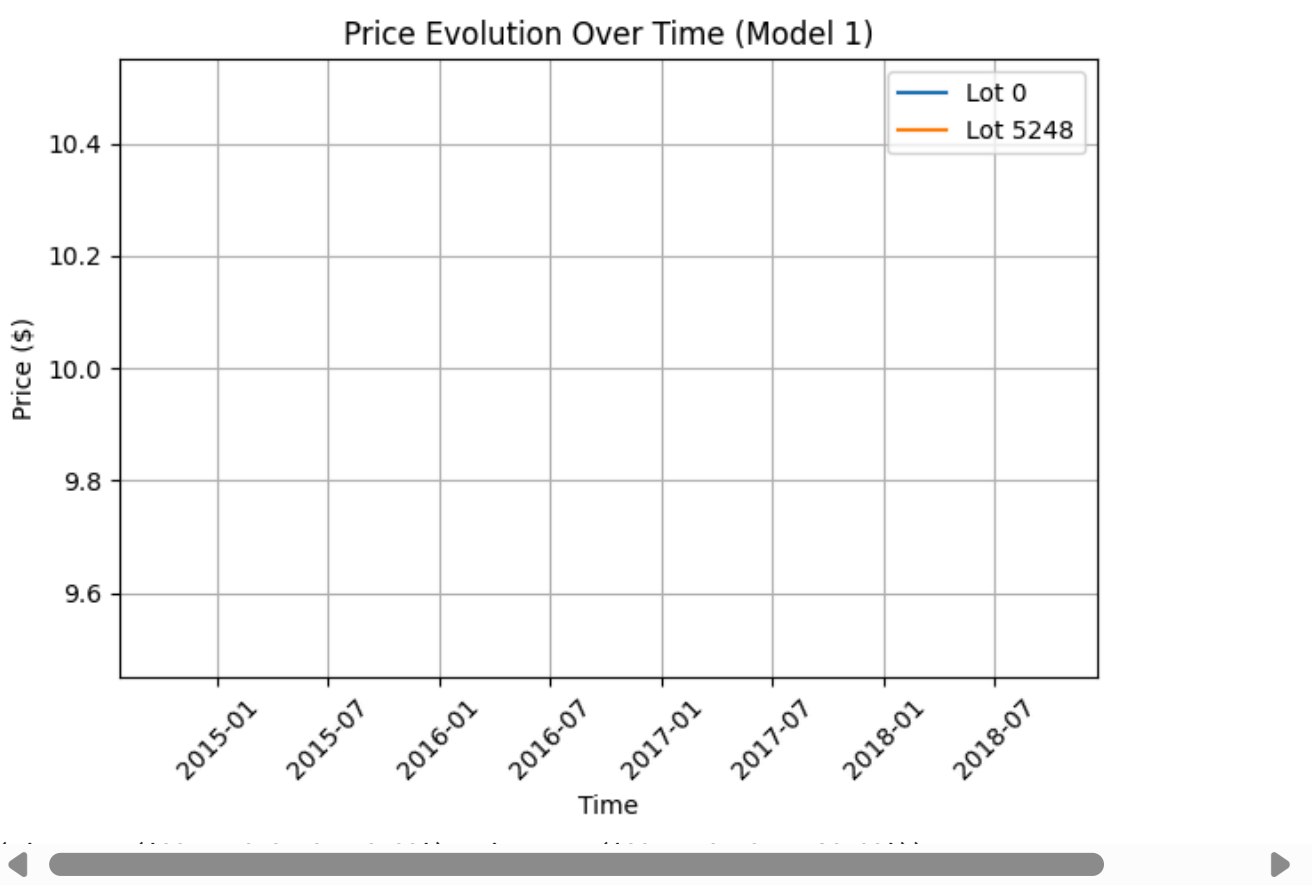
Model-1 Linera Pricing

```
df['price'] = 10.0

alpha = 0.5


for ID in df['ID'].unique():
    lot_df = df[df['ID'] == ID].copy()
    lot_df = lot_df.sort_values('timestamp')

    for i in range(1, len(lot_df)):
        occ_rate = lot_df.iloc[i-1]['occupancy'] / lot_df.iloc[i-1]['capacity']
        prev_price = lot_df.iloc[i-1]['price']
        new_price = prev_price + alpha * occ_rate
        df.loc[lot_df.index[i], 'price'] = new_price
```

```
sample_lots = df['ID'].unique()[:2]

for ID in sample_lots:
    temp = df[df['ID'] == ID]
    plt.plot(temp['timestamp'], temp['price'], label=f'Lot {ID}')

plt.title('Price Evolution Over Time (Model 1)')
plt.xlabel('Time')
plt.ylabel('Price ($)')
plt.legend()
plt.grid(True)
plt.xticks(rotation=45)
plt.tight_layout()
plt.show()
df['timestamp'].min(), df['timestamp'].max()
```



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Model-2 Demad_based pricing

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```
df['occupancy_rate'] = df['Occupancy'] / df['Capacity']

vehicle_weights = {'cycle': 0.5, 'bike': 1.0, 'car': 1.5, 'truck': 2.0}
```

```
df['vehicle_weight'] = df['VehicleType'].map(vehicle_weights)


traffic_map = {'low': 0, 'average': 1, 'high': 2}
df['traffic_level_encoded'] = df['TrafficConditionNearby'].map(traffic_map)



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a, b, c, d, e = 1.2, 0.8, 0.5, 0.7, 0.6

df['raw_demand'] = (
    a * df['occupancy_rate'] +
    b * df['QueueLength'] -
    c * df['traffic_level_encoded'] -
    d * df['IsSpecialDay'] +
    e * df['vehicle_weight']
)



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from sklearn.preprocessing import MinMaxScaler
scaler = MinMaxScaler()
df['normalized_demand'] = scaler.fit_transform(df[['raw_demand']])

lambda_ = 0.5
base_price = 10.0

df['price_model2'] = base_price * (1 + lambda_ * df['normalized_demand'])

df['price_model2'] = df['price_model2'].clip(lower=5, upper=20)



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for ID in df['ID'].unique()[:2]:
    temp = df[df['ID'] == ID]
    plt.plot(temp['timestamp'], temp['price_model2'], label=f'Lot {ID}')

plt.title("Price Evolution (Model 2)")
plt.xlabel("Time")
plt.ylabel("Price")
plt.legend()
plt.xticks(rotation=45)
plt.grid()
plt.tight_layout()
plt.show()
```

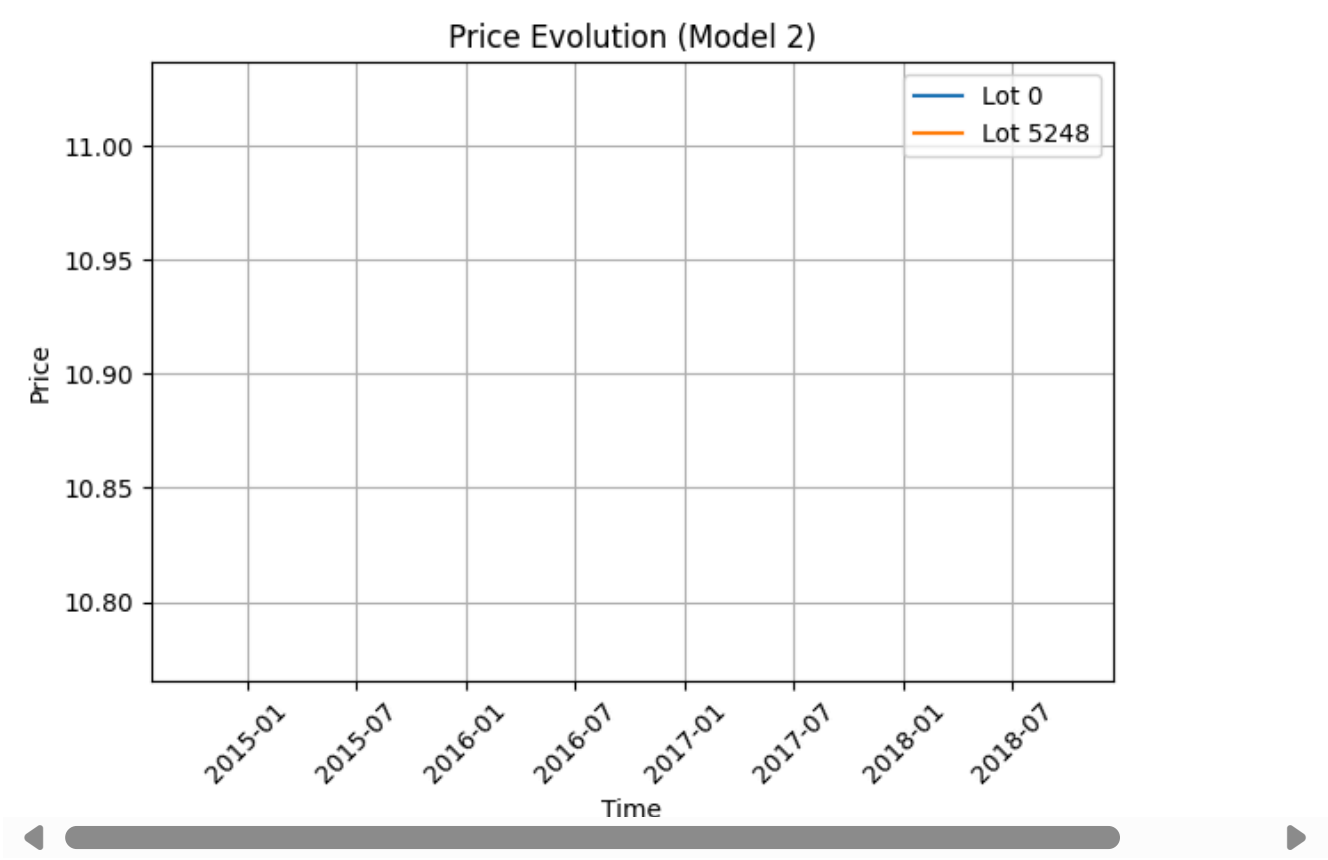

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Real Time Data Streaming Using Pathways

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Raed the streaming csv

```
stream = pw.demo.replay_csv(
    "/content/sample_data/dataset.csv",
    schema=pw.schema_from_csv("/content/sample_data/dataset.csv"),
    input_rate=1000
)
```

```
df.to_csv("stream.csv", index=False)
```

```
import pathway as pw

# Step A: Read CSV in streaming mode
stream = pw.demo.replay_csv(
    "stream.csv",
    schema=pw.schema_from_csv("stream.csv"),
    input_rate=1000  # 1 row per second
```

```
)


@pw.udf
def traffic_num(level: str) -> int:
    return {"low": 0, "average": 1, "high": 2}.get(level, 1)

@pw.udf
def vehicle_weight(v: str) -> float:
    return {"cycle": 0.5, "bike": 1.0, "car": 1.5, "truck": 2.0}.get(v, 1.0)

stream = stream.with_columns(
    occupancy_rate=stream.Occupancy / stream.Capacity,
    traffic_encoded=traffic_num(stream.TrafficConditionNearby),
    vehicle_weight=vehicle_weight(stream.VehicleType)
)



@pw.udf
def calc_price(occ_rate, queue, traffic, special, veh_wt) -> float:
    demand_raw = 1.2 * occ_rate + 0.8 * queue - 0.5 * traffic - 0.7 * special + 0.6 * veh_wt
    norm = min(1.0, max(0.0, (demand_raw - 1) / 4))
    price = 10.0 * (1 + 0.5 * norm)
    return round(min(20.0, max(5.0, price)), 2)

stream = stream.with_columns(predicted_price=calc_price(
    stream.occupancy_rate,
    stream.QueueLength,
    stream.traffic_encoded,
    stream.IsSpecialDay,
    stream.vehicle_weight
))



pw.io.jsonlines.write(stream.select(
    stream.timestamp,
    stream.ID,
    stream.predicted_price
), filename="output.json1")

pw.run()
```

Bokeh Visualisation

```
from bokeh.plotting import figure, show, output_notebook
from bokeh.models import ColumnDataSource
from bokeh.layouts import column
from bokeh.palettes import Category10

output_notebook()



sample_lots = df['ID'].unique()[:2]
```

```
sources = {}
for lot in sample_lots:
    temp = df[df['ID'] == lot].copy()
    temp = temp.sort_values('timestamp')
    temp['timestamp'] = pd.to_datetime(temp['timestamp'])

    sources[lot] = ColumnDataSource(temp)



p = figure(
    x_axis_type="datetime",
    title="Dynamic Price Evolution (Model 2)",
    width=800,
    height=400
)

colors = Category10[10]

for i, lot in enumerate(sample_lots):
    p.line(
        x='timestamp',
        y='price_model2',
        source=sources[lot],
        legend_label=f"Lot {lot}",
        line_width=2,
        color=colors[i]
    )

p.xaxis.axis_label = "Timestamp"
p.yaxis.axis_label = "Predicted Price ($)"
p.legend.location = "top_left"

show(p)
```