

```
!pip install pathway bokeh
```



Collecting pathway

Downloading pathway-0.24.1-cp310-abi3-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (60 kB)

60.4/60.4 kB 4.7 MB/s eta 0:00:00

Requirement already satisfied: bokeh in /usr/local/lib/python3.11/dist-packages (3.7.3)

Requirement already satisfied: aiohttp>=3.8.4 in /usr/local/lib/python3.11/dist-packages (from pathway) (3.11.15)

Requirement already satisfied: click>=8.1 in /usr/local/lib/python3.11/dist-packages (from pathway) (8.2.1)

Requirement already satisfied: geopy>=2.4.0 in /usr/local/lib/python3.11/dist-packages (from pathway) (2.4.1)

Collecting h3>=4 (from pathway)

Downloading h3-4.3.0-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl.metadata (18 kB)

Requirement already satisfied: numpy>=1.21 in /usr/local/lib/python3.11/dist-packages (from pathway) (2.0.0.2)

Requirement already satisfied: pandas>=2.1 in /usr/local/lib/python3.11/dist-packages (from pathway) (2.2.2)

Requirement already satisfied: scikit-learn>=1.0 in /usr/local/lib/python3.11/dist-packages (from pathway) (1.6.1)

Requirement already satisfied: shapely>=2.0.1 in /usr/local/lib/python3.11/dist-packages (from pathway) (2.1.1)

Requirement already satisfied: pyarrow<19.0.0,>=10.0.0 in /usr/local/lib/python3.11/dist-packages (from pathway) (18.1.0)

Requirement already satisfied: requests>=2.31.0 in /usr/local/lib/python3.11/dist-packages (from pathway) (2.32.3)

Collecting python-sat>=0.1.8.dev0 (from pathway)

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Collecting beartype<0.16.0,>=0.14.0 (from pathway)

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Collecting diskcache>=5.2.1 (from pathway)

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Collecting boto3<1.36.0,>=1.26.76 (from pathway)

Downloading boto3-1.35.99-py3-none-any.whl.metadata (6.7 kB)

Collecting aiobotocore==2.17.0 (from pathway)

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Requirement already satisfied: google-api-python-client>=2.108.0 in /usr/local/lib/python3.11/dist-packages (from pathway)

Requirement already satisfied: typing-extensions>=4.8.0 in /usr/local/lib/python3.11/dist-packages (from pathway) (4.14.0)

Requirement already satisfied: panel>=1.3.1 in /usr/local/lib/python3.11/dist-packages (from pathway) (1.7.2)

Collecting jupyter-bokeh>=3.0.7 (from pathway)

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Collecting jmespath>=1.0.1 (from pathway)

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Collecting aiohttp-cors>=0.7.0 (from pathway)

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Collecting opentelemetry-api>=1.22.0 (from pathway)

Downloading opentelemetry_api-1.34.1-py3-none-any.whl.metadata (1.5 kB)

Collecting opentelemetry-sdk>=1.22.0 (from pathway)

Downloading opentelemetry_sdk-1.34.1-py3-none-any.whl.metadata (1.6 kB)

Collecting opentelemetry-exporter-otlp-proto-grpc>=1.22.0 (from pathway)

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Collecting fs>=2.4.16 (from pathway)

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Collecting async-lru>=2.0.4 (from pathway)

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Requirement already satisfied: networkx>=3.2.1 in /usr/local/lib/python3.11/dist-packages (from pathway) (3.5)

Collecting google-cloud-pubsub>=2.21.1 (from pathway)

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Collecting google-cloud-bigquery~>=3.29.0 (from pathway)

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Collecting pydantic~>2.9.0 (from pathway)

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Requirement already satisfied: gitpython>=3.1.43 in /usr/local/lib/python3.11/dist-packages (from pathway) (3.1.44)

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Requirement already satisfied: multidict<7.0.0,>=6.0.0 in /usr/local/lib/python3.11/dist-packages (from aiobotocore==2.17)

Requirement already satisfied: urllib3!=2.2.0,<3,>=1.25.4 in /usr/local/lib/python3.11/dist-packages (from aiobotocore==2)

Requirement already satisfied: wrapt<2.0.0,>=1.10.10 in /usr/local/lib/python3.11/dist-packages (from aiobotocore==2.17.0->pathway)

Requirement already satisfied: Jinja2>=2.9 in /usr/local/lib/python3.11/dist-packages (from bokeh) (3.1.6)

Requirement already satisfied: contourpy>=1.2 in /usr/local/lib/python3.11/dist-packages (from bokeh) (1.3.2)

Requirement already satisfied: narwhals>=1.13 in /usr/local/lib/python3.11/dist-packages (from bokeh) (1.45.0)

Requirement already satisfied: packaging>=16.8 in /usr/local/lib/python3.11/dist-packages (from bokeh) (24.2)

Requirement already satisfied: pillow>=7.1.0 in /usr/local/lib/python3.11/dist-packages (from bokeh) (11.2.1)

Requirement already satisfied: PyYAML>=3.10 in /usr/local/lib/python3.11/dist-packages (from bokeh) (6.0.2)

Requirement already satisfied: tornado>=6.2 in /usr/local/lib/python3.11/dist-packages (from bokeh) (6.4.2)

Requirement already satisfied: xyzservices>=2021.09.1 in /usr/local/lib/python3.11/dist-packages (from bokeh) (2025.4.0)

Requirement already satisfied: aiohappyeyeballs>=2.3.0 in /usr/local/lib/python3.11/dist-packages (from aiohttp>=3.8.4->pathway)

Requirement already satisfied: aiosignal>=1.1.2 in /usr/local/lib/python3.11/dist-packages (from aiohttp>=3.8.4->pathway)

Requirement already satisfied: attrs>=17.3.0 in /usr/local/lib/python3.11/dist-packages (from aiohttp>=3.8.4->pathway) (25)

Requirement already satisfied: frozenlist>=1.1.1 in /usr/local/lib/python3.11/dist-packages (from aiohttp>=3.8.4->pathway)

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Requirement already satisfied: propcache>=0.2.0 in /usr/local/lib/python3.11/dist-packages (from aiohttp>=3.8.4->pathway)
Requirement already satisfied: yarl<2.0,>=1.17.0 in /usr/local/lib/python3.11/dist-packages (from aiohttp>=3.8.4->pathway)
INFO: pip is looking at multiple versions of boto3 to determine which version is compatible with other requirements. This
Collecting boto3<1.36.0,>=1.26.76 (from pathway)
    Downloading boto3-1.35.98-py3-none-any.whl.metadata (6.7 kB)
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Requirement already satisfied: setuptools in /usr/local/lib/python3.11/dist-packages (from fs>=2.4.16->pathway) (75.2.0)
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Requirement already satisfied: gitdb<5,>=4.0.1 in /usr/local/lib/python3.11/dist-packages (from gitpython>=3.1.43->pathway)
Requirement already satisfied: httplib2<1.0.0,>=0.19.0 in /usr/local/lib/python3.11/dist-packages (from google-api-python-
Requirement already satisfied: google-auth!=2.24.0,!2.25.0,<3.0.0,>=1.32.0 in /usr/local/lib/python3.11/dist-packages (fr
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Requirement already satisfied: google-api-core!=2.0.*,!2.1.*,!2.2.*,!2.3.0,<3.0.0,>=1.31.5 in /usr/local/lib/python3.11
Requirement already satisfied: uritemplate<5,>=3.0.1 in /usr/local/lib/python3.11/dist-packages (from google-api-python-cl
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Requirement already satisfied: grpcio<2.0.0,>=1.51.3 in /usr/local/lib/python3.11/dist-packages (from google-cloud-pubsub>
Requirement already satisfied: proto-plus<2.0.0,>=1.22.0 in /usr/local/lib/python3.11/dist-packages (from google-cloud-put
Requirement already satisfied: protobuf!=4.21.0,!4.21.1,!4.21.2,!4.21.3,!4.21.4,!4.21.5,<7.0.0,>=3.20.2 in /usr/local
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Requirement already satisfied: grpcio-status>=1.33.2 in /usr/local/lib/python3.11/dist-packages (from google-cloud-pubsub>
Requirement already satisfied: MarkupSafe>=2.0 in /usr/local/lib/python3.11/dist-packages (from Jinja2>=2.9->bokeh) (3.0.2
Collecting ipywidgets==8.* (from jupyter-bokeh>=3.0.7->pathway)
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Requirement already satisfied: traitlets>=4.3.1 in /usr/local/lib/python3.11/dist-packages (from ipywidgets==8.*->jupyter-
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Requirement already satisfied: googleapis-common-protos~1.52 in /usr/local/lib/python3.11/dist-packages (from openteleme
Collecting opentelemetry-exporter-otlp-proto-common==1.34.1 (from opentelemetry-exporter-otlp-proto-grpc>=1.22.0->pathway)
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Requirement already satisfied: charset-normalizer<4,>=2 in /usr/local/lib/python3.11/dist-packages (from requests>=2.31.0-
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Requirement already satisfied: zipp~=2.0 in /usr/local/lib/python3.11/dist-packages (from importlib-metadata>=8.0.0->pathway)

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Requirement already satisfied: zipp~=3.20 in /usr/local/lib/python3.11/dist-packages (from importlib-metadata<4.0.0,>=3.1)
Requirement already satisfied: mdurl~=0.1 in /usr/local/lib/python3.11/dist-packages (from markdown-it-py->panel>=1.3.1->pathway)
Requirement already satisfied: webencodings in /usr/local/lib/python3.11/dist-packages (from bleach->panel>=1.3.1->pathway)
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Collecting jedi>=0.16 (from ipython>=6.1.0->ipywidgets==8.*->jupyter-bokeh>=3.0.7->pathway)
    Downloading jedi-0.19.2-py2.py3-none-any.whl.metadata (22 kB)
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Downloading aiohttp_cors-0.8.1-py3-none-any.whl (25 kB)
Downloading asyncio_lru-2.0.5-py3-none-any.whl (6.1 kB)
Downloading beartype-0.15.0-py3-none-any.whl (777 kB)
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Downloading boto3-1.35.93-py3-none-any.whl (139 kB)
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Downloading ipywidgets-8.1.7-py3-none-any.whl (139 kB)
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Downloading opentelemetry_api-1.34.1-py3-none-any.whl (65 kB)
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Downloading opentelemetry_exporter_otlp_proto_grpc-1.34.1-py3-none-any.whl (18 kB)
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Downloading pydantic-2.9.2-py3-none-any.whl (434 kB)
    434.9/434.9 kB 30.5 MB/s eta 0:00:00
Downloading pydantic_core-2.23.4-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.whl (2.1 MB)
    2.1/2.1 kB 65.0 MB/s eta 0:00:00
Downloading python_sat-1.8.dev17-cp311-cp311-manylinux_2_17_x86_64.manylinux2014_x86_64.manylinux_2_28_x86_64.whl (2.7 MB)
    2.7/2.7 kB 72.0 MB/s eta 0:00:00
Downloading aioitertools-0.12.0-py3-none-any.whl (24 kB)
Downloading appdirs-1.4.4-py2.py3-none-any.whl (9.6 kB)
Downloading botocore-1.35.93-py3-none-any.whl (13.3 MB)
    13.3/13.3 kB 72.6 MB/s eta 0:00:00
Downloading s3transfer-0.10.4-py3-none-any.whl (83 kB)
    83.2/83.2 kB 7.8 MB/s eta 0:00:00
Downloading pyarrow_hotfix-0.7-py3-none-any.whl (7.9 kB)
Downloading comm-0.2.2-py3-none-any.whl (7.2 kB)
Downloading widgetsnbextension-4.0.14-py3-none-any.whl (2.2 MB)
    2.2/2.2 kB 64.8 MB/s eta 0:00:00
Downloading jedi-0.19.2-py2.py3-none-any.whl (1.6 MB)
    1.6/1.6 kB 53.7 MB/s eta 0:00:00
Installing collected packages: appdirs, widgetsnbextension, python-sat, pydantic-core, pyarrow-hotfix, opentelemetry-protoc
Attempting uninstall: widgetsnbextension
    Found existing installation: widgetsnbextension 3.6.10
    Uninstalling widgetsnbextension-3.6.10:
        Successfully uninstalled widgetsnbextension-3.6.10
    Attempting uninstall: pydantic-core

```

```
Found existing installation: pydantic_core 2.33.2
Uninstalling pydantic_core-2.33.2:
  Successfully uninstalled pydantic_core-2.33.2
Attempting uninstall: pydantic
  Found existing installation: pydantic 2.11.7
  Uninstalling pydantic-2.11.7:
    Successfully uninstalled pydantic-2.11.7
Attempting uninstall: ipywidgets
  Found existing installation: ipywidgets 7.7.1
  Uninstalling ipywidgets-7.7.1:
    Successfully uninstalled ipywidgets-7.7.1
Attempting uninstall: google-cloud-bigquery
  Found existing installation: google-cloud-bigquery 3.34.0
  Uninstalling google-cloud-bigquery-3.34.0:
    Successfully uninstalled google-cloud-bigquery-3.34.0
ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This behaviour bigframes 2.8.0 requires google-cloud-bigquery[bqstorage,pandas]>=3.31.0, but you have google-cloud-bigquery 3.29.0 which
Successfully installed aiohttpcortex-2.17.0 aiohttp-cors-0.8.1 aioitertools-0.12.0 appdirs-1.4.4 async-lru-2.0.5 beartype-0.
WARNING: The following packages were previously imported in this runtime:
[google]
You must restart the runtime in order to use newly installed versions.
```

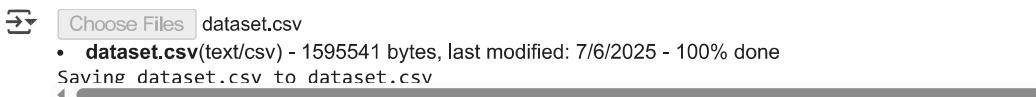
RESTART SESSION

```
import pandas as pd
import numpy as np
import pathway as pw
from bokeh.plotting import figure, show, output_notebook
from bokeh.io import push_notebook
from bokeh.layouts import column
import time
from IPython.display import display

output_notebook()
```



```
from google.colab import files
uploaded = files.upload()
```



```
import pandas as pd

df = pd.read_csv("dataset.csv") # No need for /content/ path if uploaded manually
print("Shape:", df.shape)
df.head()
```

→ Shape: (18368, 12)

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

Next steps: [Generate code with df](#) [View recommended plots](#) [New interactive sheet](#)

```
# Load the dataset (uploaded in the Files section)
df = pd.read_csv("/content/dataset.csv")

# Display basic structure
print("Shape:", df.shape)
df.head()
```

Shape: (18368, 12)

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

Next steps: [Generate code with df](#) [View recommended plots](#) [New interactive sheet](#)

```
# Add base price for each lot
df['Price'] = 10.0 # Base price

# Get list of all unique parking lot IDs (or use Lat-Long as unique ID)
df['LotID'] = df['Latitude'].astype(str) + "_" + df['Longitude'].astype(str)

# Sort by time (assuming there's a timestamp column or simulated time index)
df['TimeIndex'] = np.tile(np.arange(0, df.shape[0] // 14), 14)
df = df.sort_values(by=['TimeIndex', 'LotID']).reset_index(drop=True)
```

```
def linear_price_update(prev_price, occupancy, capacity, alpha=2):
    usage_ratio = occupancy / capacity if capacity > 0 else 0
    return prev_price + alpha * usage_ratio
```

```
import time
from bokeh.plotting import figure, show, output_notebook
from bokeh.io import push_notebook
from bokeh.layouts import column

output_notebook()

# Initialize storage
lot_prices = {}
price_history = {lot: [] for lot in df['LotID'].unique()}

# Setup Bokeh plots
plots = []
for lot in df['LotID'].unique():
    p = figure(title=f"Price Trend - Lot {lot}", width=400, height=300)
    p.line([], [], line_width=2, legend_label="Price", name="price_line")
    plots.append(p)
```

```
layout = column(*plots)
handle = show(layout, notebook_handle=True)
```

```
# Set number of time steps to simulate
max_steps = 10 # change this to more if needed
```

```
# Linear Pricing Function
def linear_price_update(prev_price, occupancy, capacity, alpha=2):
    usage_ratio = occupancy / capacity if capacity > 0 else 0
    return prev_price + alpha * usage_ratio
```

```
# Run real-time simulation
for t in range(min(df['TimeIndex'].max()) + 1, max_steps):
    current_time_slice = df[df['TimeIndex'] == t]

    for idx, row in current_time_slice.iterrows():
        lot = row['LotID']
        prev_price = lot_prices.get(lot, 10.0)
```

```

new_price = linear_price_update(prev_price, row['Occupancy'], row['Capacity'])
lot_prices[lot] = new_price
price_history[lot].append(new_price)

# Update plots
for i, lot in enumerate(df['LotID'].unique()):
    line = plots[i].select(name="price_line")[0]
    line.data_source.data = {
        'x': list(range(len(price_history[lot]))),
        'y': price_history[lot]
    }

push_notebook(handle=handle)
time.sleep(0.05) # fast visualization delay

```



```

# Vehicle weight mapping
vehicle_weights = {
    'car': 1.0,
    'bike': 0.5,
    'truck': 1.5
}

# Hyperparameters (tune these later)
alpha = 2.0
beta = 0.1
gamma = 0.3
delta = 1.0
epsilon = 0.5
lambda_ = 0.5 # price sensitivity to demand

# Base price
BASE_PRICE = 10.0

def demand_based_price(row, prev_price):
    # Extract features
    occ_ratio = row['Occupancy'] / row['Capacity'] if row['Capacity'] > 0 else 0
    queue = row['QueueLength']
    traffic = row['Traffic']
    is_special = row['IsSpecialDay']
    vehicle_type = row['VehicleType'].lower()

    # Assign vehicle type weight
    vehicle_weight = vehicle_weights.get(vehicle_type, 1.0)

    # Raw demand
    demand = (alpha * occ_ratio +
              beta * queue -
              gamma * traffic +
              delta * is_special +
              epsilon * vehicle_weight)

    # Normalize demand using sigmoid (to keep within [0,1])
    norm_demand = 1 / (1 + np.exp(-demand))

    # Price update formula
    new_price = BASE_PRICE * (1 + lambda_ * norm_demand)

    # Bound price between
    return max(5, min(20, new_price))

print(df.columns.tolist())

```

```
↳ ['ID', 'SystemCodeNumber', 'Capacity', 'Latitude', 'Longitude', 'Occupancy', 'VehicleType', 'TrafficConditionNearby', 'Que
```

```

def demand_based_price(row, prev_price):
    # Extract features
    occ_ratio = row['Occupancy'] / row['Capacity'] if row['Capacity'] > 0 else 0
    queue = row['QueueLength']
    traffic = row['TrafficConditionNearby'] #  corrected
    is_special = row['IsSpecialDay']
    vehicle_type = row['VehicleType'].lower()

    # Assign vehicle type weight
    vehicle_weight = vehicle_weights.get(vehicle_type, 1.0)

    # Raw demand score
    demand = (alpha * occ_ratio +
               beta * queue -
               gamma * traffic +
               delta * is_special +
               epsilon * vehicle_weight)

    # Normalize demand (sigmoid)
    norm_demand = 1 / (1 + np.exp(-demand))

    # Compute price
    new_price = BASE_PRICE * (1 + lambda_ * norm_demand)

    # Bound the price
    return max(5, min(20, new_price))

# STEP 1: Data Cleaning (do this once after loading the dataset)
df['TrafficConditionNearby'] = pd.to_numeric(df['TrafficConditionNearby'], errors='coerce').fillna(0)
df['QueueLength'] = pd.to_numeric(df['QueueLength'], errors='coerce').fillna(0)
df['IsSpecialDay'] = pd.to_numeric(df['IsSpecialDay'], errors='coerce').fillna(0)
df['Occupancy'] = pd.to_numeric(df['Occupancy'], errors='coerce').fillna(0)
df['Capacity'] = pd.to_numeric(df['Capacity'], errors='coerce').fillna(1) # Avoid division by zero

# STEP 2: Parameters & Vehicle Mapping
vehicle_weights = {
    'car': 1.0,
    'bike': 0.5,
    'truck': 1.5
}

alpha = 2.0
beta = 0.1
gamma = 0.3
delta = 1.0
epsilon = 0.5
lambda_ = 0.5
BASE_PRICE = 10.0

# STEP 3: Demand-based price update function
def demand_based_price(row, prev_price):
    occ_ratio = row['Occupancy'] / row['Capacity'] if row['Capacity'] > 0 else 0
    queue = row['QueueLength']
    traffic = row['TrafficConditionNearby']
    is_special = row['IsSpecialDay']
    vehicle_type = row['VehicleType'].lower()
    vehicle_weight = vehicle_weights.get(vehicle_type, 1.0)

    # Demand calculation
    demand = (alpha * occ_ratio +
               beta * queue -
               gamma * traffic +
               delta * is_special +
               epsilon * vehicle_weight)
```

```

# Normalize demand
norm_demand = 1 / (1 + np.exp(-demand)) # Sigmoid

# Calculate price
new_price = BASE_PRICE * (1 + lambda_ * norm_demand)

# Clip to bounds
return max(5, min(20, new_price))

import time
from bokeh.plotting import figure, show, output_notebook
from bokeh.io import push_notebook
from bokeh.layouts import column

output_notebook()

# Reset storage
lot_prices = {}
price_history = {lot: [] for lot in df['LotID'].unique()}

# Setup Bokeh plots
plots = []
renderers = []

for lot in df['LotID'].unique():
    p = figure(title=f"Model 2: Price Trend - Lot {lot}",
               width=400, height=250,
               x_axis_label='Time Step',
               y_axis_label='Price ($)')
    r = p.line([], [], line_width=2, legend_label="Price", name="price_line")
    plots.append(p)
    renderers.append(r)

layout = column(*plots)
handle = show(layout, notebook_handle=True)

# Simulate up to 10 steps (change as needed)
max_steps = 10

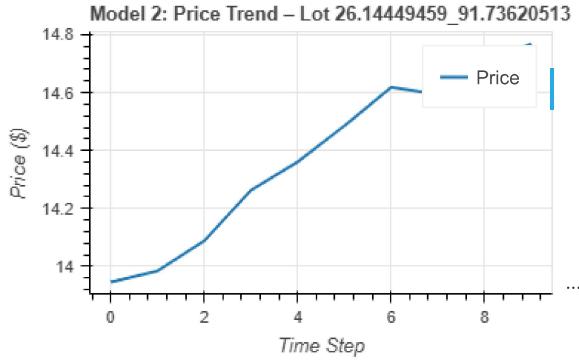
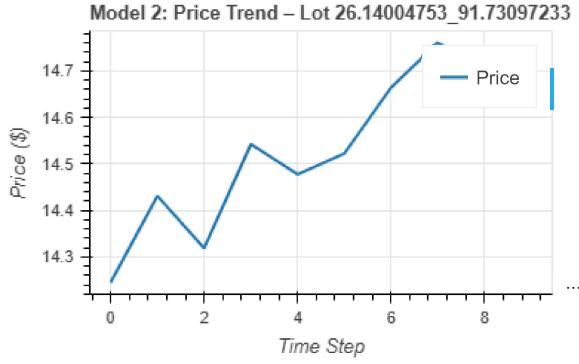
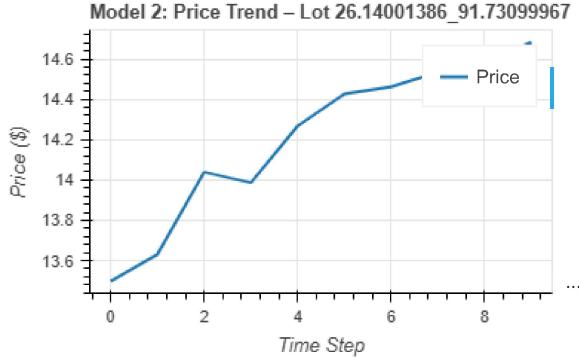
for t in range(min(df['TimeIndex'].max() + 1, max_steps)):
    current_time_slice = df[df['TimeIndex'] == t]

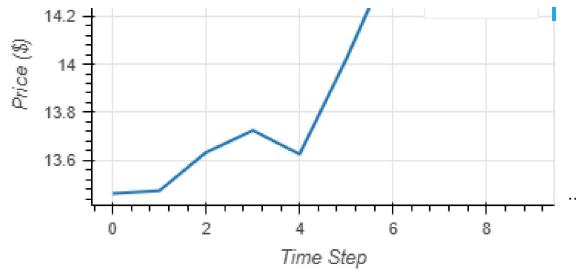
    for idx, row in current_time_slice.iterrows():
        lot = row['LotID']
        prev_price = lot_prices.get(lot, BASE_PRICE)
        new_price = demand_based_price(row, prev_price)
        lot_prices[lot] = new_price
        price_history[lot].append(new_price)

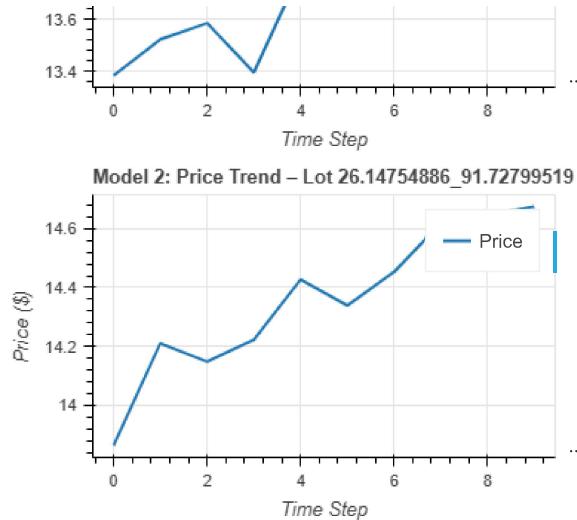
    # Update plots
    for i, lot in enumerate(df['LotID'].unique()):
        r = renderers[i]
        r.data_source.data = {
            'x': list(range(len(price_history[lot]))),
            'y': price_history[lot]
        }

push_notebook(handle=handle)
time.sleep(0.05)

```







```
from math import radians, cos, sin, asin, sqrt

def haversine(lat1, lon1, lat2, lon2):
    R = 6371 # Earth radius in km
    lat1, lon1, lat2, lon2 = map(radians, [lat1, lon1, lat2, lon2])
    dlat = lat2 - lat1
    dlon = lon2 - lon1
    a = sin(dlat/2)**2 + cos(lat1) * cos(lat2) * sin(dlon/2)**2
    c = 2 * asin(sqrt(a))
    return R * c # in kilometers

# Build a competitor map: for each lot, list nearby lots within 1 km
competitor_map = {}

unique_lots = df[['LotID', 'Latitude', 'Longitude']].drop_duplicates()

for idx1, row1 in unique_lots.iterrows():
    lots = []
    for idx2, row2 in unique_lots.iterrows():
        if idx1 != idx2:
            distance = haversine(row1['Latitude'], row1['Longitude'], row2['Latitude'], row2['Longitude'])
            if distance <= 1:
                lots.append(row2['LotID'])
    competitor_map[row1['LotID']] = lots
```