Demand Forecasting: Predict Future Demand for Products to Optimize Inventory Management and Supply Chains Using Machine Learning

This project will try to forecast the demand of a meal delivery company. They have various fulfillment centers in these cities for dispatching meal orders to their customers. The client wants help in demand forecasting for upcoming weeks so that these centers will plan the stock of raw materials accordingly.

The replenishment of majority of raw materials is done on weekly basis and since the raw material is perishable, the procurement planning is of utmost importance. Secondly, staffing of the centers is also one area wherein accurate demand forecasts are really helpful. Given the following information, the task is to build a predictive model to predict the demand for the company. Below are the information of the datasets:

- `train.csv` : Contains the historical demand data for all centers
- `fulfilment_center_info.csv` : Contains information for each fulfillment center
- `meal_info.csv` : Contains information for each meal being served

The link to the datase: *https://www.kaggle.com/datasets/ghoshsaptarshi/av-genpact-hack-dec2018*

Import necessary libraries

In [1]:
```
import numpy as np
import pandas as pd
import random
from scipy import stats
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.ensemble import RandomForestRegressor
from sklearn.datasets import load_iris
from sklearn.model_selection import train_test_split, GridSearchCV
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_absolute_error, mean_squared_error, r2_score, conf
import tensorflow as tf
from tensorflow.keras import Sequential
from tensorflow.keras.layers import Dense, Dropout
from tensorflow.keras.callbacks import EarlyStopping
from tensorflow.keras.losses import Huber
import keras_tuner as kt
import lightgbm as lgb
import optuna
```

```
C:\Users\PC\anaconda3\envs\gpu_env\lib\site-packages\tqdm\auto.py:21: TqdmWarning: I
Progress not found. Please update jupyter and ipywidgets. See https://ipywidgets.rea
dthedocs.io/en/stable/user_install.html
  from .autonotebook import tqdm as notebook_tqdm
```

Data Loading & Merging

In this section we:

1. Read in the raw CSV files (`train.csv` , `meal_info.csv` , `fulfilment_center_info.csv`).
2. Merge them into a single DataFrame on the `meal_id` and `centre_id` keys.
3. Take an initial look at the combined dataset's shape and key columns.

In [2]:
```
train = pd.read_csv("train.csv")
meal_info = pd.read_csv("meal_info.csv")
fulfilment_center_info = pd.read_csv("fulfilment_center_info.csv")
```

In [3]:
```
train = train.merge(meal_info, on='meal_id', how='left')
train = train.merge(fulfilment_center_info, on='center_id', how='left')
# Select 10% of the dataset randomly
train = train.sample(frac=0.1, random_state=42)
```

In [4]:
```
train.head()
```

Out[4]:

	id	week	center_id	meal_id	checkout_price	base_price	emailer_for_promot
203536	1078631	68	177	1962	639.23	641.23	
301801	1234949	98	29	2707	177.57	177.57	
254032	1160043	84	83	2640	282.33	280.33	
339158	1342057	110	124	2304	474.39	474.39	
3203	1108055	2	52	2539	133.92	133.92	

In [5]:
```
train.to_csv('merged.csv', index = False)
```

In [6]:
```
merged = pd.read_csv('merged.csv')
```

Exploratory Data Analysis (EDA)

Here we explore the merged dataset to understand:

- Distribution of the target variable (`num_orders`).
- Trends and seasonality across weeks and centres.
- Missing values and basic summary statistics.
- Correlations between features and the target.

Descriptive Statistics

In [7]:
```
merged.describe(include = 'all')
```

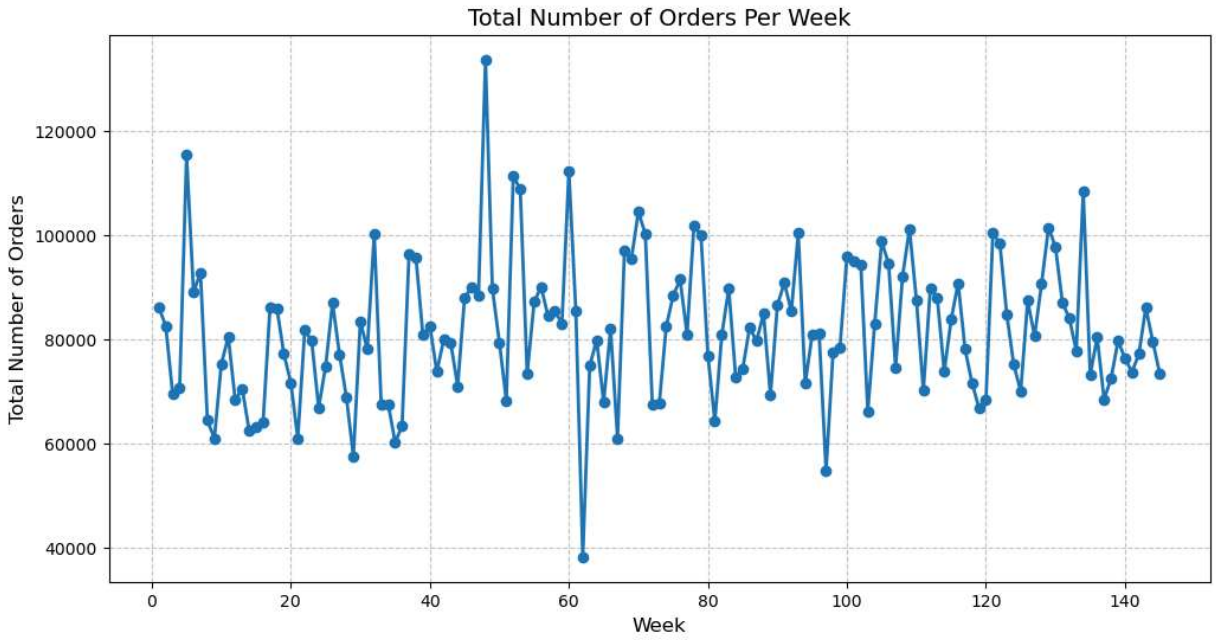
Out[7]:

	id	week	center_id	meal_id	checkout_price	base_p
count	4.565500e+04	45655.000000	45655.000000	45655.000000	45655.000000	45655.000
unique	NaN	NaN	NaN	NaN	NaN	N
top	NaN	NaN	NaN	NaN	NaN	N
freq	NaN	NaN	NaN	NaN	NaN	N
mean	1.249944e+06	75.022758	82.244113	2023.393144	331.852813	353.790
std	1.438026e+05	41.557672	46.051258	545.226512	152.645773	160.502
min	1.000002e+06	1.000000	10.000000	1062.000000	47.590000	87.300
25%	1.125852e+06	40.000000	43.000000	1558.000000	228.980000	243.500
50%	1.248770e+06	76.000000	76.000000	1971.000000	295.850000	310.430
75%	1.374996e+06	111.000000	110.000000	2539.000000	445.230000	461.735
max	1.499983e+06	145.000000	186.000000	2956.000000	767.330000	865.270

Uni-variate visualization

Total Number of Orders Per Week

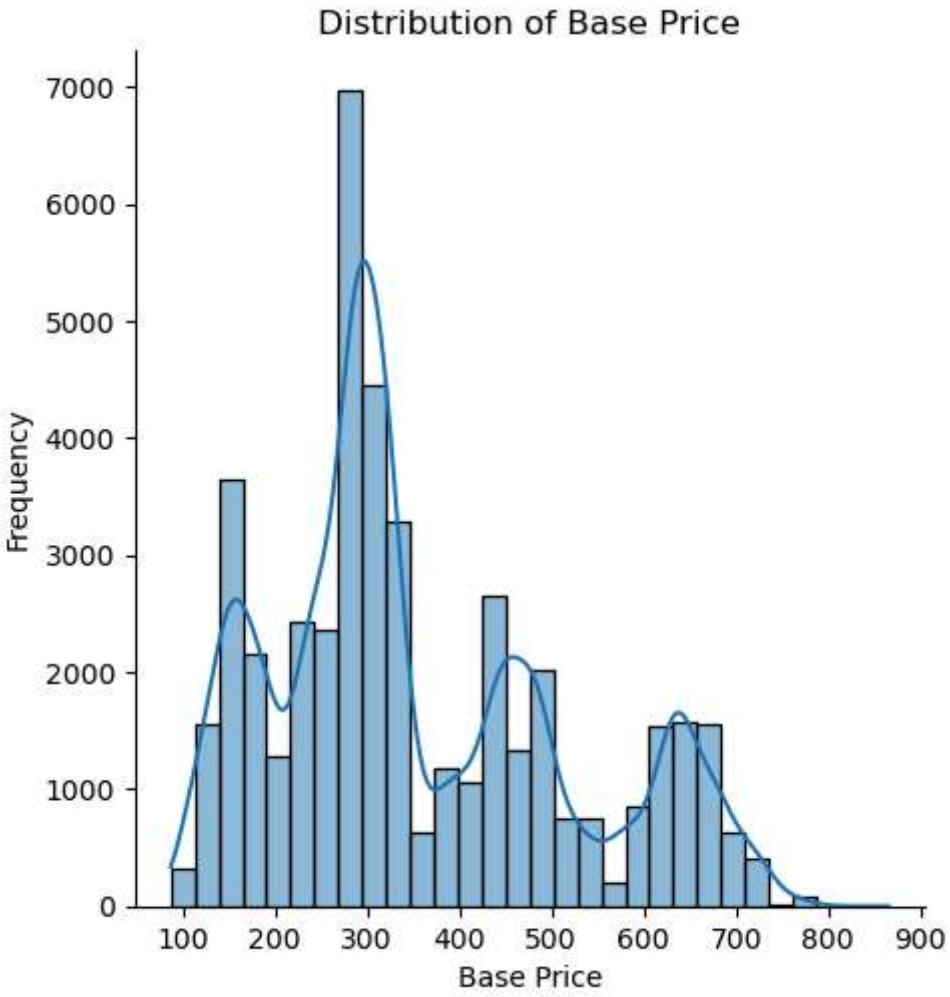
In [8]:
```
# Aggregating the total number of orders per week
orders_per_week = merged.groupby('week')['num_orders'].sum().reset_index()

# Plotting a line graph for total number of orders per week
plt.figure(figsize=(12, 6))
plt.plot(orders_per_week['week'], orders_per_week['num_orders'], marker = 'o', line
plt.title("Total Number of Orders Per Week", fontsize = 14)
plt.xlabel("Week", fontsize = 12)
plt.ylabel("Total Number of Orders", fontsize = 12)
plt.grid(axis = 'both', linestyle = '--', alpha = 0.7)
plt.xticks(fontsize = 10)
plt.yticks(fontsize = 10)
plt.show()
```



Distribution of Base Price

In [9]:
```
plt.figure(figsize = (10, 6))
sns.displot(merged['base_price'], kde = True, bins = 30)
plt.title('Distribution of Base Price')
plt.xlabel('Base Price')
plt.ylabel('Frequency')
plt.show()
```

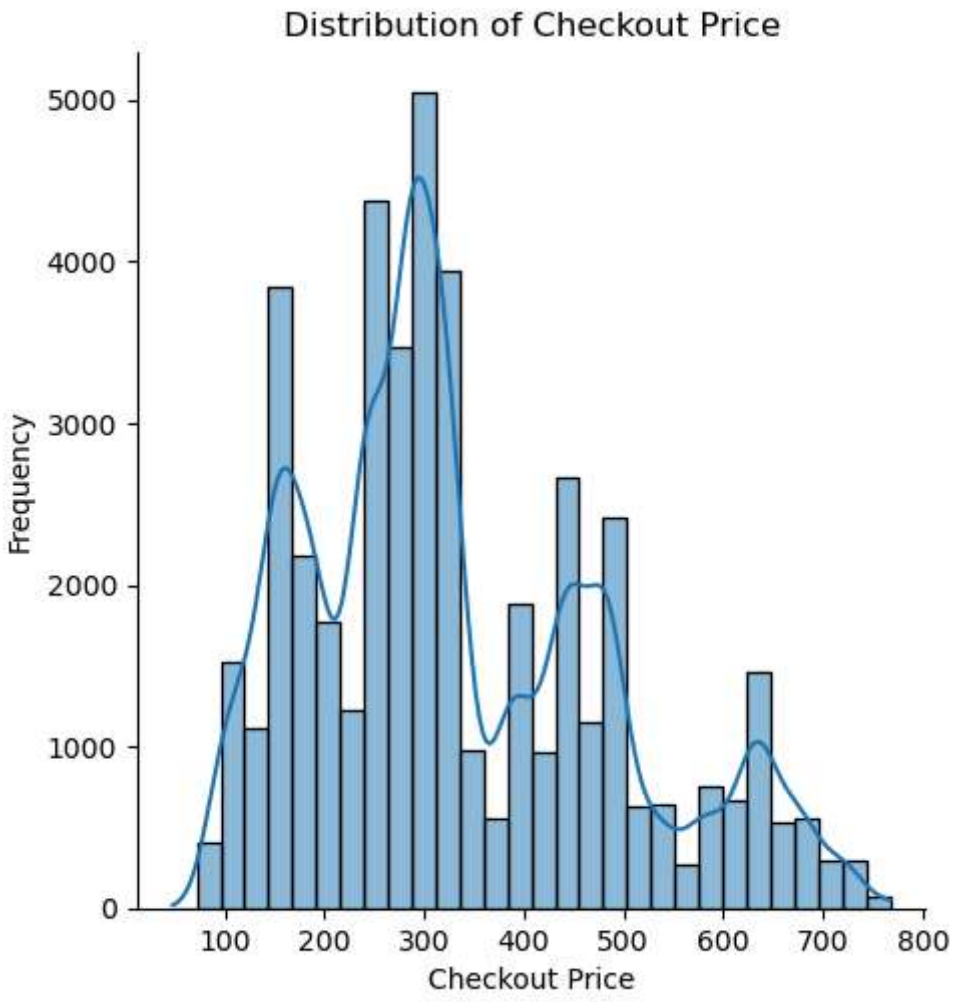
```
<Figure size 1000x600 with 0 Axes>
```



Distribution of Checkout Price

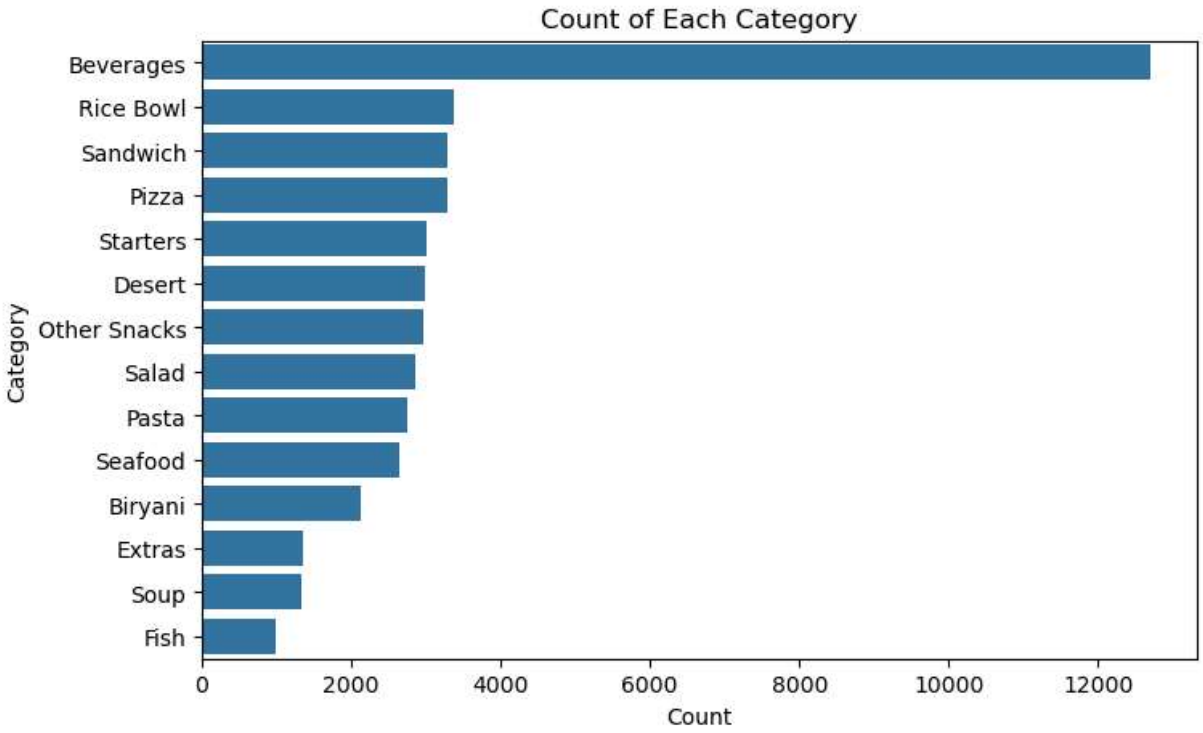
In [10]:
```
plt.figure(figsize = (10, 6))
sns.displot(merged['checkout_price'], kde = True, bins = 30)
plt.title('Distribution of Checkout Price')
plt.xlabel('Checkout Price')
plt.ylabel('Frequency')
plt.show()
```

```
<Figure size 1000x600 with 0 Axes>
```



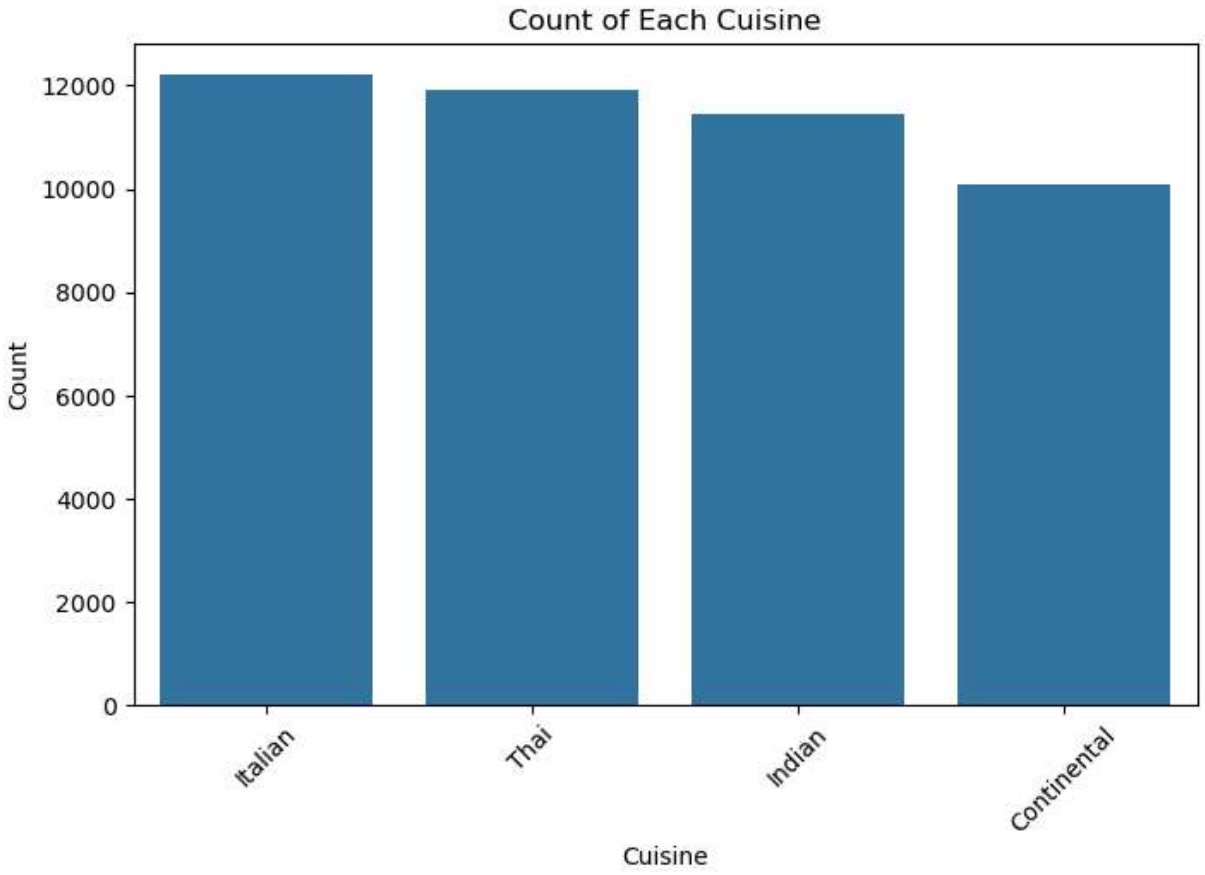
Distribution of Category

In [11]:
```
plt.figure(figsize = (8, 5))
sns.countplot(y = merged['category'], order = merged['category'].value_counts().ind
plt.title('Count of Each Category')
plt.xlabel('Count')
plt.ylabel('Category')
plt.show()
```



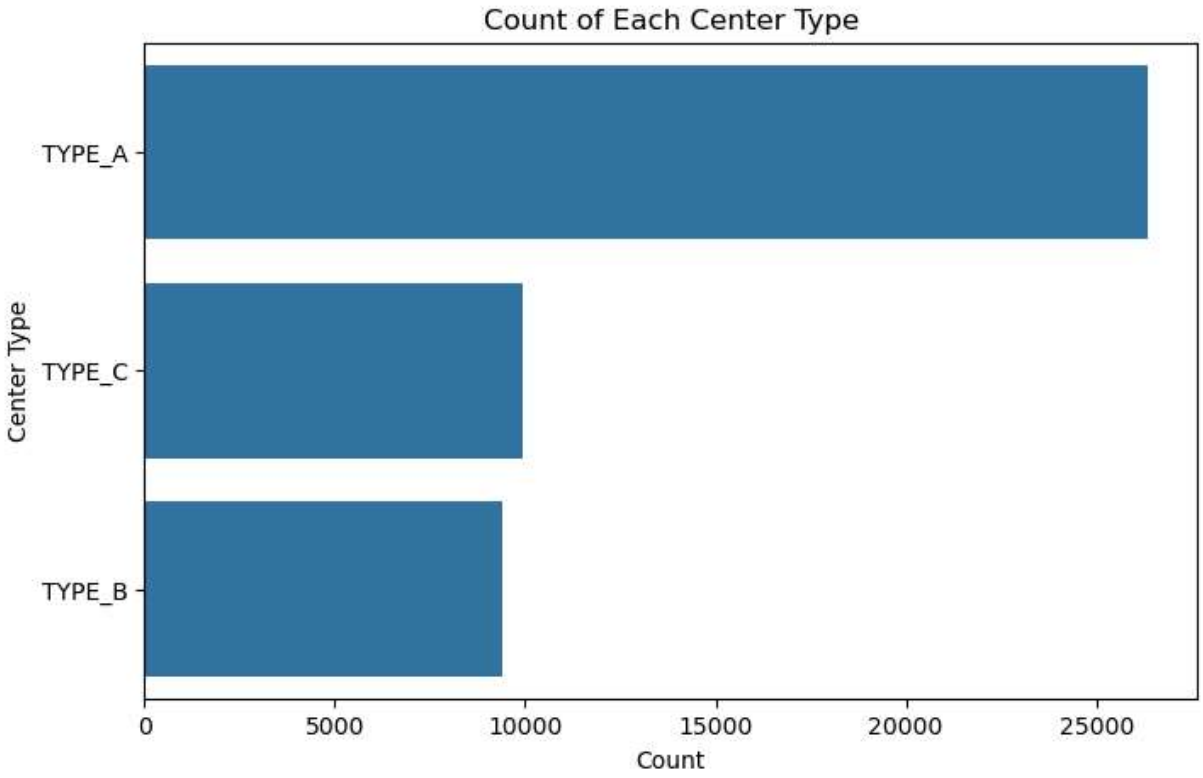
Distribution of Cuisine

In [12]:
```
plt.figure(figsize = (8, 5))
sns.countplot(x = merged['cuisine'], order = merged['cuisine'].value_counts().index
plt.title('Count of Each Cuisine')
plt.xlabel('Cuisine')
plt.ylabel('Count')
plt.xticks(rotation = 45)
plt.show()
```



Distribution of Center Type

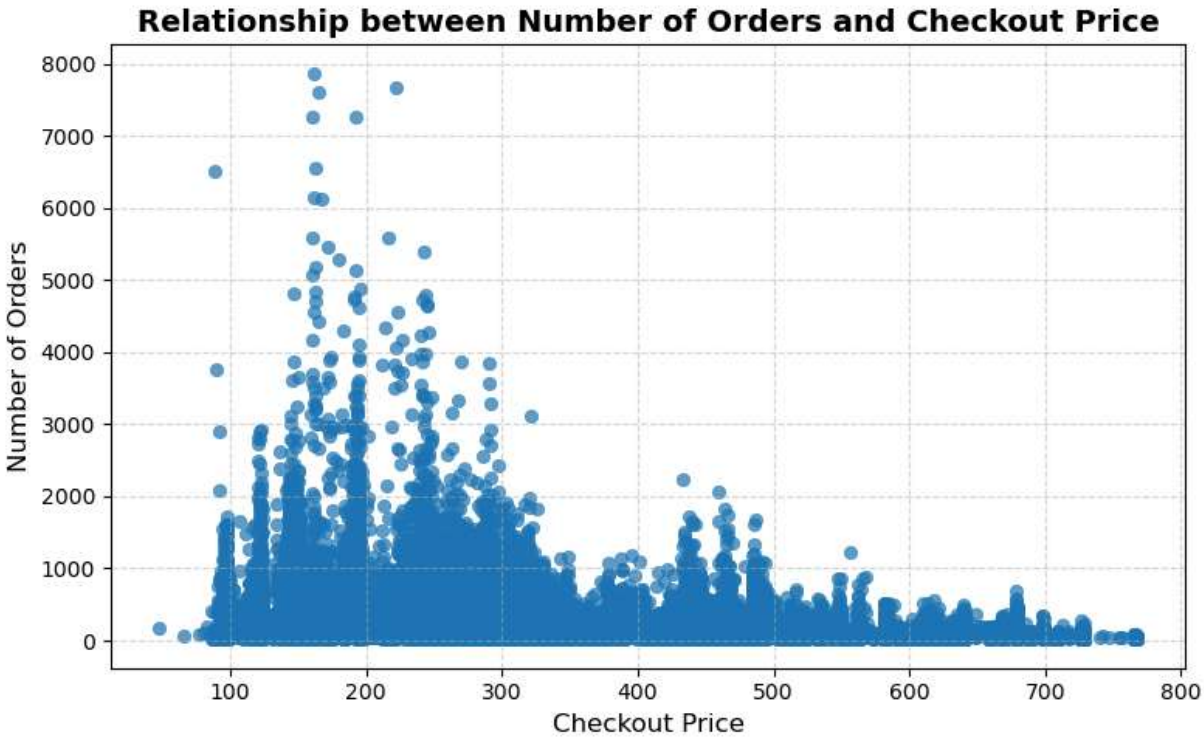
In [13]:
```
plt.figure(figsize = (8, 5))
sns.countplot(y = merged['center_type'], order = merged['center_type'].value_counts
plt.title('Count of Each Center Type')
plt.xlabel('Count')
plt.ylabel('Center Type')
plt.show()
```



BI-variate Visualizations

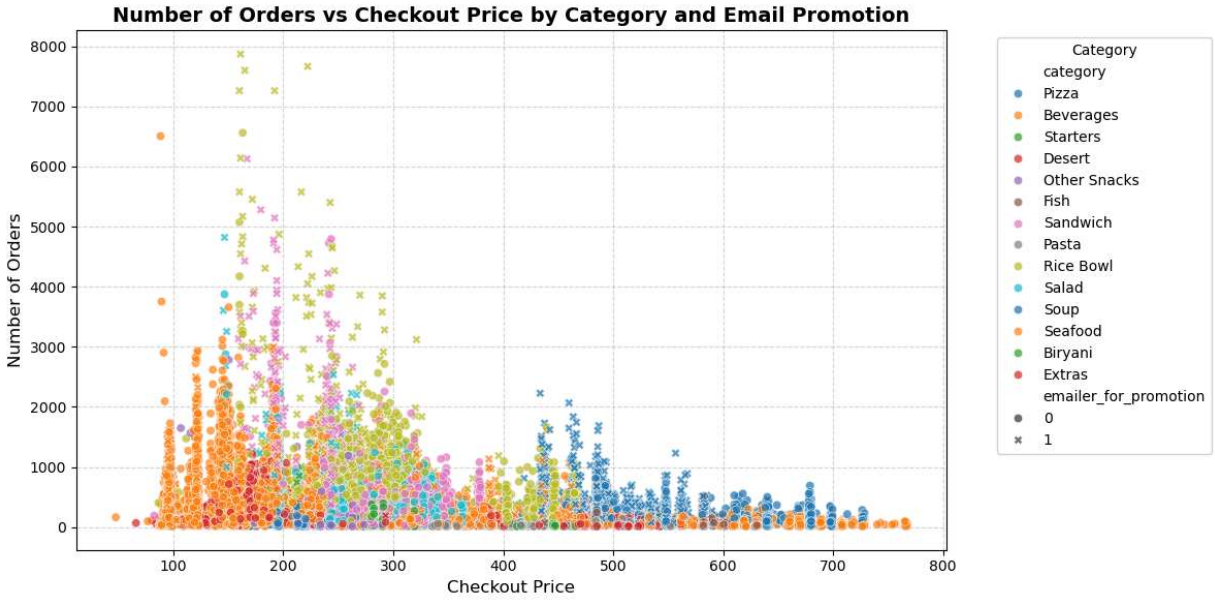
Number of Orders vs Checkout Price

In [14]:
```
plt.figure(figsize = (8, 5))
sns.scatterplot(x = merged['checkout_price'], y = merged['num_orders'], alpha = 0.7
plt.title('Relationship between Number of Orders and Checkout Price', fontsize = 14
plt.xlabel('Checkout Price', fontsize = 12)
plt.ylabel('Number of Orders', fontsize = 12)
plt.grid(visible = True, linestyle = '--', alpha = 0.5)
plt.tight_layout()
plt.show()
```



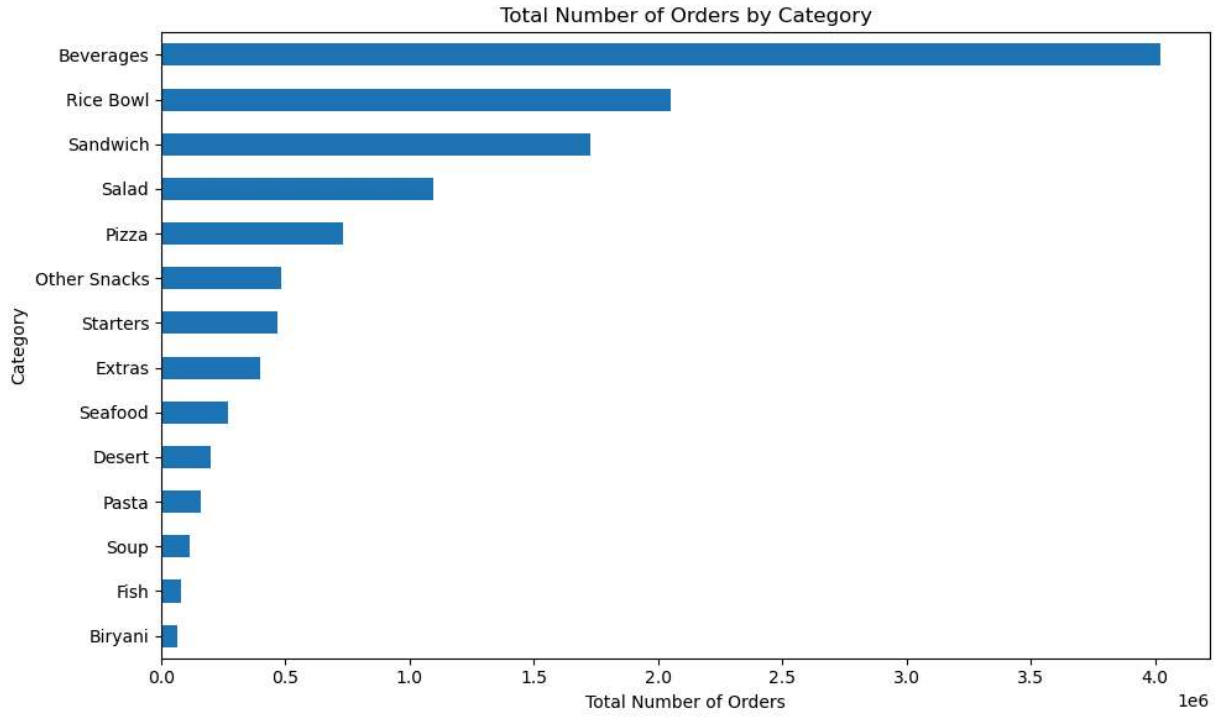
Number of Orders versus Checkout Price by Category and Email Promotion

In [15]:
```
plt.figure(figsize=(12, 6))
sns.scatterplot(
    x = merged['checkout_price'],
    y = merged['num_orders'],
    hue = merged['category'],
    style = merged['emailer_for_promotion'],
    palette = 'tab10',
    alpha = 0.7
)
plt.title('Number of Orders vs Checkout Price by Category and Email Promotion', fon
plt.xlabel('Checkout Price', fontsize = 12)
plt.ylabel('Number of Orders', fontsize = 12)
plt.legend(title ='Category', bbox_to_anchor = (1.05, 1), loc = 'upper left')
plt.grid(visible = True, linestyle = '--', alpha = 0.5)
plt.tight_layout()
plt.show()
```



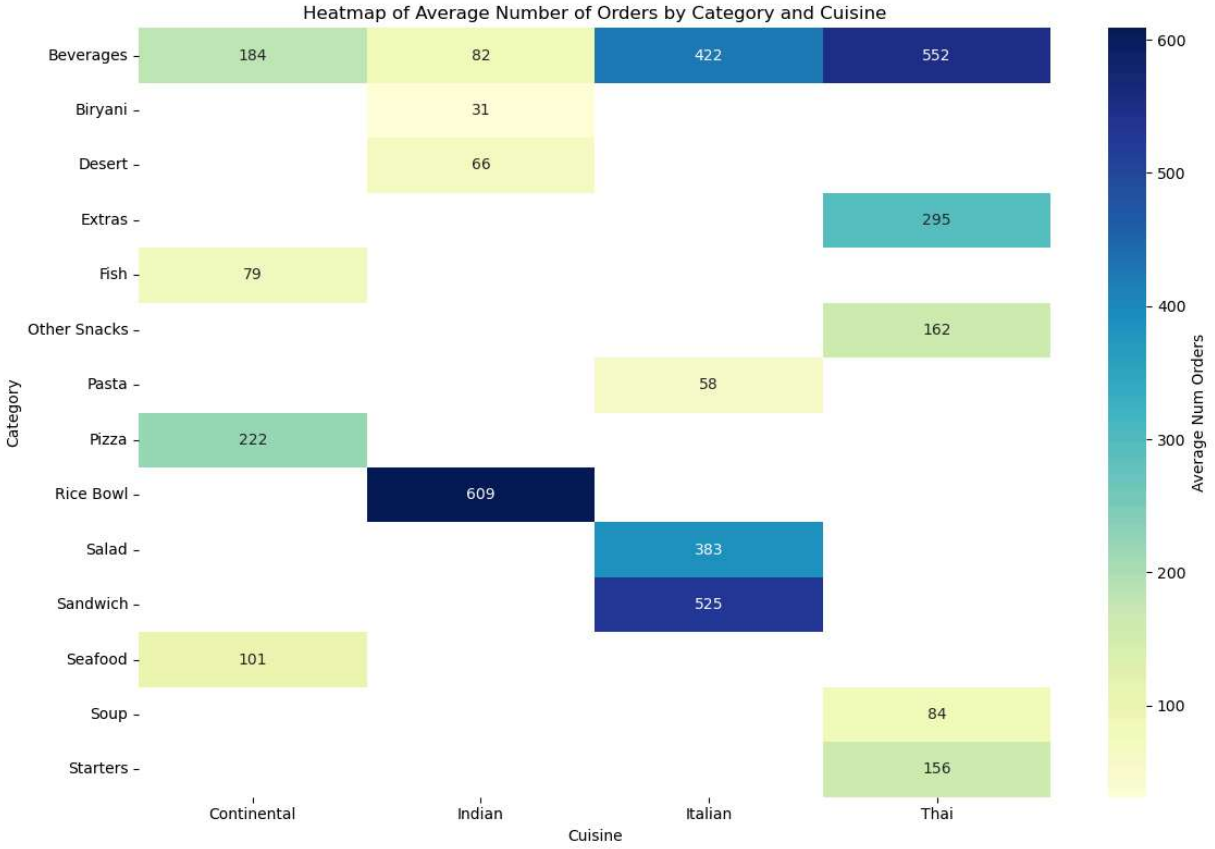
Number of Order by Category

In [16]:
```
# Group data by category and sum the num_orders
category_orders = merged.groupby('category')['num_orders'].sum().sort_values()

# Plot the data
plt.figure(figsize = (10, 6))
category_orders.plot(kind = 'barh')
plt.title('Total Number of Orders by Category')
plt.xlabel('Total Number of Orders')
plt.ylabel('Category')
plt.tight_layout()
plt.show()
```



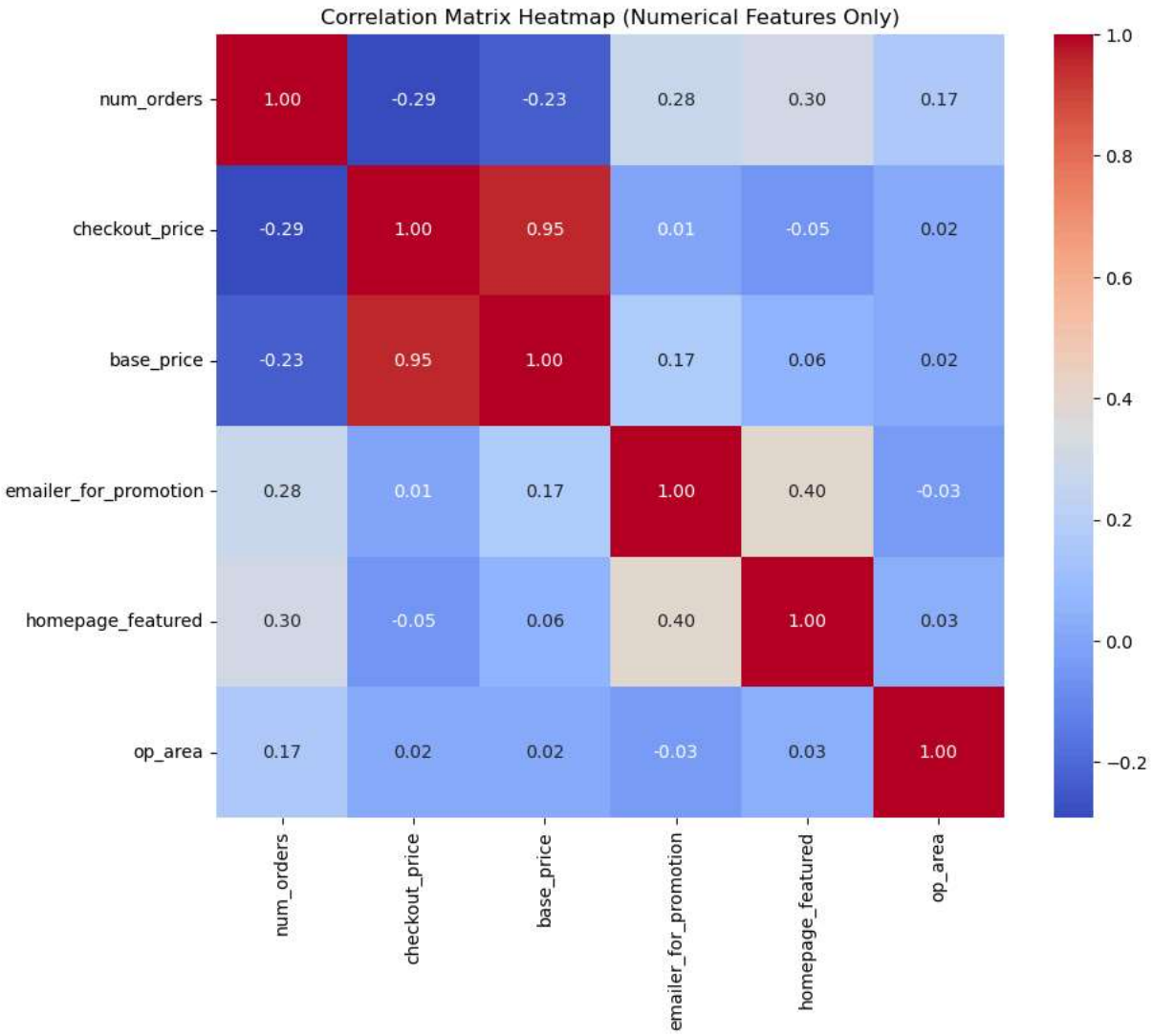
Average Number of Orders by Category and Cuisine

In [17]:
```
heatmap_data = merged.groupby(['category', 'cuisine'])['num_orders'].mean().unstack
plt.figure(figsize = (12, 8))
sns.heatmap(heatmap_data, annot=True, fmt = ".0f", cmap = 'YlGnBu', cbar_kws = {'la
plt.title('Heatmap of Average Number of Orders by Category and Cuisine')
plt.xlabel('Cuisine')
plt.ylabel('Category')
plt.tight_layout()
plt.show()
```



Correlation Analysis (Numeric Features)

In [18]:
```
# Calculate the correlation matrix for numerical features
correlation_matrix = merged[['num_orders','checkout_price',
                             'base_price', 'emailer_for_promotion',
                             'homepage_featured',
                             'op_area']].corr()

# Plot the heatmap
plt.figure(figsize = (10, 8))
sns.heatmap(correlation_matrix, annot = True, fmt = ".2f", cmap =  'coolwarm', cbar
plt.title("Correlation Matrix Heatmap (Numerical Features Only)")
plt.show()
```



Feature Engineering & Preprocessing

To prepare data for modeling, we will:

- Encode the cyclical `week` feature using sine and cosine transforms.
- Create discount-related features from menu and centre data.
- One-hot encode categorical variables such as `category` and `centre_type`.
- Scale numerical features using standardization.
- Split into training and test sets using an 80/20 time-based split.

Missing Values

In [19]:
```
merged.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 45655 entries, 0 to 45654
Data columns (total 15 columns):
 #   Column                 Non-Null Count  Dtype  
---  ------                 --------------  -----  
 0   id                     45655 non-null  int64  
 1   week                   45655 non-null  int64  
 2   center_id              45655 non-null  int64  
 3   meal_id                45655 non-null  int64  
 4   checkout_price         45655 non-null  float64
 5   base_price             45655 non-null  float64
 6   emailer_for_promotion  45655 non-null  int64  
 7   homepage_featured      45655 non-null  int64  
 8   num_orders             45655 non-null  int64  
 9   category               45655 non-null  object 
 10  cuisine                45655 non-null  object 
 11  city_code              45655 non-null  int64  
 12  region_code            45655 non-null  int64  
 13  center_type            45655 non-null  object 
 14  op_area                45655 non-null  float64
dtypes: float64(3), int64(9), object(3)
memory usage: 5.2+ MB
```

Drop Useless Columns

In [20]:
```python
merged = merged.drop(columns=['id', 'Unnamed: 0'], errors='ignore')
```

Outliers

In [21]:
```python
# Function to identify outliers using the IQR method for multiple columns
def identify_outliers_iqr(data, columns):
    outlier_info = {}
    for column in columns:
        # Calculate Q1 (25th percentile) and Q3 (75th percentile)
        Q1 = data[column].quantile(0.25)
        Q3 = data[column].quantile(0.75)
        # Calculate the IQR
        IQR = Q3 - Q1
        # Calculate the lower and upper bounds for outliers
        lower_bound = Q1 - 1.5 * IQR
        upper_bound = Q3 + 1.5 * IQR
        # Identify outliers
        outliers = data[(data[column] < lower_bound) | (data[column] > upper_bound)]
        outlier_info[column] = {
            "Lower Bound": lower_bound,
            "Upper Bound": upper_bound,
            "Outliers Count": len(outliers),
            "Outliers": outliers
        }
    return outlier_info

columns_to_check = ['checkout_price', 'base_price']
outliers_info = identify_outliers_iqr(merged, columns_to_check)

# Display results
```

```
for column, info in outliers_info.items():
    print(f"Column: {column}")
    print(f"  Lower Bound: {info['Lower Bound']}")
    print(f"  Upper Bound: {info['Upper Bound']}")
    print(f"  Outliers Count: {info['Outliers Count']}")
    print(f"  Outliers:\n{info['Outliers']}\n")
```

```
Column: checkout_price
  Lower Bound: -95.39500000000007
  Upper Bound: 769.605
  Outliers Count: 0
  Outliers:
Empty DataFrame
Columns: [week, center_id, meal_id, checkout_price, base_price, emailer_for_promotio
n, homepage_featured, num_orders, category, cuisine, city_code, region_code, center_
type, op_area]
Index: []

Column: base_price
  Lower Bound: -83.85250000000002
  Upper Bound: 789.0875000000001
  Outliers Count: 1
  Outliers:
       week  center_id  meal_id  checkout_price  base_price  \
21780   137         93     1445          765.33      865.27

       emailer_for_promotion  homepage_featured  num_orders category  \
21780                      0                  0          53  Seafood

           cuisine  city_code  region_code center_type  op_area
21780  Continental        461           34      TYPE_A      3.9
```

Feature Engineering

Cyclic encoding for week

In [22]:
```
# Maximum week value for cyclic encoding
max_week = merged['week'].max()

# Compute sine and cosine transformations for cyclic encoding
merged['week_sin'] = np.sin(2 * np.pi * merged['week'] / max_week)
merged['week_cos'] = np.cos(2 * np.pi * merged['week'] / max_week)

# Display the updated dataset with new cyclic features
merged[['week', 'week_sin', 'week_cos']].head()
```

Out[22]:

	week	week_sin	week_cos
0	68	0.193762	-0.981049
1	98	-0.893452	-0.449158
2	84	-0.477952	-0.878386
3	110	-0.998533	0.054139
4	2	0.086556	0.996247

New Features

price_difference: The difference between base_price and checkout_price. Represents the absolute discount or markup applied. **discount_ratio**: The relative discount as a fraction of base_price. Useful for understanding the magnitude of the discount in proportion to the base price.

In [23]:
```
# Create additional features based on price
merged['price_difference'] = merged['base_price'] - merged['checkout_price']
merged['discount_ratio'] = (merged['base_price'] - merged['checkout_price']) / merg

# Display the updated dataset with the new features
merged[['base_price', 'checkout_price', 'price_difference', 'discount_ratio']].head
```

Out[23]:

	base_price	checkout_price	price_difference	discount_ratio
0	641.23	639.23	2.0	0.003119
1	177.57	177.57	0.0	0.000000
2	280.33	282.33	-2.0	-0.007134
3	474.39	474.39	0.0	0.000000
4	133.92	133.92	0.0	0.000000

Encoding of Categorical Variables

In [24]:
```
merged = pd.get_dummies(merged, columns=['category','cuisine','center_type',
                                         'city_code','region_code', 'center_id', 'm
                        , drop_first=True
                       )
merged = merged.astype({col: 'int64' for col in merged.select_dtypes('bool').column
```

Feature Scaling

In [25]:
```
from sklearn.preprocessing import StandardScaler

# Identify numeric features for scaling
numeric_columns = ['checkout_price', 'base_price', 'op_area']
# Initialize the scaler
scaler = StandardScaler()
```

```
# Scale the numeric features
merged[numeric_columns] = scaler.fit_transform(merged[numeric_columns])
```

In [26]:
```
merged.to_csv('merged_final.csv', index = False)
```

In [27]:
```
merged_final = pd.read_csv('merged_final.csv')
```

In [28]:
```
merged_final.head()
```

Out[28]:

	week	checkout_price	base_price	emailer_for_promotion	homepage_featured	num_orde
0	68	2.013685	1.790891	0	0	
1	98	-1.010736	-1.097945	0	0	1
2	84	-0.324433	-0.457699	0	0	3
3	110	0.933788	0.751393	0	0	
4	2	-1.296695	-1.369907	0	0	4

5 rows × 212 columns

Model Training

We will define and train the following models on the preprocessed training set:

- **Baseline:** Moving Average and Multiple Linear Regression
- **Random Forest Regressor**
- **LightGBM Regressor**
- **Feed-forward Neural Network**

For each, we'll fit to the training data and save the predictions for later evaluation.

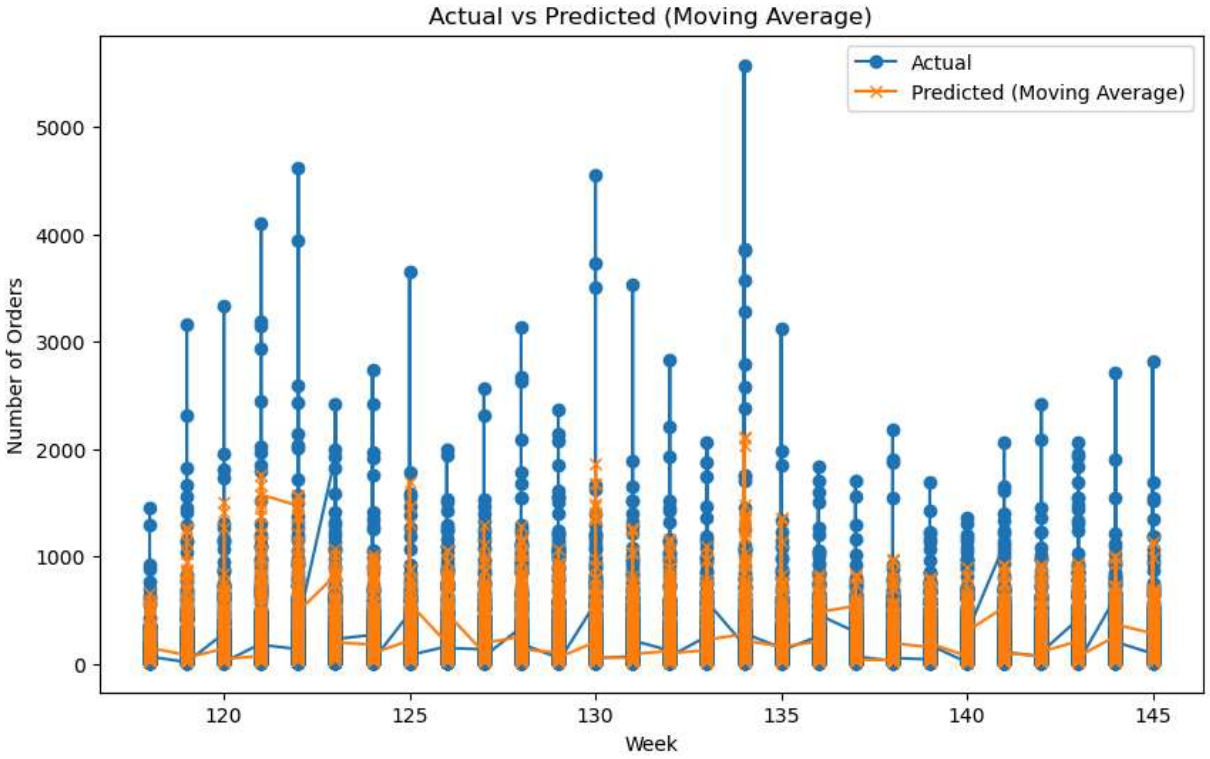
Moving Average

In [29]:
```
import pandas as pd
from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
import numpy as np

# Sort data by 'week'
merged_final_MA = merged_final.sort_values(by='week')

# Define the target column
target = 'num_orders'

# Calculate the moving average (e.g., 3-week moving average)
merged_final_MA['moving_avg'] = merged_final_MA[target].rolling(window=3).mean()

# Split the dataset
split_index = int(0.8 * len(merged_final_MA))
```

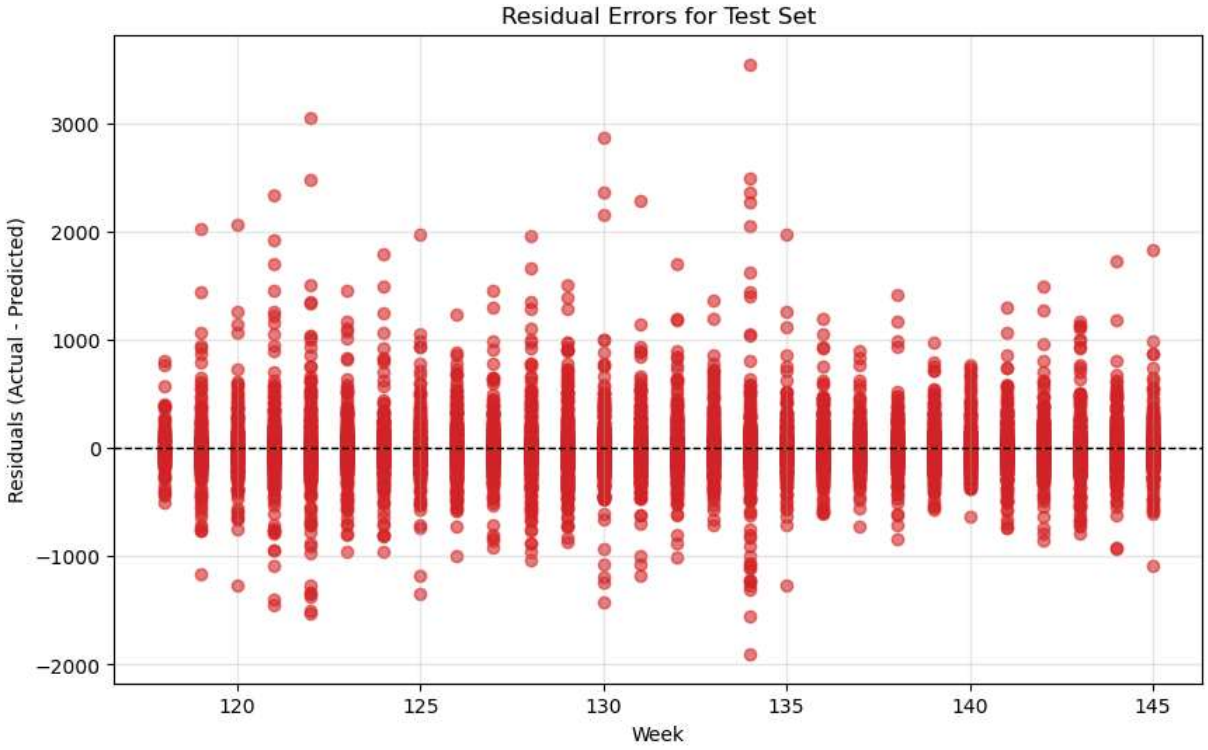
```
train_data = merged_final_MA.iloc[:split_index]
test_data = merged_final_MA.iloc[split_index:]

# Use moving average as predictions for the test set
test_data['predicted_num_orders'] = test_data['moving_avg']

# Drop rows in the test set where moving average is NaN (due to insufficient data)
test_data = test_data.dropna(subset=['predicted_num_orders'])

# Evaluate the model
y_true = test_data[target]
y_pred = test_data['predicted_num_orders']

mse = mean_squared_error(y_true, y_pred)
mae = mean_absolute_error(y_true, y_pred)
r2 = r2_score(y_true, y_pred)
rmse = np.sqrt(mse)


print("Evaluation Metrics:")
print(f"Mean Absolute Error (MAE): {mae:.2f}")
print(f"Mean Squared Error (MSE): {mse:.2f}")
print(f"Root Mean Squared Error (RMSE): {rmse:.2f}")
print(f"R-Squared (R²): {r2:.3f}")

# Plot actual vs predicted values
import matplotlib.pyplot as plt

plt.figure(figsize = (10, 6))
plt.plot(test_data['week'], y_true, label = 'Actual', marker = 'o')
plt.plot(test_data['week'], y_pred, label = 'Predicted (Moving Average)', marker =
plt.title('Actual vs Predicted (Moving Average)')
plt.xlabel('Week')
plt.ylabel('Number of Orders')
plt.legend()
plt.show()
```

```
Evaluation Metrics:
Mean Absolute Error (MAE): 171.83
Mean Squared Error (MSE): 80254.09
Root Mean Squared Error (RMSE): 283.29
R-Squared (R²): 0.335
```

```
C:\Users\PC\AppData\Local\Temp\ipykernel_21984\1201078262.py:20: SettingWithCopyWarn
ing:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/u
ser_guide/indexing.html#returning-a-view-versus-a-copy
  test_data['predicted_num_orders'] = test_data['moving_avg']
```



In [30]:
```
# Calculate residual errors
residuals = y_true - y_pred

# Plot residual errors
plt.figure(figsize=(10, 6))
plt.scatter(test_data['week'], residuals, color='tab:red', alpha=0.6)
plt.axhline(0, color='black', linestyle='--', linewidth=1)
plt.title('Residual Errors for Test Set')
plt.xlabel('Week')
plt.ylabel('Residuals (Actual - Predicted)')
plt.grid(True, alpha=0.3)
plt.show()
```



Regression Model

Data Partitioning

In [31]:
```
# Sort the dataset by 'week' to preserve chronological order
merged_final = merged_final.sort_values(by='week')

# Define predictors and target
target = 'num_orders'
predictors = [col for col in merged_final.columns if col not in ['num_orders']]

# Separate predictors and target
X = merged_final[predictors]
y = merged_final[target]

# Calculate the split index (80% for training)
split_index = int(0.8 * len(merged_final))

# Perform the split
X_train, X_test = X.iloc[:split_index], X.iloc[split_index:]
y_train, y_test = y.iloc[:split_index], y.iloc[split_index:]
```

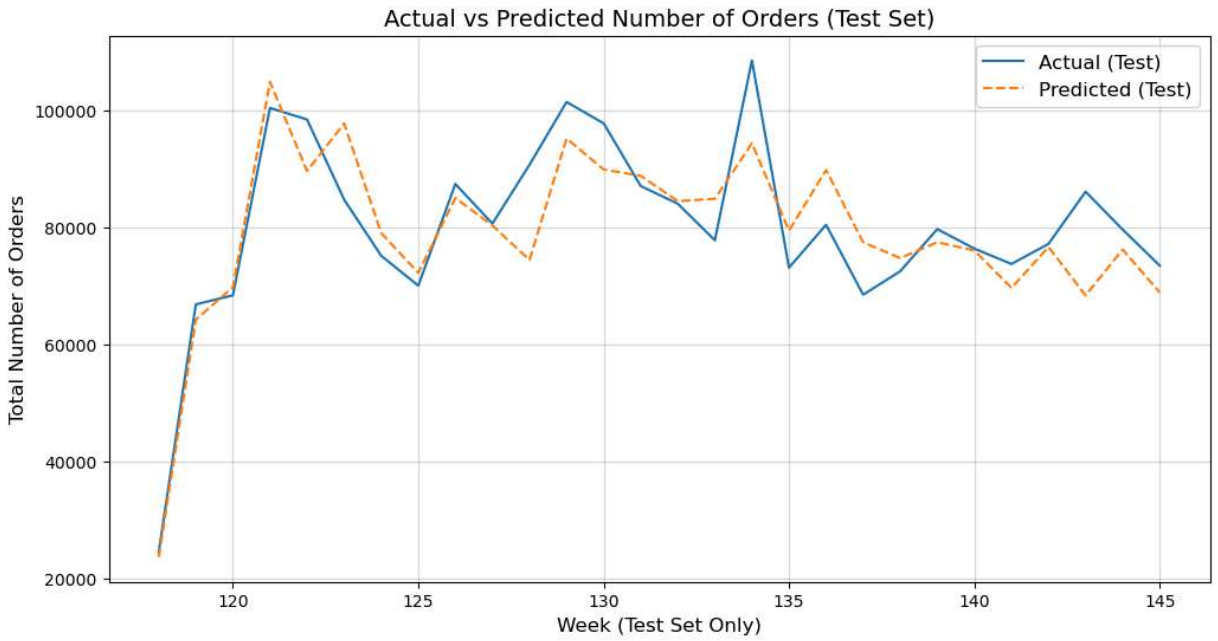
Linear Regerssion Model

In [32]:
```
# Re-initialize and train the regression model
model = LinearRegression()
model.fit(X_train, y_train)

# Predict on the testing data
y_pred = model.predict(X_test)
```

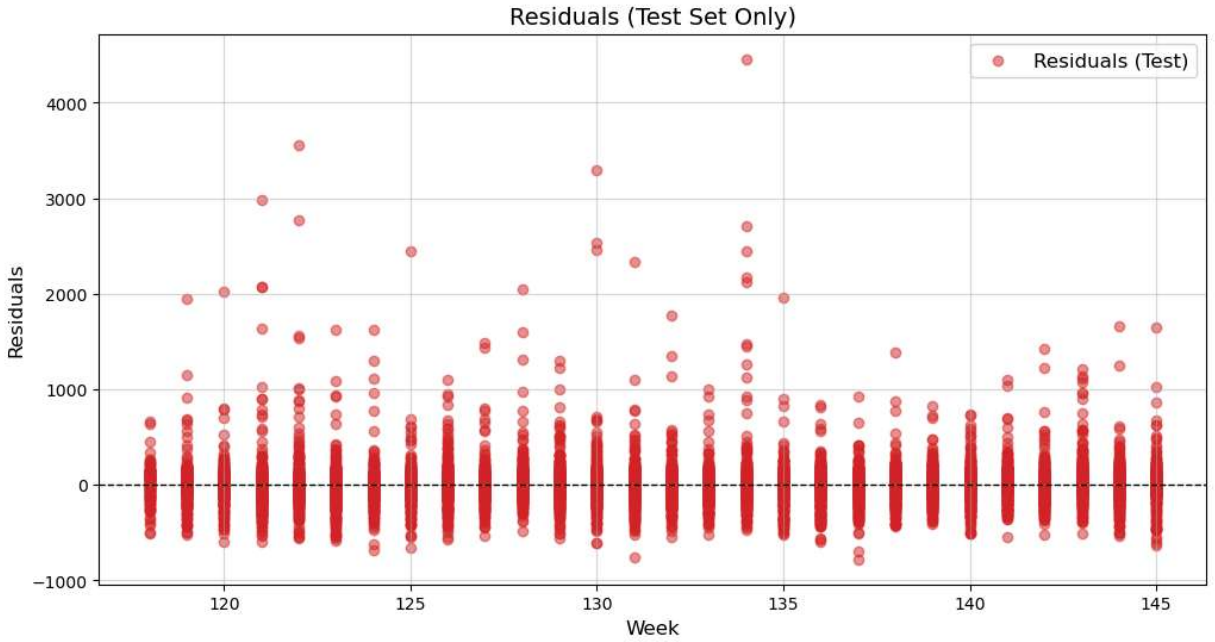
```
# Calculate evaluation metrics
mse = mean_squared_error(y_test, y_pred)
rmse = np.sqrt(mse)
mae = mean_absolute_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

# Print evaluation metrics
print("Evaluation Metrics:")
print(f"Mean Absolute Error (MAE): {mae:.2f}")
print(f"Mean Squared Error (MSE): {mse:.2f}")
print(f"Root Mean Squared Error (RMSE): {rmse:.2f}")
print(f"R-Squared (R²): {r2:.3f}")
```

```
Evaluation Metrics:
Mean Absolute Error (MAE): 147.78
Mean Squared Error (MSE): 56868.03
Root Mean Squared Error (RMSE): 238.47
R-Squared (R²): 0.529
```

In [33]:
```
# Group by 'week' in the test set
test_weeks = X_test['week']
y_test_grouped = y_test.groupby(test_weeks).sum()
y_pred_grouped = pd.Series(y_pred.flatten(), index=X_test.index).groupby(test_weeks

# Plot Actual vs Predicted for the Test Set
plt.figure(figsize=(12, 6))
plt.plot(y_test_grouped.index, y_test_grouped, label = 'Actual (Test)', color = 'ta
plt.plot(y_pred_grouped.index, y_pred_grouped, label = 'Predicted (Test)', color =
plt.title("Actual vs Predicted Number of Orders (Test Set)", fontsize=14)
plt.xlabel("Week (Test Set Only)", fontsize = 12)
plt.ylabel("Total Number of Orders", fontsize = 12)
plt.legend(fontsize = 12)
plt.grid(alpha = 0.5)
plt.show()
```



In [34]:
```
# Residuals (Errors) for the Test Set
residuals = y_test - y_pred.flatten()

# Plot Residuals
plt.figure(figsize=(12, 6))
plt.scatter(test_weeks, residuals, alpha=0.5, color='tab:red', label='Residuals (Te
plt.axhline(0, color='black', linestyle='--', linewidth=1)
plt.title("Residuals (Test Set Only)", fontsize=14)
plt.xlabel("Week", fontsize=12)
plt.ylabel("Residuals", fontsize=12)
plt.legend(fontsize=12)
plt.grid(alpha=0.5)
plt.show()
```



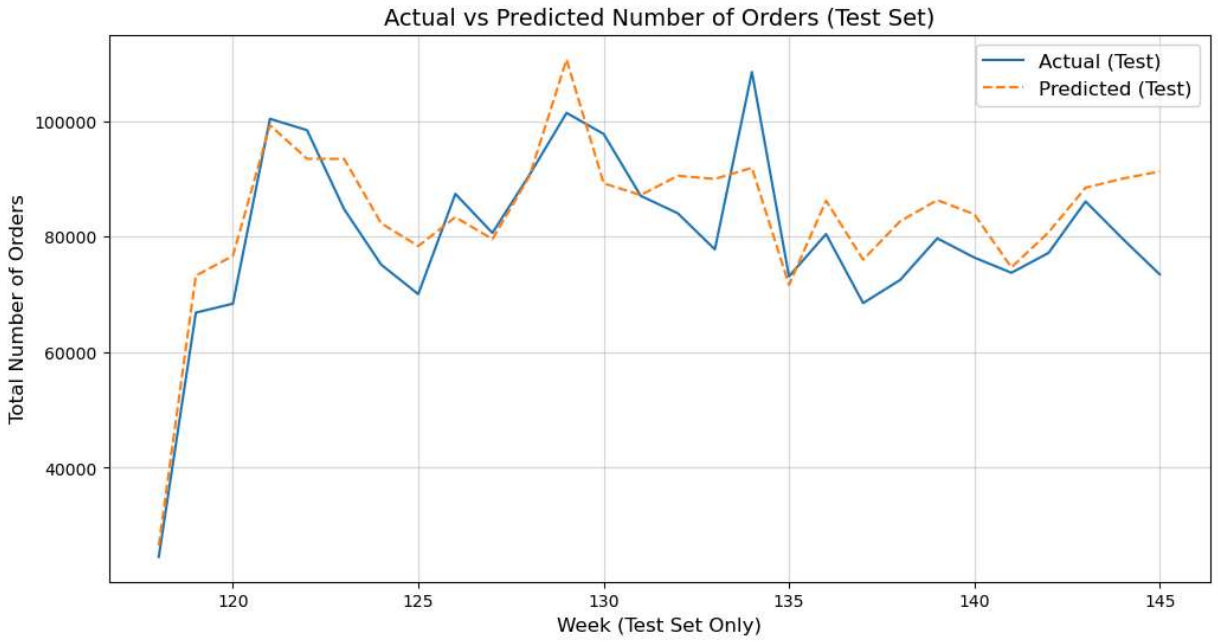
Random Forest

In [35]:
```
# Train the Random Forest model
rf_model = RandomForestRegressor(random_state = 42, n_estimators = 100, n_jobs = -1
rf_model.fit(X_train, y_train)

# Predict on the test set
y_pred = rf_model.predict(X_test)
```

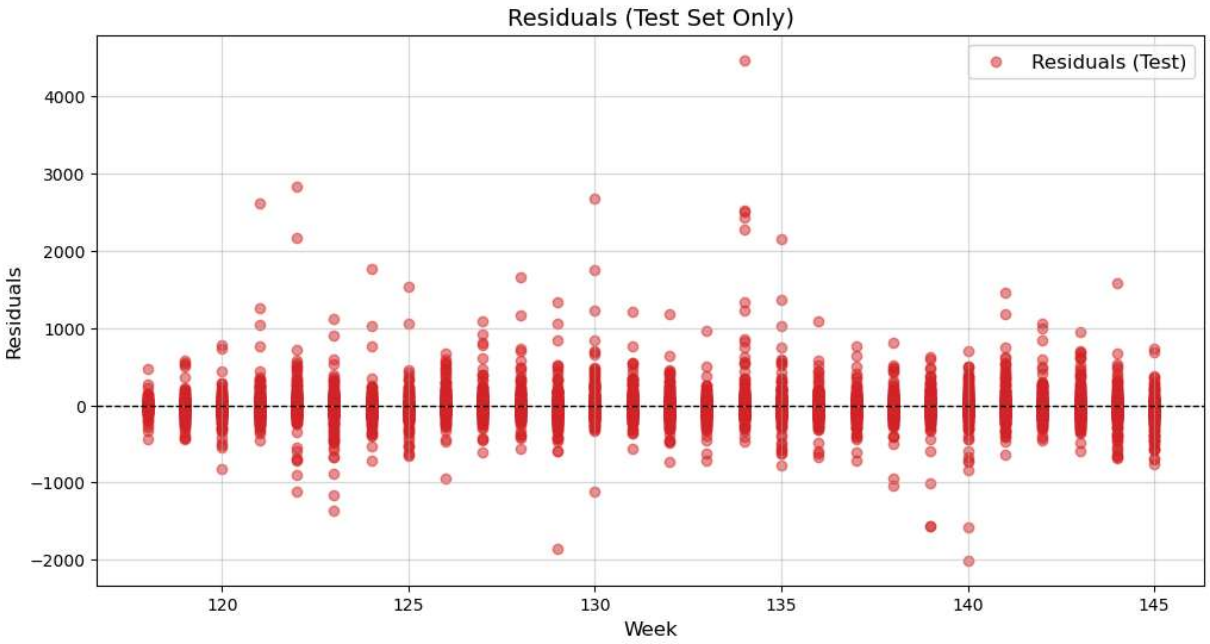
In [36]:
```
# Calculate performance metrics
mae = mean_absolute_error(y_test, y_pred)
mse = mean_squared_error(y_test, y_pred)
rmse = np.sqrt(mse)
r_squared = r2_score(y_test, y_pred)

print("\nPerformance Metrics on Test Set:")
print(f"Mean Absolute Error (MAE): {mae}")
print(f"Mean Squared Error (MSE): {mse}")
print(f"Root Mean Squared Error (RMSE): {rmse}")
print(f"R-Squared (R²): {r_squared}")
```

```
Performance Metrics on Test Set:
Mean Absolute Error (MAE): 99.20112035921586
Mean Squared Error (MSE): 36675.22037648669
Root Mean Squared Error (RMSE): 191.507755395145
R-Squared (R²): 0.6959575809416447
```

In [37]:
```python
# Group by 'week' in the test set
test_weeks = X_test['week']
y_test_grouped = y_test.groupby(test_weeks).sum()
y_pred_grouped = pd.Series(y_pred.flatten(), index=X_test.index).groupby(test_weeks

# Plot Actual vs Predicted for the Test Set
plt.figure(figsize=(12, 6))
plt.plot(y_test_grouped.index, y_test_grouped, label='Actual (Test)', color='tab:bl
plt.plot(y_pred_grouped.index, y_pred_grouped, label='Predicted (Test)', color='tab
plt.title("Actual vs Predicted Number of Orders (Test Set)", fontsize=14)
plt.xlabel("Week (Test Set Only)", fontsize=12)
plt.ylabel("Total Number of Orders", fontsize=12)
plt.legend(fontsize=12)
plt.grid(alpha=0.5)
plt.show()
```

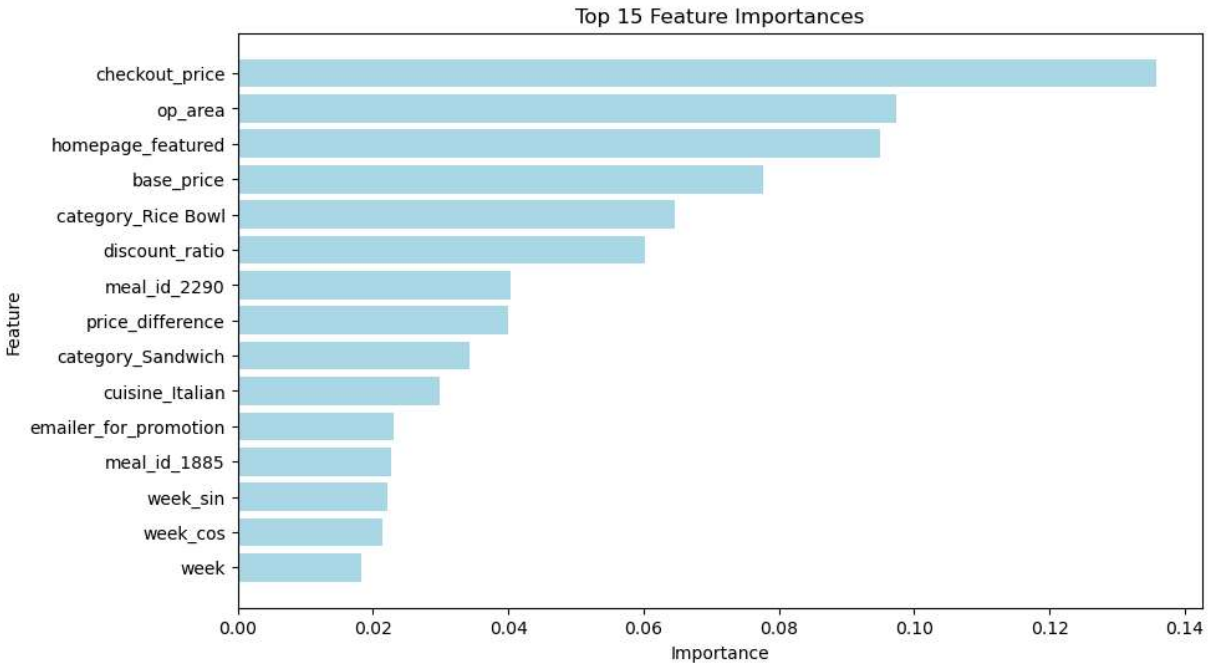


In [38]:
```python
# Residuals (Errors) for the Test Set
residuals = y_test - y_pred.flatten()

# Plot Residuals
plt.figure(figsize=(12, 6))
plt.scatter(test_weeks, residuals, alpha=0.5, color='tab:red', label='Residuals (Te
plt.axhline(0, color='black', linestyle='--', linewidth=1)
plt.title("Residuals (Test Set Only)", fontsize=14)
plt.xlabel("Week", fontsize=12)
plt.ylabel("Residuals", fontsize=12)
plt.legend(fontsize=12)
plt.grid(alpha=0.5)
plt.show()
```



Feature Importance

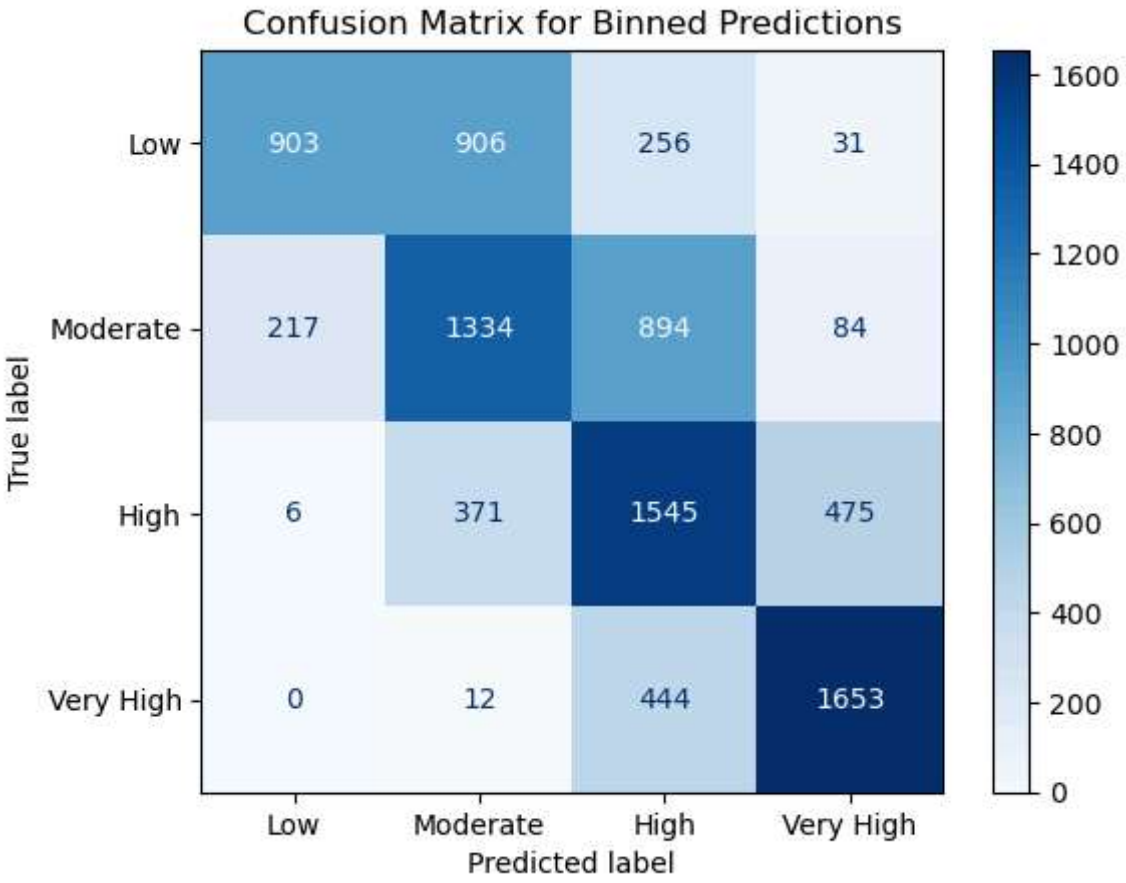
In [39]:
```
# Get feature importances from the trained model
feature_importances = rf_model.feature_importances_

# Create a DataFrame for features and their importance
importance_df = pd.DataFrame({'Feature': X_train.columns,
                              'Importance': feature_importances
                             }
                            )

# Sort features by importance
importance_df = importance_df.sort_values(by = 'Importance', ascending=False)

# Get top 15 features
top_features = importance_df.head(15)

# Plot top 15 feature importances
plt.figure(figsize = (10, 6))
plt.barh(top_features['Feature'], top_features['Importance'], color='lightblue')
plt.gca().invert_yaxis()
plt.title('Top 15 Feature Importances')
plt.xlabel('Importance')
plt.ylabel('Feature')
plt.show()
```



Confusion Matrix

In [40]:

```
# Define the bins and labels
bins = [0, 50, 136, 324, np.inf]
labels = ['Low', 'Moderate', 'High', 'Very High']

# Bin the actual and predicted values
y_test_binned = np.digitize(y_test, bins=bins) - 1
y_pred_binned = np.digitize(y_pred, bins=bins) - 1

# Generate confusion matrix
cm = confusion_matrix(y_test_binned, y_pred_binned, labels=range(len(labels)))

# Plot the confusion matrix
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=labels)
disp.plot(cmap=plt.cm.Blues)
plt.title("Confusion Matrix for Binned Predictions")
plt.show()
```



Hypertuning

In [41]:

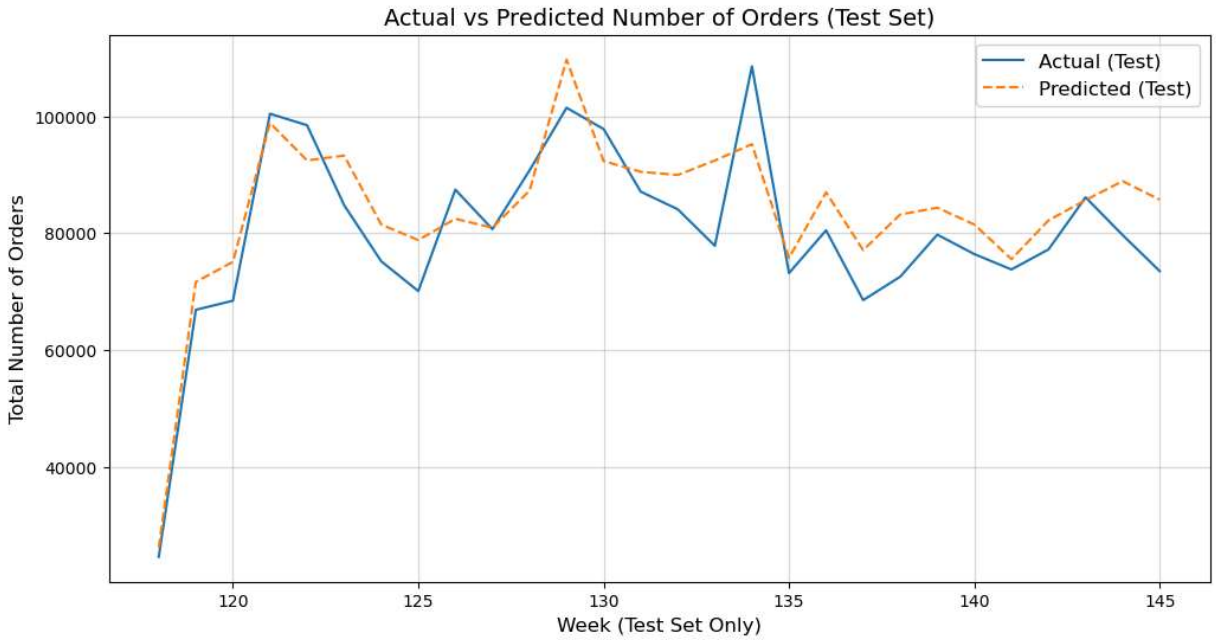
```
from sklearn.datasets import load_iris
from sklearn.ensemble import RandomForestRegressor
from sklearn.model_selection import train_test_split, GridSearchCV

# Define the Random Forest model
rf_model = RandomForestRegressor(random_state=42)

# Define the hyperparameter grid
param_grid = {'n_estimators': [10, 50, 100, 200],
              'max_depth': [None, 10, 20, 30],
              'min_samples_split': [2, 5, 10],
              'min_samples_leaf': [1, 2, 4],
              'max_features': ['sqrt', 'log2'],
              'bootstrap': [True, False]
             }

# Set up GridSearchCV
grid_search = GridSearchCV(estimator = rf_model,
                           param_grid = param_grid,
                           cv = 5,
                           scoring = 'neg_mean_squared_error',
                           verbose = 2,
                           n_jobs = -1
                          )

# Fit the model
```

```
grid_search.fit(X_train, y_train)

# Get the best parameters and the best score
best_params = grid_search.best_params_
best_score = -grid_search.best_score_
print("Best Parameters:", best_params)
print("Best Cross-Validation MSE:", best_score)

# Evaluate on the test set
best_model = grid_search.best_estimator_
y_pred = best_model.predict(X_test)

# Calculate performance metrics
mae = mean_absolute_error(y_test, y_pred)
mse = mean_squared_error(y_test, y_pred)
rmse = np.sqrt(mse)
r_squared = r2_score(y_test, y_pred)

print("\nPerformance Metrics on Test Set:")
print(f"Mean Absolute Error (MAE): {mae}")
print(f"Mean Squared Error (MSE): {mse}")
print(f"Root Mean Squared Error (RMSE): {rmse}")
print(f"R-Squared (R²): {r_squared}")
```

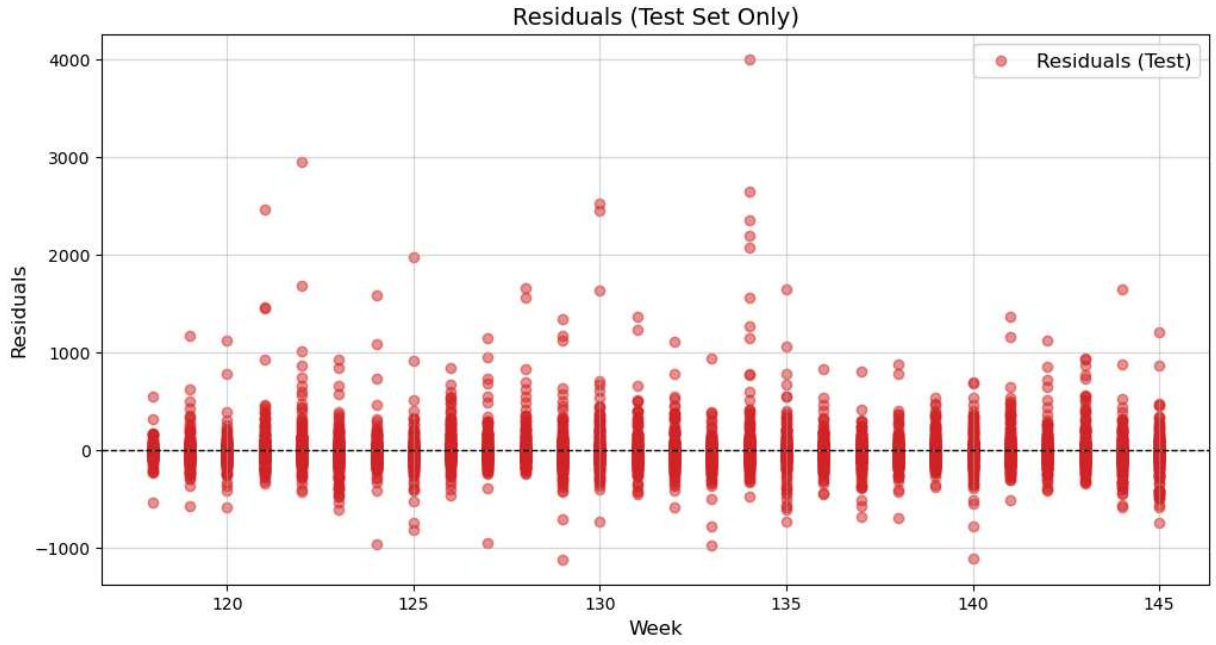
```
Fitting 5 folds for each of 576 candidates, totalling 2880 fits
Best Parameters: {'bootstrap': False, 'max_depth': 30, 'max_features': 'sqrt', 'min_
samples_leaf': 1, 'min_samples_split': 5, 'n_estimators': 200}
Best Cross-Validation MSE: 42076.94153252221

Performance Metrics on Test Set:
Mean Absolute Error (MAE): 93.98244651385077
Mean Squared Error (MSE): 32321.970699428206
Root Mean Squared Error (RMSE): 179.7831212862548
R-Squared (R²): 0.7320465955130866
```

In [42]:

```
# Group by 'week' in the test set
test_weeks = X_test['week']
y_test_grouped = y_test.groupby(test_weeks).sum()
y_pred_grouped = pd.Series(y_pred.flatten(), index=X_test.index).groupby(test_weeks

# Plot Actual vs Predicted for the Test Set
plt.figure(figsize=(12, 6))
plt.plot(y_test_grouped.index, y_test_grouped, label='Actual (Test)', color='tab:bl
plt.plot(y_pred_grouped.index, y_pred_grouped, label='Predicted (Test)', color='tab
plt.title("Actual vs Predicted Number of Orders (Test Set)", fontsize=14)
plt.xlabel("Week (Test Set Only)", fontsize=12)
plt.ylabel("Total Number of Orders", fontsize=12)
plt.legend(fontsize=12)
plt.grid(alpha=0.5)
plt.show()
```



In [43]:
```
# Residuals (Errors) for the Test Set
residuals = y_test - y_pred.flatten()

# Plot Residuals
plt.figure(figsize=(12, 6))
plt.scatter(test_weeks, residuals, alpha=0.5, color='tab:red', label='Residuals (Te
plt.axhline(0, color='black', linestyle='--', linewidth=1)
plt.title("Residuals (Test Set Only)", fontsize=14)
plt.xlabel("Week", fontsize=12)
plt.ylabel("Residuals", fontsize=12)
plt.legend(fontsize=12)
plt.grid(alpha=0.5)
plt.show()
```



Neural Network

In [51]:

```
y_train = y_train.astype("float32")
y_test  = y_test.astype("float32")
# Set seeds for reproducibility
np.random.seed(42)
tf.random.set_seed(42)
random.seed(42)

# Build the model
model = Sequential([Dense(64, activation = 'relu',
                          input_shape = (X_train.shape[1],)
                         ),
                    Dropout(0.2),
                    Dense(32, activation = 'relu'),
                    Dropout(0.2),
                    Dense(1, activation = 'linear')
                   ]
                  )

# Compile the model
model.compile(optimizer = 'adam', loss = 'mean_squared_error', metrics = ['mae'])

# Train the model
history = model.fit(X_train,
                    y_train,
                    validation_data = (X_test, y_test),
                    epochs=50, batch_size = 32, verbose = 1
                   )
```

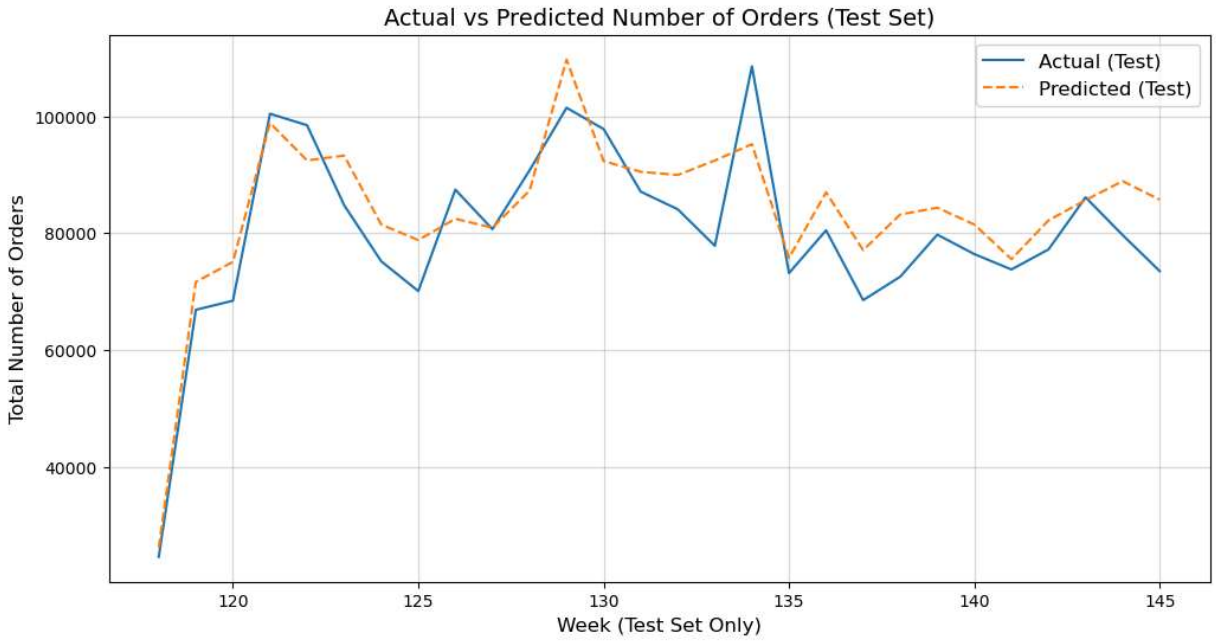
```
Epoch 1/50
1142/1142 [==============================] - 2s 1ms/step - loss: 126030.0078 - mae:
193.6038 - val_loss: 77728.8047 - val_mae: 184.4048
Epoch 2/50
1142/1142 [==============================] - 1s 1ms/step - loss: 72351.9922 - mae: 1
37.1294 - val_loss: 47673.9297 - val_mae: 120.7540
Epoch 3/50
1142/1142 [==============================] - 1s 1ms/step - loss: 58910.9648 - mae: 1
22.3192 - val_loss: 47835.9961 - val_mae: 126.1727
Epoch 4/50
1142/1142 [==============================] - 1s 1ms/step - loss: 53813.5742 - mae: 1
17.2223 - val_loss: 43524.6484 - val_mae: 110.2604
Epoch 5/50
1142/1142 [==============================] - 1s 1ms/step - loss: 51850.3789 - mae: 1
14.4421 - val_loss: 41496.3164 - val_mae: 115.6064
Epoch 6/50
1142/1142 [==============================] - 1s 1ms/step - loss: 49231.6914 - mae: 1
12.8224 - val_loss: 42242.2891 - val_mae: 120.6610
Epoch 7/50
1142/1142 [==============================] - 1s 1ms/step - loss: 47642.8828 - mae: 1
10.8296 - val_loss: 41479.0664 - val_mae: 107.8172
Epoch 8/50
1142/1142 [==============================] - 1s 1ms/step - loss: 47346.7461 - mae: 1
09.5473 - val_loss: 48713.1367 - val_mae: 114.6722
Epoch 9/50
1142/1142 [==============================] - 1s 1ms/step - loss: 46368.5703 - mae: 1
09.0198 - val_loss: 41979.4922 - val_mae: 121.8901
Epoch 10/50
1142/1142 [==============================] - 1s 1ms/step - loss: 44568.1641 - mae: 1
06.8270 - val_loss: 38581.6172 - val_mae: 102.5066
Epoch 11/50
1142/1142 [==============================] - 1s 1ms/step - loss: 45035.7734 - mae: 1
06.0461 - val_loss: 38138.4336 - val_mae: 114.6992
Epoch 12/50
1142/1142 [==============================] - 1s 1ms/step - loss: 43626.8867 - mae: 1
05.4251 - val_loss: 39928.5273 - val_mae: 106.5165
Epoch 13/50
1142/1142 [==============================] - 1s 1ms/step - loss: 42975.6953 - mae: 1
03.9849 - val_loss: 34704.9570 - val_mae: 100.0387
Epoch 14/50
1142/1142 [==============================] - 1s 1ms/step - loss: 41682.0703 - mae: 1
02.9846 - val_loss: 38428.9922 - val_mae: 97.7583
Epoch 15/50
1142/1142 [==============================] - 1s 998us/step - loss: 40384.3594 - mae:
101.8436 - val_loss: 41245.0156 - val_mae: 100.3751
Epoch 16/50
1142/1142 [==============================] - 1s 1ms/step - loss: 40454.3828 - mae: 1
01.5405 - val_loss: 41157.2812 - val_mae: 99.7850
Epoch 17/50
1142/1142 [==============================] - 1s 1ms/step - loss: 38644.0391 - mae: 1
00.3089 - val_loss: 34983.7422 - val_mae: 104.5757
Epoch 18/50
1142/1142 [==============================] - 1s 1ms/step - loss: 38546.1484 - mae: 9
9.4395 - val_loss: 35815.8281 - val_mae: 102.2134
Epoch 19/50
1142/1142 [==============================] - 1s 1ms/step - loss: 38800.9531 - mae: 9
```

```
9.5600 - val_loss: 34534.6641 - val_mae: 105.9521
Epoch 20/50
1142/1142 [==============================] - 1s 1ms/step - loss: 37694.2070 - mae: 9
8.4680 - val_loss: 42432.2109 - val_mae: 124.1921
Epoch 21/50
1142/1142 [==============================] - 1s 1ms/step - loss: 37020.2617 - mae: 9
7.5281 - val_loss: 34586.5273 - val_mae: 95.4619
Epoch 22/50
1142/1142 [==============================] - 1s 1ms/step - loss: 37133.0195 - mae: 9
7.2852 - val_loss: 31773.4355 - val_mae: 97.7456
Epoch 23/50
1142/1142 [==============================] - 1s 1ms/step - loss: 36410.5312 - mae: 9
6.6768 - val_loss: 36924.5820 - val_mae: 106.3716
Epoch 24/50
1142/1142 [==============================] - 1s 990us/step - loss: 35475.0859 - mae:
96.2853 - val_loss: 32740.6543 - val_mae: 99.2715
Epoch 25/50
1142/1142 [==============================] - 1s 996us/step - loss: 35415.6758 - mae:
95.3758 - val_loss: 33115.3203 - val_mae: 101.0339
Epoch 26/50
1142/1142 [==============================] - 1s 1ms/step - loss: 35901.1445 - mae: 9
6.1337 - val_loss: 35607.2109 - val_mae: 97.9791
Epoch 27/50
1142/1142 [==============================] - 1s 1ms/step - loss: 34935.0625 - mae: 9
5.6918 - val_loss: 32958.1719 - val_mae: 103.7166
Epoch 28/50
1142/1142 [==============================] - 1s 1ms/step - loss: 33750.4766 - mae: 9
4.5406 - val_loss: 40806.7773 - val_mae: 97.1541
Epoch 29/50
1142/1142 [==============================] - 1s 1ms/step - loss: 34582.1328 - mae: 9
5.3422 - val_loss: 34588.2773 - val_mae: 108.6584
Epoch 30/50
1142/1142 [==============================] - 1s 1ms/step - loss: 33853.3242 - mae: 9
4.1213 - val_loss: 34758.4570 - val_mae: 101.8662
Epoch 31/50
1142/1142 [==============================] - 1s 1ms/step - loss: 34424.9062 - mae: 9
4.7779 - val_loss: 37070.0234 - val_mae: 94.5649
Epoch 32/50
1142/1142 [==============================] - 1s 1ms/step - loss: 33878.4102 - mae: 9
4.1382 - val_loss: 34553.2148 - val_mae: 93.5446
Epoch 33/50
1142/1142 [==============================] - 1s 1ms/step - loss: 33865.8320 - mae: 9
4.5342 - val_loss: 29872.6738 - val_mae: 91.8558
Epoch 34/50
1142/1142 [==============================] - 1s 1ms/step - loss: 33271.8516 - mae: 9
3.3716 - val_loss: 34921.3203 - val_mae: 116.6621
Epoch 35/50
1142/1142 [==============================] - 1s 1ms/step - loss: 33747.7031 - mae: 9
3.2951 - val_loss: 33883.3086 - val_mae: 103.7353
Epoch 36/50
1142/1142 [==============================] - 1s 995us/step - loss: 33233.6055 - mae:
93.8673 - val_loss: 34416.7852 - val_mae: 114.6437
Epoch 37/50
1142/1142 [==============================] - 1s 1ms/step - loss: 32896.5430 - mae: 9
3.2076 - val_loss: 31157.5137 - val_mae: 92.2473
Epoch 38/50
```

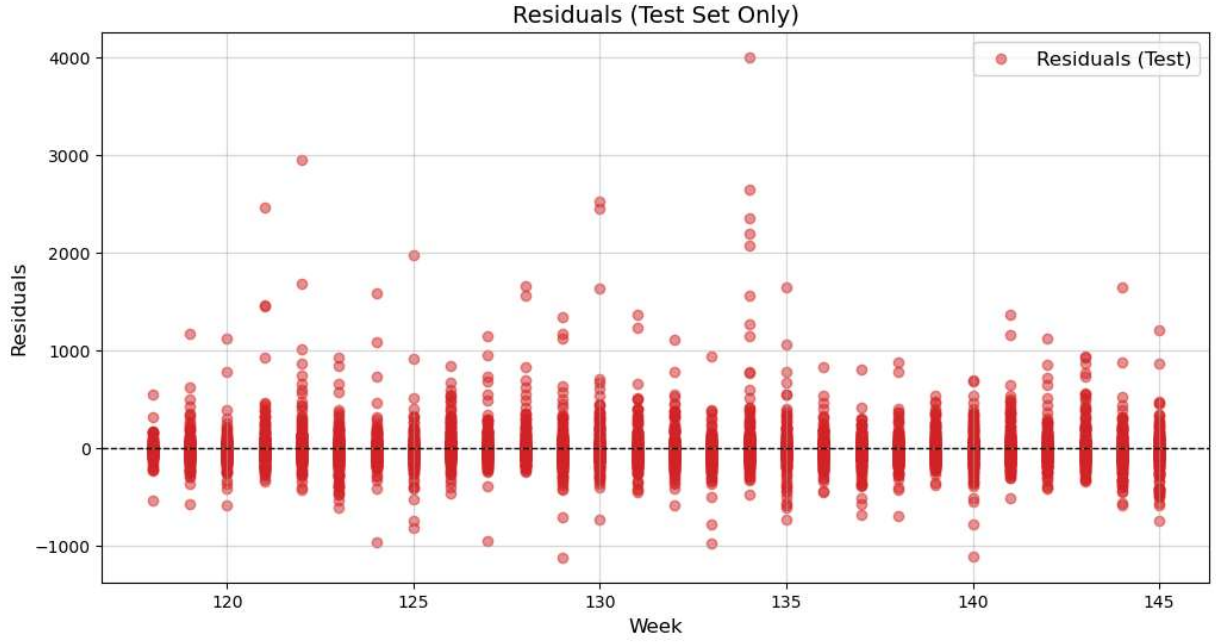
```
1142/1142 [==============================] - 1s 999us/step - loss: 32715.0332 - mae:
93.1460 - val_loss: 35637.1953 - val_mae: 112.4048
Epoch 39/50
1142/1142 [==============================] - 1s 1ms/step - loss: 31568.7480 - mae: 9
3.0068 - val_loss: 32256.1016 - val_mae: 92.5465
Epoch 40/50
1142/1142 [==============================] - 1s 1ms/step - loss: 32783.0312 - mae: 9
2.8247 - val_loss: 33188.0664 - val_mae: 92.1386
Epoch 41/50
1142/1142 [==============================] - 1s 1ms/step - loss: 32535.5469 - mae: 9
3.2193 - val_loss: 31846.7363 - val_mae: 96.2947
Epoch 42/50
1142/1142 [==============================] - 1s 1ms/step - loss: 33161.3984 - mae: 9
2.3445 - val_loss: 31612.2754 - val_mae: 99.7647
Epoch 43/50
1142/1142 [==============================] - 1s 1ms/step - loss: 32473.4004 - mae: 9
2.5338 - val_loss: 32850.0430 - val_mae: 93.0847
Epoch 44/50
1142/1142 [==============================] - 1s 1ms/step - loss: 31657.8398 - mae: 9
1.5564 - val_loss: 29622.8398 - val_mae: 91.9281
Epoch 45/50
1142/1142 [==============================] - 1s 1ms/step - loss: 31358.8125 - mae: 9
1.8794 - val_loss: 32686.7969 - val_mae: 94.4269
Epoch 46/50
1142/1142 [==============================] - 1s 1ms/step - loss: 31603.3418 - mae: 9
1.7687 - val_loss: 33069.4492 - val_mae: 94.3573
Epoch 47/50
1142/1142 [==============================] - 1s 1ms/step - loss: 31037.0352 - mae: 9
2.0609 - val_loss: 33269.9727 - val_mae: 92.1897
Epoch 48/50
1142/1142 [==============================] - 1s 1ms/step - loss: 32540.4883 - mae: 9
3.0140 - val_loss: 30227.3164 - val_mae: 90.1856
Epoch 49/50
1142/1142 [==============================] - 1s 1ms/step - loss: 31865.6113 - mae: 9
2.4663 - val_loss: 28476.5898 - val_mae: 89.9389
Epoch 50/50
1142/1142 [==============================] - 1s 1ms/step - loss: 30686.3848 - mae: 9
2.0895 - val_loss: 29503.0078 - val_mae: 94.9503
```

In [52]:

```
# Group by 'week' in the test set
test_weeks = X_test['week']
y_test_grouped = y_test.groupby(test_weeks).sum()
y_pred_grouped = pd.Series(y_pred.flatten(), index = X_test.index).groupby(test_wee

# Plot Actual vs Predicted for the Test Set
plt.figure(figsize = (12, 6))
plt.plot(y_test_grouped.index, y_test_grouped, label = 'Actual (Test)', color = 'ta
plt.plot(y_pred_grouped.index, y_pred_grouped, label = 'Predicted (Test)', color =
plt.title("Actual vs Predicted Number of Orders (Test Set)", fontsize=14)
plt.xlabel("Week (Test Set Only)", fontsize=12)
plt.ylabel("Total Number of Orders", fontsize=12)
plt.legend(fontsize = 12)
plt.grid(alpha = 0.5)
plt.show()
```



In [53]:
```
# Residuals (Errors) for the Test Set
residuals = y_test - y_pred.flatten()

# Plot Residuals
plt.figure(figsize = (12, 6))
plt.scatter(test_weeks, residuals, alpha = 0.5, color = 'tab:red', label = 'Residua
plt.axhline(0, color = 'black', linestyle = '--', linewidth = 1)
plt.title("Residuals (Test Set Only)", fontsize = 14)
plt.xlabel("Week", fontsize = 12)
plt.ylabel("Residuals", fontsize = 12)
plt.legend(fontsize = 12)
plt.grid(alpha = 0.5)
plt.show()
```



Feature Importance

In [54]:

```
from sklearn.inspection import permutation_importance

result = permutation_importance(model, X_test, y_test, scoring='neg_mean_squared_er

# Create a DataFrame of feature importances
importance_df = pd.DataFrame({
    'Feature': X_test.columns,
    'Importance': result.importances_mean
}).sort_values(by='Importance', ascending=False)

# Display the top 15 features
importance_df.head(15)
```

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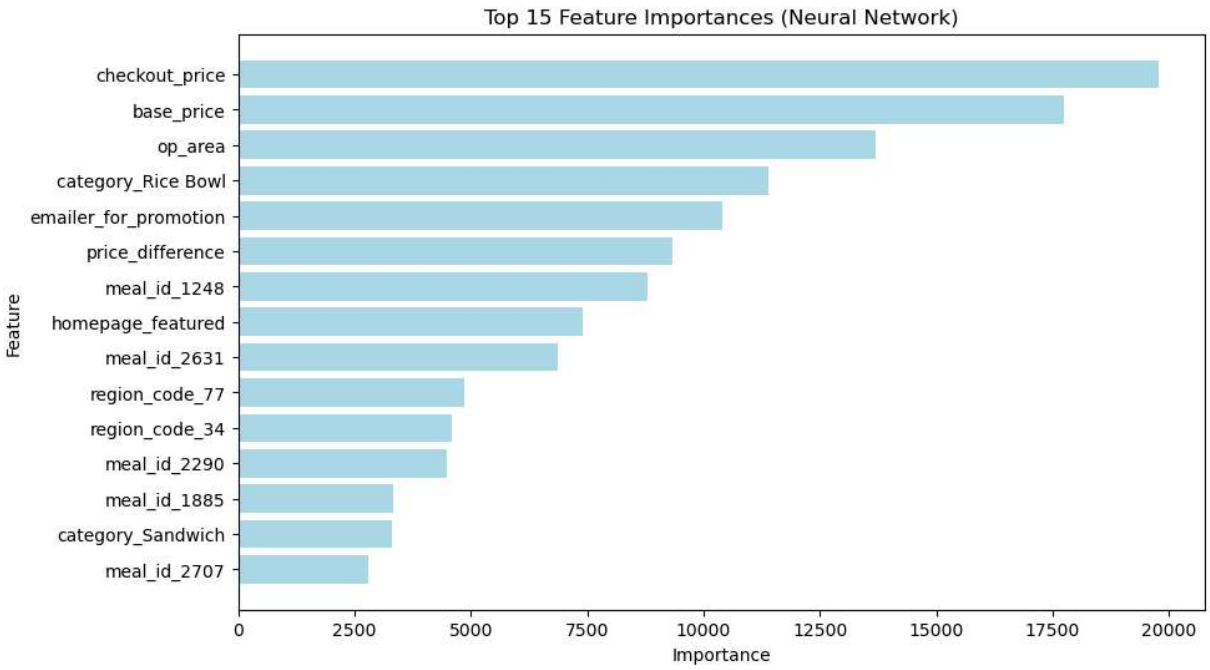
Out[54]:

	Feature	Importance
1	checkout_price	19771.648438
2	base_price	17751.207031
5	op_area	13705.476562
17	category_Rice Bowl	11405.523438
3	emailer_for_promotion	10413.931641
8	price_difference	9327.720703
167	meal_id_1248	8794.654297
4	homepage_featured	7405.802734
202	meal_id_2631	6868.646484
82	region_code_77	4864.347656
78	region_code_34	4591.335938
190	meal_id_2290	4491.298828
182	meal_id_1885	3333.271484
19	category_Sandwich	3300.959961
206	meal_id_2707	2792.070312

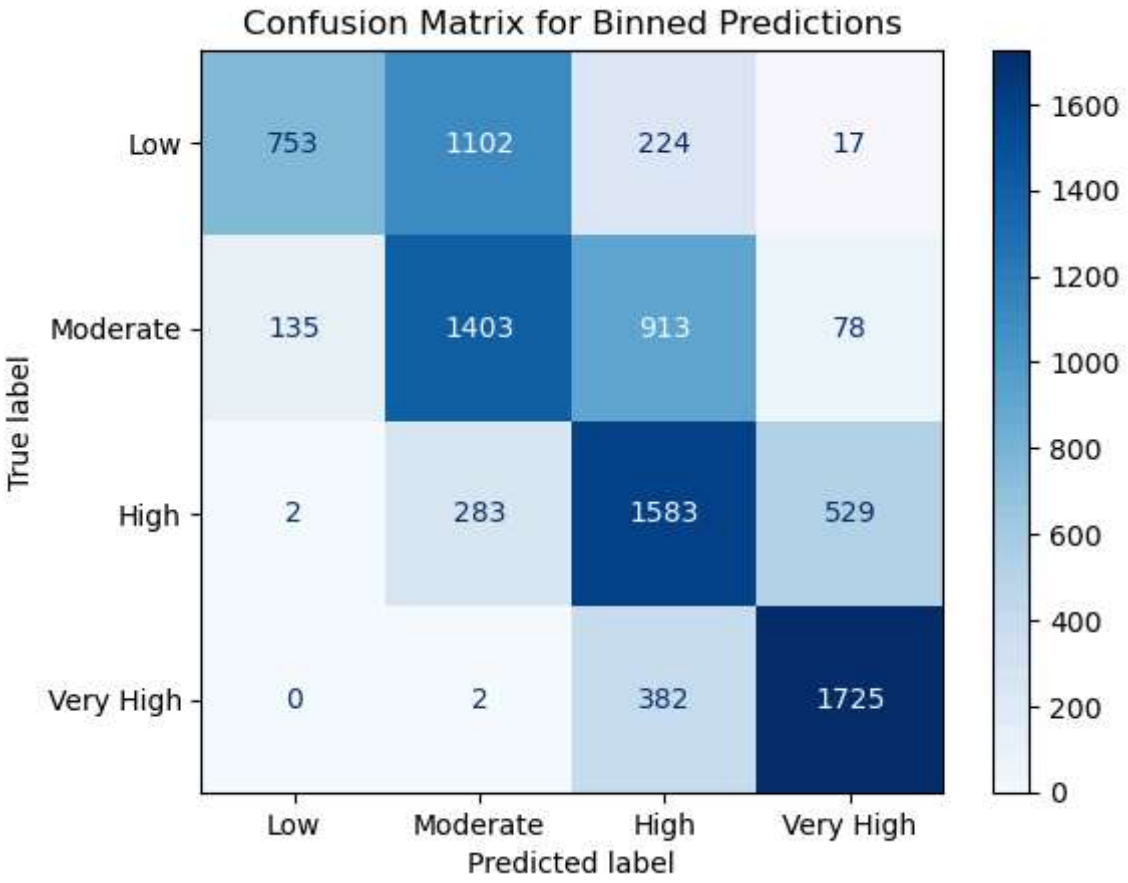
In [55]:
```
# Get top 15 features
top_features = importance_df.head(15)

# Create a bar plot
plt.figure(figsize=(10, 6))
plt.barh(top_features['Feature'], top_features['Importance'], color='lightblue')
plt.gca().invert_yaxis()  # Invert y-axis for descending order
plt.title('Top 15 Feature Importances (Neural Network)')
plt.xlabel('Importance')
plt.ylabel('Feature')
plt.show()
```



Confusion Matrix

In [56]:

```
# Define the bins and labels
bins = [0, 50, 136, 324, np.inf]
labels = ['Low', 'Moderate', 'High', 'Very High']

# Bin the actual and predicted values
y_test_binned = np.digitize(y_test, bins=bins) - 1
y_pred_binned = np.digitize(y_pred, bins=bins) - 1

# Generate confusion matrix
cm = confusion_matrix(y_test_binned, y_pred_binned, labels=range(len(labels)))

# Plot the confusion matrix
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=labels)
disp.plot(cmap=plt.cm.Blues)
plt.title("Confusion Matrix for Binned Predictions")
plt.show()
```



Hypertuning

In [63]:

```
from tensorflow.keras.metrics import MeanAbsoluteError, MeanSquaredError, RootMeanS


def custom_loss(y_true, y_pred):
    mae = tf.reduce_mean(tf.abs(y_true - y_pred))  # MAE
    mse = tf.reduce_mean(tf.square(y_true - y_pred))  # MSE
    rmse = tf.sqrt(mse)  # RMSE
    return 0.5 * mae + 0.5 * rmse

# Define build function for keras tuner
def build_model(hp):
    # Hyperparameters
    units_1 = hp.Int('units_1', min_value = 32, max_value = 256, step = 32)
    dropout_1 = hp.Float('dropout_1', min_value = 0.0, max_value = 0.5, step = 0.1)
    units_2 = hp.Int('units_2', min_value = 16, max_value = 128, step = 16)
    dropout_2 = hp.Float('dropout_2', min_value = 0.0, max_value = 0.5, step = 0.1)
    learning_rate = hp.Choice('learning_rate', values = [1e-2, 1e-3, 1e-4])
    batch_size = hp.Choice('batch_size', values = [16, 32, 64])

    # Build the Sequential model
    model = Sequential()
    model.add(Dense(units_1, activation = 'relu', input_shape = (X_train.shape[1],)
    model.add(Dropout(dropout_1))
    model.add(Dense(units_2, activation = 'relu'))
    model.add(Dropout(dropout_2))
    model.add(Dense(1, activation = 'linear'))
```

```
    # Compile the model
    optimizer = tf.keras.optimizers.Adam(learning_rate = learning_rate)
    model.compile(optimizer=optimizer, loss=custom_loss, metrics= [MeanAbsoluteErro
    return model

# Hyperparameter tuning with keras tuner (random search)
tuner = kt.RandomSearch(
    build_model,
    objective = 'val_mae',
    max_trials = 20,
    executions_per_trial = 2,
    directory = 'my_dir',
    project_name = 'hyper_tuning_regression_5'
)

# Early stopping callback
early_stopping = EarlyStopping(monitor = 'val_loss', patience = 10, restore_best_we

# Perform the search
tuner.search(
    X_train, y_train,
    validation_data = (X_test, y_test),
    epochs = 100,
    callbacks = [early_stopping],
    verbose = 1
)

# Retrieve the best hyperparameters
best_hps = tuner.get_best_hyperparameters(num_trials=1)[0]

print("\nBest Hyperparameters found:")
print(f"units_1: {best_hps.get('units_1')}")
print(f"dropout_1: {best_hps.get('dropout_1')}")
print(f"units_2: {best_hps.get('units_2')}")
print(f"dropout_2: {best_hps.get('dropout_2')}")
print(f"learning_rate: {best_hps.get('learning_rate')}")
print(f"batch_size: {best_hps.get('batch_size')}")

# Build and train the best model
nr_best_model = tuner.hypermodel.build(best_hps)

history = nr_best_model.fit(
    X_train, y_train,
    validation_data = (X_test, y_test),
    epochs = 200,
    batch_size = best_hps.get('batch_size'),
    callbacks = [early_stopping],
    verbose = 1
)

# Evaluate the new model
y_pred = nr_best_model.predict(X_test)
```

```
Reloading Tuner from my_dir\hyper_tuning_regression_5\tuner0.json

Best Hyperparameters found:
units_1: 96
dropout_1: 0.1
units_2: 128
dropout_2: 0.1
learning_rate: 0.001
batch_size: 32
Epoch 1/200
1142/1142 [==============================] - 1s 999us/step - loss: 210.3191 - mean_a
bsolute_error: 151.8872 - mean_squared_error: 99730.5781 - root_mean_squared_error:
315.8015 - val_loss: 155.1329 - val_mean_absolute_error: 111.1580 - val_mean_squared
_error: 52052.4062 - val_root_mean_squared_error: 228.1500
Epoch 2/200
1142/1142 [==============================] - 1s 905us/step - loss: 154.4714 - mean_a
bsolute_error: 109.9008 - mean_squared_error: 55625.6602 - root_mean_squared_error:
235.8509 - val_loss: 148.1994 - val_mean_absolute_error: 108.7749 - val_mean_squared
_error: 45934.2969 - val_root_mean_squared_error: 214.3229
Epoch 3/200
1142/1142 [==============================] - 1s 897us/step - loss: 146.9992 - mean_a
bsolute_error: 104.6366 - mean_squared_error: 49850.0703 - root_mean_squared_error:
223.2713 - val_loss: 150.1102 - val_mean_absolute_error: 105.8305 - val_mean_squared
_error: 48682.8945 - val_root_mean_squared_error: 220.6420
Epoch 4/200
1142/1142 [==============================] - 1s 873us/step - loss: 142.2308 - mean_a
bsolute_error: 101.0930 - mean_squared_error: 46842.9648 - root_mean_squared_error:
216.4324 - val_loss: 147.3599 - val_mean_absolute_error: 109.8654 - val_mean_squared
_error: 43882.9844 - val_root_mean_squared_error: 209.4827
Epoch 5/200
1142/1142 [==============================] - 1s 898us/step - loss: 138.5020 - mean_a
bsolute_error: 98.3468 - mean_squared_error: 44665.5430 - root_mean_squared_error: 2
11.3422 - val_loss: 140.5576 - val_mean_absolute_error: 109.6735 - val_mean_squared_
error: 36616.7695 - val_root_mean_squared_error: 191.3551
Epoch 6/200
1142/1142 [==============================] - 1s 911us/step - loss: 134.4794 - mean_a
bsolute_error: 95.8717 - mean_squared_error: 41929.4609 - root_mean_squared_error: 2
04.7668 - val_loss: 135.2337 - val_mean_absolute_error: 101.7128 - val_mean_squared_
error: 36850.7383 - val_root_mean_squared_error: 191.9655
Epoch 7/200
1142/1142 [==============================] - 1s 910us/step - loss: 132.4236 - mean_a
bsolute_error: 94.2458 - mean_squared_error: 40419.5742 - root_mean_squared_error: 2
01.0462 - val_loss: 135.8306 - val_mean_absolute_error: 100.4795 - val_mean_squared_
error: 38152.3945 - val_root_mean_squared_error: 195.3264
Epoch 8/200
1142/1142 [==============================] - 1s 903us/step - loss: 129.7198 - mean_a
bsolute_error: 92.0831 - mean_squared_error: 38750.3828 - root_mean_squared_error: 1
96.8512 - val_loss: 149.5540 - val_mean_absolute_error: 103.5700 - val_mean_squared_
error: 49522.3125 - val_root_mean_squared_error: 222.5361
Epoch 9/200
1142/1142 [==============================] - 1s 880us/step - loss: 127.9740 - mean_a
bsolute_error: 91.0770 - mean_squared_error: 37887.2656 - root_mean_squared_error: 1
94.6465 - val_loss: 127.6981 - val_mean_absolute_error: 93.7105 - val_mean_squared_e
rror: 33978.0195 - val_root_mean_squared_error: 184.3313
Epoch 10/200
1142/1142 [==============================] - 1s 901us/step - loss: 125.8522 - mean_a
```

```
bsolute_error: 89.5146 - mean_squared_error: 36477.7734 - root_mean_squared_error: 1
90.9915 - val_loss: 125.4369 - val_mean_absolute_error: 89.1880 - val_mean_squared_e
rror: 34527.4688 - val_root_mean_squared_error: 185.8157
Epoch 11/200
1142/1142 [==============================] - 1s 937us/step - loss: 125.4471 - mean_a
bsolute_error: 89.3396 - mean_squared_error: 36334.8789 - root_mean_squared_error: 1
90.6171 - val_loss: 130.0602 - val_mean_absolute_error: 93.5341 - val_mean_squared_e
rror: 36360.5859 - val_root_mean_squared_error: 190.6845
Epoch 12/200
1142/1142 [==============================] - 1s 898us/step - loss: 123.0227 - mean_a
bsolute_error: 87.5506 - mean_squared_error: 34652.0898 - root_mean_squared_error: 1
86.1507 - val_loss: 127.1904 - val_mean_absolute_error: 93.5646 - val_mean_squared_e
rror: 34179.2539 - val_root_mean_squared_error: 184.8763
Epoch 13/200
1142/1142 [==============================] - 1s 897us/step - loss: 122.0883 - mean_a
bsolute_error: 87.1165 - mean_squared_error: 33562.5703 - root_mean_squared_error: 1
83.2009 - val_loss: 121.6003 - val_mean_absolute_error: 89.8442 - val_mean_squared_e
rror: 30297.4121 - val_root_mean_squared_error: 174.0615
Epoch 14/200
1142/1142 [==============================] - 1s 887us/step - loss: 120.9177 - mean_a
bsolute_error: 86.2063 - mean_squared_error: 32877.9141 - root_mean_squared_error: 1
81.3227 - val_loss: 124.6891 - val_mean_absolute_error: 90.3590 - val_mean_squared_e
rror: 33494.5195 - val_root_mean_squared_error: 183.0151
Epoch 15/200
1142/1142 [==============================] - 1s 896us/step - loss: 120.5858 - mean_a
bsolute_error: 86.0276 - mean_squared_error: 33054.1719 - root_mean_squared_error: 1
81.8081 - val_loss: 129.5901 - val_mean_absolute_error: 93.8028 - val_mean_squared_e
rror: 35507.8047 - val_root_mean_squared_error: 188.4352
Epoch 16/200
1142/1142 [==============================] - 1s 885us/step - loss: 119.1456 - mean_a
bsolute_error: 85.0267 - mean_squared_error: 32137.5293 - root_mean_squared_error: 1
79.2694 - val_loss: 125.0795 - val_mean_absolute_error: 94.7262 - val_mean_squared_e
rror: 31261.8867 - val_root_mean_squared_error: 176.8103
Epoch 17/200
1142/1142 [==============================] - 1s 904us/step - loss: 118.6320 - mean_a
bsolute_error: 84.6757 - mean_squared_error: 32050.4160 - root_mean_squared_error: 1
79.0263 - val_loss: 124.2729 - val_mean_absolute_error: 93.1651 - val_mean_squared_e
rror: 31050.7129 - val_root_mean_squared_error: 176.2121
Epoch 18/200
1142/1142 [==============================] - 1s 874us/step - loss: 117.3597 - mean_a
bsolute_error: 83.8107 - mean_squared_error: 31193.2930 - root_mean_squared_error: 1
76.6162 - val_loss: 119.9052 - val_mean_absolute_error: 87.7843 - val_mean_squared_e
rror: 30382.4980 - val_root_mean_squared_error: 174.3058
Epoch 19/200
1142/1142 [==============================] - 1s 866us/step - loss: 116.9411 - mean_a
bsolute_error: 83.6169 - mean_squared_error: 30235.0156 - root_mean_squared_error: 1
73.8822 - val_loss: 118.7608 - val_mean_absolute_error: 86.0757 - val_mean_squared_e
rror: 29548.5781 - val_root_mean_squared_error: 171.8970
Epoch 20/200
1142/1142 [==============================] - 1s 887us/step - loss: 116.1794 - mean_a
bsolute_error: 82.9882 - mean_squared_error: 30273.4727 - root_mean_squared_error: 1
73.9927 - val_loss: 119.3656 - val_mean_absolute_error: 87.6667 - val_mean_squared_e
rror: 29627.4512 - val_root_mean_squared_error: 172.1263
Epoch 21/200
1142/1142 [==============================] - 1s 871us/step - loss: 115.3836 - mean_a
bsolute_error: 82.6315 - mean_squared_error: 29681.5859 - root_mean_squared_error: 1
```

```
72.2834 - val_loss: 121.8761 - val_mean_absolute_error: 87.7811 - val_mean_squared_e
rror: 31747.5117 - val_root_mean_squared_error: 178.1783
Epoch 22/200
1142/1142 [==============================] - 1s 966us/step - loss: 115.2305 - mean_a
bsolute_error: 82.3060 - mean_squared_error: 29823.9902 - root_mean_squared_error: 1
72.6962 - val_loss: 117.8825 - val_mean_absolute_error: 87.0491 - val_mean_squared_e
rror: 28286.2148 - val_root_mean_squared_error: 168.1851
Epoch 23/200
1142/1142 [==============================] - 1s 897us/step - loss: 114.4337 - mean_a
bsolute_error: 82.0718 - mean_squared_error: 29156.7246 - root_mean_squared_error: 1
70.7534 - val_loss: 122.3278 - val_mean_absolute_error: 90.4887 - val_mean_squared_e
rror: 31391.7715 - val_root_mean_squared_error: 177.1772
Epoch 24/200
1142/1142 [==============================] - 1s 854us/step - loss: 113.6282 - mean_a
bsolute_error: 81.3611 - mean_squared_error: 28714.5449 - root_mean_squared_error: 1
69.4537 - val_loss: 126.2171 - val_mean_absolute_error: 92.7866 - val_mean_squared_e
rror: 31878.4766 - val_root_mean_squared_error: 178.5454
Epoch 25/200
1142/1142 [==============================] - 1s 839us/step - loss: 114.0646 - mean_a
bsolute_error: 81.5163 - mean_squared_error: 28762.2402 - root_mean_squared_error: 1
69.5943 - val_loss: 122.0510 - val_mean_absolute_error: 90.3533 - val_mean_squared_e
rror: 30997.6992 - val_root_mean_squared_error: 176.0616
Epoch 26/200
1142/1142 [==============================] - 1s 872us/step - loss: 112.6175 - mean_a
bsolute_error: 80.6651 - mean_squared_error: 28189.4395 - root_mean_squared_error: 1
67.8971 - val_loss: 117.2564 - val_mean_absolute_error: 85.8554 - val_mean_squared_e
rror: 27971.7910 - val_root_mean_squared_error: 167.2477
Epoch 27/200
1142/1142 [==============================] - 1s 862us/step - loss: 112.9351 - mean_a
bsolute_error: 81.1076 - mean_squared_error: 28229.4746 - root_mean_squared_error: 1
68.0163 - val_loss: 118.4417 - val_mean_absolute_error: 88.1649 - val_mean_squared_e
rror: 28214.9258 - val_root_mean_squared_error: 167.9730
Epoch 28/200
1142/1142 [==============================] - 1s 871us/step - loss: 111.4029 - mean_a
bsolute_error: 80.1998 - mean_squared_error: 27376.0078 - root_mean_squared_error: 1
65.4570 - val_loss: 118.0692 - val_mean_absolute_error: 84.9190 - val_mean_squared_e
rror: 30474.7734 - val_root_mean_squared_error: 174.5703
Epoch 29/200
1142/1142 [==============================] - 1s 869us/step - loss: 111.4047 - mean_a
bsolute_error: 79.7819 - mean_squared_error: 27147.8398 - root_mean_squared_error: 1
64.7660 - val_loss: 116.6077 - val_mean_absolute_error: 85.6031 - val_mean_squared_e
rror: 28062.5430 - val_root_mean_squared_error: 167.5188
Epoch 30/200
1142/1142 [==============================] - 1s 912us/step - loss: 111.4044 - mean_a
bsolute_error: 79.8735 - mean_squared_error: 27369.1582 - root_mean_squared_error: 1
65.4363 - val_loss: 114.8324 - val_mean_absolute_error: 84.7646 - val_mean_squared_e
rror: 27282.9121 - val_root_mean_squared_error: 165.1754
Epoch 31/200
1142/1142 [==============================] - 1s 919us/step - loss: 110.1259 - mean_a
bsolute_error: 79.3507 - mean_squared_error: 26684.0039 - root_mean_squared_error: 1
63.3524 - val_loss: 119.9555 - val_mean_absolute_error: 89.0585 - val_mean_squared_e
rror: 29382.9863 - val_root_mean_squared_error: 171.4147
Epoch 32/200
1142/1142 [==============================] - 1s 919us/step - loss: 109.8323 - mean_a
bsolute_error: 78.9639 - mean_squared_error: 26921.9199 - root_mean_squared_error: 1
64.0790 - val_loss: 119.1227 - val_mean_absolute_error: 86.6430 - val_mean_squared_e
```

```
rror: 29817.8574 - val_root_mean_squared_error: 172.6785
Epoch 33/200
1142/1142 [==============================] - 1s 890us/step - loss: 109.5570 - mean_a
bsolute_error: 78.5847 - mean_squared_error: 26666.5391 - root_mean_squared_error: 1
63.2989 - val_loss: 121.0974 - val_mean_absolute_error: 89.2399 - val_mean_squared_e
rror: 28851.6543 - val_root_mean_squared_error: 169.8577
Epoch 34/200
1142/1142 [==============================] - 1s 874us/step - loss: 110.0807 - mean_a
bsolute_error: 79.0600 - mean_squared_error: 26815.2988 - root_mean_squared_error: 1
63.7538 - val_loss: 123.2415 - val_mean_absolute_error: 93.5285 - val_mean_squared_e
rror: 28113.0703 - val_root_mean_squared_error: 167.6695
Epoch 35/200
1142/1142 [==============================] - 1s 877us/step - loss: 109.4789 - mean_a
bsolute_error: 78.7950 - mean_squared_error: 26479.4160 - root_mean_squared_error: 1
62.7250 - val_loss: 116.2928 - val_mean_absolute_error: 86.5744 - val_mean_squared_e
rror: 27028.3008 - val_root_mean_squared_error: 164.4029
Epoch 36/200
1142/1142 [==============================] - 1s 895us/step - loss: 109.0079 - mean_a
bsolute_error: 78.2818 - mean_squared_error: 25932.1172 - root_mean_squared_error: 1
61.0345 - val_loss: 114.8154 - val_mean_absolute_error: 83.6403 - val_mean_squared_e
rror: 27500.6934 - val_root_mean_squared_error: 165.8333
Epoch 37/200
1142/1142 [==============================] - 1s 985us/step - loss: 108.3666 - mean_a
bsolute_error: 77.7805 - mean_squared_error: 25804.7129 - root_mean_squared_error: 1
60.6385 - val_loss: 114.7877 - val_mean_absolute_error: 84.4959 - val_mean_squared_e
rror: 27111.5391 - val_root_mean_squared_error: 164.6558
Epoch 38/200
1142/1142 [==============================] - 1s 909us/step - loss: 108.7287 - mean_a
bsolute_error: 77.9713 - mean_squared_error: 26323.2012 - root_mean_squared_error: 1
62.2443 - val_loss: 114.5986 - val_mean_absolute_error: 83.7941 - val_mean_squared_e
rror: 27297.6191 - val_root_mean_squared_error: 165.2199
Epoch 39/200
1142/1142 [==============================] - 1s 960us/step - loss: 107.6682 - mean_a
bsolute_error: 77.3863 - mean_squared_error: 25486.3516 - root_mean_squared_error: 1
59.6445 - val_loss: 116.9204 - val_mean_absolute_error: 84.2174 - val_mean_squared_e
rror: 29126.6992 - val_root_mean_squared_error: 170.6655
Epoch 40/200
1142/1142 [==============================] - 1s 966us/step - loss: 107.6000 - mean_a
bsolute_error: 77.4610 - mean_squared_error: 25102.6699 - root_mean_squared_error: 1
58.4382 - val_loss: 119.4146 - val_mean_absolute_error: 85.4274 - val_mean_squared_e
rror: 31241.1016 - val_root_mean_squared_error: 176.7515
Epoch 41/200
1142/1142 [==============================] - 1s 918us/step - loss: 107.2073 - mean_a
bsolute_error: 77.3983 - mean_squared_error: 24944.6895 - root_mean_squared_error: 1
57.9389 - val_loss: 117.1921 - val_mean_absolute_error: 86.2754 - val_mean_squared_e
rror: 26910.2070 - val_root_mean_squared_error: 164.0433
Epoch 42/200
1142/1142 [==============================] - 1s 915us/step - loss: 106.8215 - mean_a
bsolute_error: 76.9755 - mean_squared_error: 25258.5977 - root_mean_squared_error: 1
58.9295 - val_loss: 118.2804 - val_mean_absolute_error: 86.7925 - val_mean_squared_e
rror: 29167.5254 - val_root_mean_squared_error: 170.7850
Epoch 43/200
1142/1142 [==============================] - 1s 929us/step - loss: 106.8845 - mean_a
bsolute_error: 76.8509 - mean_squared_error: 25073.3945 - root_mean_squared_error: 1
58.3458 - val_loss: 116.4473 - val_mean_absolute_error: 87.5508 - val_mean_squared_e
rror: 26297.9688 - val_root_mean_squared_error: 162.1665
```

```
Epoch 44/200
1142/1142 [==============================] - 1s 887us/step - loss: 105.9750 - mean_a
bsolute_error: 76.3727 - mean_squared_error: 24506.8574 - root_mean_squared_error: 1
56.5467 - val_loss: 113.5506 - val_mean_absolute_error: 83.1964 - val_mean_squared_e
rror: 26394.3887 - val_root_mean_squared_error: 162.4635
Epoch 45/200
1142/1142 [==============================] - 1s 947us/step - loss: 107.2684 - mean_a
bsolute_error: 77.1501 - mean_squared_error: 24630.3887 - root_mean_squared_error: 1
56.9407 - val_loss: 117.5542 - val_mean_absolute_error: 87.5797 - val_mean_squared_e
rror: 27393.1016 - val_root_mean_squared_error: 165.5086
Epoch 46/200
1142/1142 [==============================] - 1s 953us/step - loss: 105.9278 - mean_a
bsolute_error: 76.2930 - mean_squared_error: 24733.2637 - root_mean_squared_error: 1
57.2681 - val_loss: 118.5803 - val_mean_absolute_error: 84.8179 - val_mean_squared_e
rror: 30091.1758 - val_root_mean_squared_error: 173.4681
Epoch 47/200
1142/1142 [==============================] - 1s 949us/step - loss: 105.5698 - mean_a
bsolute_error: 76.2506 - mean_squared_error: 24379.8105 - root_mean_squared_error: 1
56.1404 - val_loss: 117.2622 - val_mean_absolute_error: 85.3858 - val_mean_squared_e
rror: 28465.2559 - val_root_mean_squared_error: 168.7165
Epoch 48/200
1142/1142 [==============================] - 1s 866us/step - loss: 106.2584 - mean_a
bsolute_error: 76.1571 - mean_squared_error: 24608.9297 - root_mean_squared_error: 1
56.8723 - val_loss: 123.9424 - val_mean_absolute_error: 89.5072 - val_mean_squared_e
rror: 31779.5117 - val_root_mean_squared_error: 178.2681
Epoch 49/200
1142/1142 [==============================] - 1s 918us/step - loss: 105.3981 - mean_a
bsolute_error: 76.1021 - mean_squared_error: 24315.3145 - root_mean_squared_error: 1
55.9337 - val_loss: 119.7590 - val_mean_absolute_error: 85.8153 - val_mean_squared_e
rror: 30874.1309 - val_root_mean_squared_error: 175.7104
Epoch 50/200
1142/1142 [==============================] - 1s 853us/step - loss: 104.9390 - mean_a
bsolute_error: 75.7125 - mean_squared_error: 23827.7207 - root_mean_squared_error: 1
54.3623 - val_loss: 126.2062 - val_mean_absolute_error: 95.5926 - val_mean_squared_e
rror: 29605.8105 - val_root_mean_squared_error: 172.0634
Epoch 51/200
1142/1142 [==============================] - 1s 913us/step - loss: 104.5606 - mean_a
bsolute_error: 75.6690 - mean_squared_error: 23734.0957 - root_mean_squared_error: 1
54.0587 - val_loss: 119.2383 - val_mean_absolute_error: 88.6437 - val_mean_squared_e
rror: 27640.7305 - val_root_mean_squared_error: 166.2550
Epoch 52/200
1142/1142 [==============================] - 1s 848us/step - loss: 105.0164 - mean_a
bsolute_error: 75.7778 - mean_squared_error: 24024.9473 - root_mean_squared_error: 1
54.9998 - val_loss: 131.8884 - val_mean_absolute_error: 93.5103 - val_mean_squared_e
rror: 37333.2773 - val_root_mean_squared_error: 193.2182
Epoch 53/200
1142/1142 [==============================] - 1s 906us/step - loss: 105.3869 - mean_a
bsolute_error: 76.2401 - mean_squared_error: 23792.0098 - root_mean_squared_error: 1
54.2466 - val_loss: 120.2545 - val_mean_absolute_error: 90.9446 - val_mean_squared_e
rror: 27460.7266 - val_root_mean_squared_error: 165.7128
Epoch 54/200
1142/1142 [==============================] - 1s 940us/step - loss: 104.9052 - mean_a
bsolute_error: 75.8035 - mean_squared_error: 23821.1387 - root_mean_squared_error: 1
54.3410 - val_loss: 113.4987 - val_mean_absolute_error: 83.9833 - val_mean_squared_e
rror: 25717.0918 - val_root_mean_squared_error: 160.3655
Epoch 55/200
```

```
1142/1142 [==============================] - 1s 858us/step - loss: 103.3259 - mean_a
bsolute_error: 75.1234 - mean_squared_error: 23035.8047 - root_mean_squared_error: 1
51.7755 - val_loss: 114.0390 - val_mean_absolute_error: 83.1626 - val_mean_squared_e
rror: 26835.7578 - val_root_mean_squared_error: 163.8162
Epoch 56/200
1142/1142 [==============================] - 1s 955us/step - loss: 103.3136 - mean_a
bsolute_error: 74.8789 - mean_squared_error: 23094.8340 - root_mean_squared_error: 1
51.9698 - val_loss: 121.3455 - val_mean_absolute_error: 89.2353 - val_mean_squared_e
rror: 30094.5586 - val_root_mean_squared_error: 173.4778
Epoch 57/200
1142/1142 [==============================] - 1s 921us/step - loss: 103.6384 - mean_a
bsolute_error: 74.9555 - mean_squared_error: 23220.6895 - root_mean_squared_error: 1
52.3834 - val_loss: 124.9838 - val_mean_absolute_error: 93.9511 - val_mean_squared_e
rror: 28978.1289 - val_root_mean_squared_error: 170.2296
Epoch 58/200
1142/1142 [==============================] - 1s 913us/step - loss: 103.2669 - mean_a
bsolute_error: 74.4917 - mean_squared_error: 23060.1484 - root_mean_squared_error: 1
51.8557 - val_loss: 114.3509 - val_mean_absolute_error: 83.7745 - val_mean_squared_e
rror: 26472.1172 - val_root_mean_squared_error: 162.7025
Epoch 59/200
1142/1142 [==============================] - 1s 923us/step - loss: 102.9681 - mean_a
bsolute_error: 74.5855 - mean_squared_error: 22683.0312 - root_mean_squared_error: 1
50.6089 - val_loss: 118.8009 - val_mean_absolute_error: 88.8045 - val_mean_squared_e
rror: 28875.4141 - val_root_mean_squared_error: 169.9277
Epoch 60/200
1142/1142 [==============================] - 1s 950us/step - loss: 102.9786 - mean_a
bsolute_error: 74.5873 - mean_squared_error: 22694.2168 - root_mean_squared_error: 1
50.6460 - val_loss: 121.0151 - val_mean_absolute_error: 86.2529 - val_mean_squared_e
rror: 31984.1270 - val_root_mean_squared_error: 178.8411
Epoch 61/200
1142/1142 [==============================] - 1s 862us/step - loss: 102.9835 - mean_a
bsolute_error: 74.2926 - mean_squared_error: 22659.7402 - root_mean_squared_error: 1
50.5315 - val_loss: 117.6093 - val_mean_absolute_error: 87.8243 - val_mean_squared_e
rror: 26353.5273 - val_root_mean_squared_error: 162.3377
Epoch 62/200
1142/1142 [==============================] - 1s 955us/step - loss: 103.3974 - mean_a
bsolute_error: 75.0175 - mean_squared_error: 22828.6074 - root_mean_squared_error: 1
51.0914 - val_loss: 125.4901 - val_mean_absolute_error: 93.6307 - val_mean_squared_e
rror: 31267.4727 - val_root_mean_squared_error: 176.8261
Epoch 63/200
1142/1142 [==============================] - 1s 897us/step - loss: 102.8895 - mean_a
bsolute_error: 74.5451 - mean_squared_error: 23191.9375 - root_mean_squared_error: 1
52.2890 - val_loss: 125.6281 - val_mean_absolute_error: 89.5106 - val_mean_squared_e
rror: 33442.6875 - val_root_mean_squared_error: 182.8734
Epoch 64/200
1142/1142 [==============================] - 1s 892us/step - loss: 102.8784 - mean_a
bsolute_error: 74.4677 - mean_squared_error: 22772.4961 - root_mean_squared_error: 1
50.9056 - val_loss: 117.0560 - val_mean_absolute_error: 84.2855 - val_mean_squared_e
rror: 28636.1016 - val_root_mean_squared_error: 169.2220
286/286 [==============================] - 0s 421us/step
```

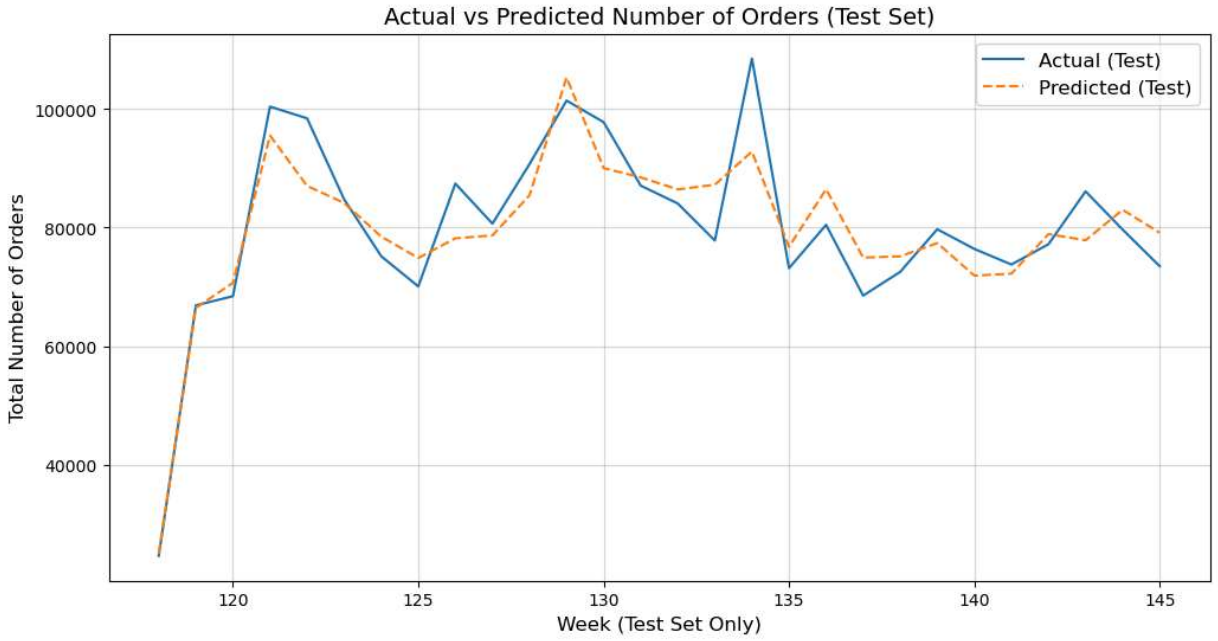
Model Evaluation

In [64]:
```
# Calculate evaluation metrics
mse = mean_squared_error(y_test, y_pred)
```

```
mae = mean_absolute_error(y_test, y_pred)
rmse = np.sqrt(mse)
r2 = r2_score(y_test, y_pred)

print("\nEvaluation Metrics on Test Set:")
print(f"MSE  : {mse:.4f}")
print(f"MAE  : {mae:.4f}")
print(f"RMSE : {rmse:.4f}")
print(f"R^2  : {r2:.4f}")
```

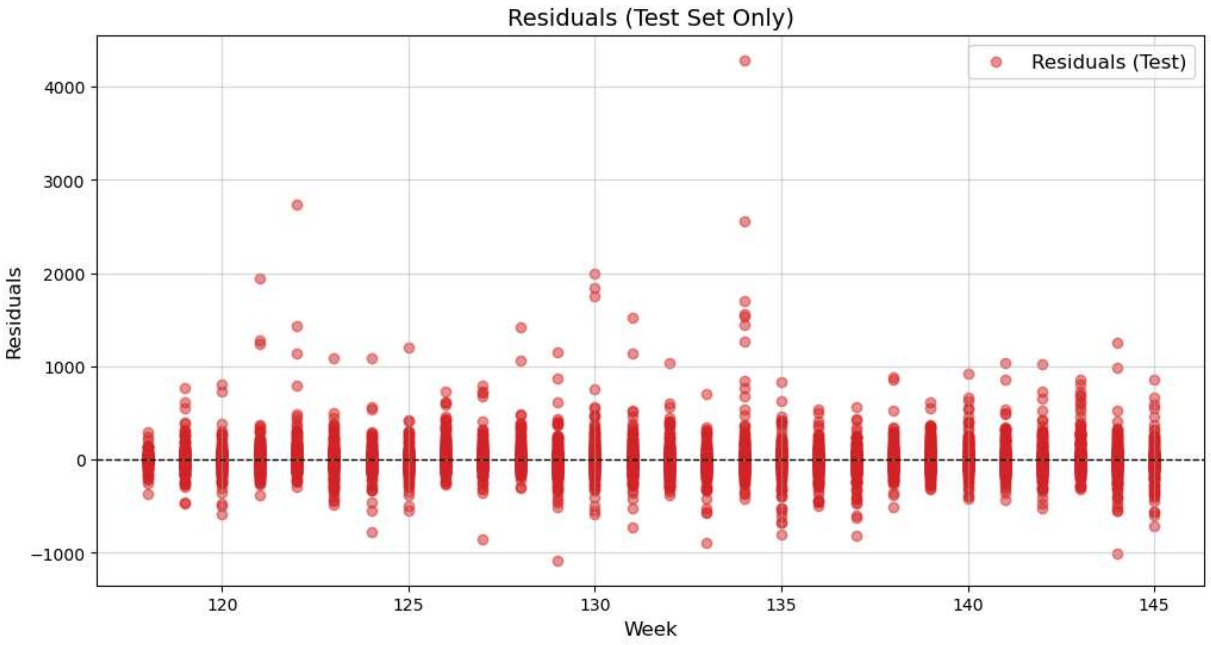
```
Evaluation Metrics on Test Set:
MSE  : 25717.0859
MAE  : 83.9833
RMSE : 160.3655
R^2  : 0.7868
```

In [65]:
```
# Group by 'week' in the test set
test_weeks = X_test['week']
y_test_grouped = y_test.groupby(test_weeks).sum()
y_pred_grouped = pd.Series(y_pred.flatten(), index = X_test.index).groupby(test_wee

# Plot Actual vs Predicted for the Test Set
plt.figure(figsize = (12, 6))
plt.plot(y_test_grouped.index, y_test_grouped, label = 'Actual (Test)', color = 'ta
plt.plot(y_pred_grouped.index, y_pred_grouped, label = 'Predicted (Test)', color =
plt.title("Actual vs Predicted Number of Orders (Test Set)", fontsize=14)
plt.xlabel("Week (Test Set Only)", fontsize=12)
plt.ylabel("Total Number of Orders", fontsize=12)
plt.legend(fontsize = 12)
plt.grid(alpha = 0.5)
plt.show()
```



In [66]:
```
# Residuals (Errors) for the Test Set
residuals = y_test - y_pred.flatten()

# Plot Residuals
```

```
plt.figure(figsize = (12, 6))
plt.scatter(test_weeks, residuals, alpha = 0.5, color = 'tab:red', label = 'Residua
plt.axhline(0, color = 'black', linestyle = '--', linewidth = 1)
plt.title("Residuals (Test Set Only)", fontsize = 14)
plt.xlabel("Week", fontsize = 12)
plt.ylabel("Residuals", fontsize = 12)
plt.legend(fontsize = 12)
plt.grid(alpha = 0.5)
plt.show()
```



LightGBM

In [67]:
```
# Convert data into LightGBM dataset format
train_data = lgb.Dataset(X_train, label=y_train)
test_data = lgb.Dataset(X_test, label=y_test, reference=train_data)

# Set LightGBM hyperparameters
params = {'objective': 'regression',
          'metric': 'rmse',
          'boosting_type': 'gbdt',
          'learning_rate': 0.05,
          'num_leaves': 31,
          'max_depth': -1,
          'verbose': -1
         }

# Train LightGBM model with early stopping and callbacks
model = lgb.train(params,
                  train_data,
                  valid_sets = [train_data, test_data],
                  valid_names = ['train', 'test'],
                  num_boost_round = 500,
                  callbacks = [lgb.early_stopping(stopping_rounds = 50),
                               lgb.log_evaluation(10)]
                 )
```

```python
# Make predictions
y_pred = model.predict(X_test, num_iteration=model.best_iteration)

# Evaluate the model
mse = mean_squared_error(y_test, y_pred)
mae = mean_absolute_error(y_test, y_pred)
rmse = np.sqrt(mse)
r2 = r2_score(y_test, y_pred)

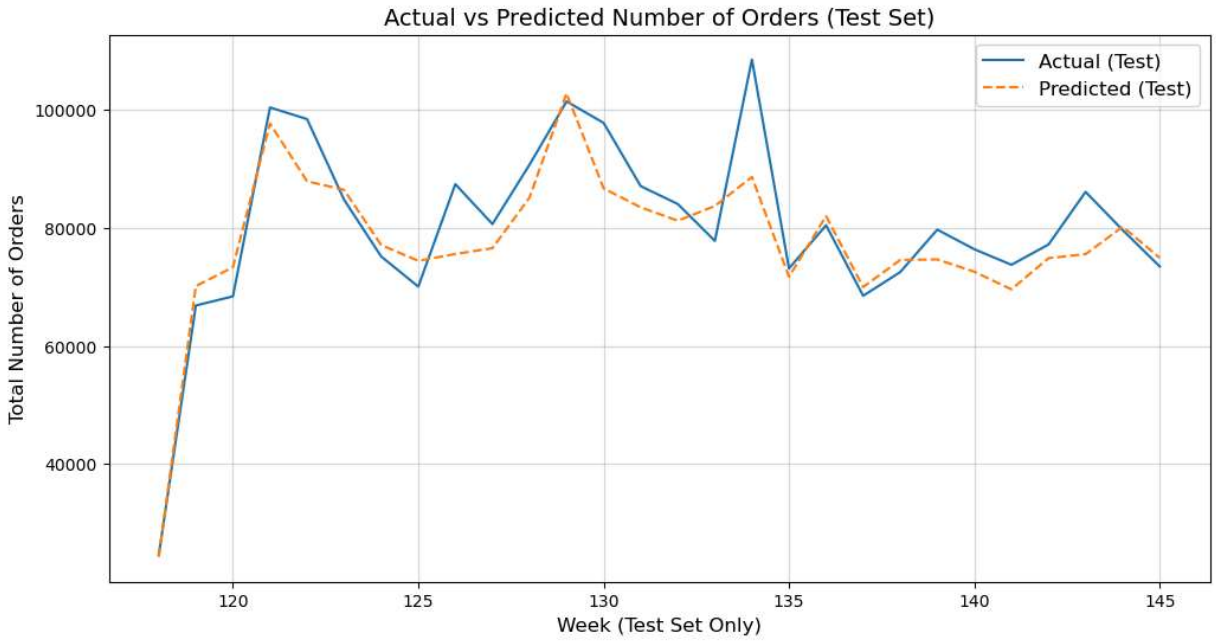
print("Evaluation Metrics:")
print(f"Mean Absolute Error (MAE): {mae:.4f}")
print(f"Mean Squared Error (MSE): {mse:.4f}")
print(f"Root Mean Squared Error (RMSE): {rmse:.4f}")
print(f"R^2 Score: {r2:.4f}")
```

```
Training until validation scores don't improve for 50 rounds
[10]    train's rmse: 300.952   test's rmse: 283.749
[20]    train's rmse: 256.078   test's rmse: 249.971
[30]    train's rmse: 229.466   test's rmse: 227.631
[40]    train's rmse: 212.5     test's rmse: 214.944
[50]    train's rmse: 200.708   test's rmse: 206.73
[60]    train's rmse: 192.097   test's rmse: 200.776
[70]    train's rmse: 184.712   test's rmse: 195.069
[80]    train's rmse: 179.139   test's rmse: 191.752
[90]    train's rmse: 174.656   test's rmse: 188.922
[100]   train's rmse: 171.171   test's rmse: 186.436
[110]   train's rmse: 168.01    test's rmse: 185.082
[120]   train's rmse: 165.296   test's rmse: 183.364
[130]   train's rmse: 163.16    test's rmse: 182.214
[140]   train's rmse: 161.195   test's rmse: 181.345
[150]   train's rmse: 159.435   test's rmse: 180.92
[160]   train's rmse: 157.9     test's rmse: 180.252
[170]   train's rmse: 156.527   test's rmse: 179.823
[180]   train's rmse: 155.235   test's rmse: 179.403
[190]   train's rmse: 153.944   test's rmse: 178.985
[200]   train's rmse: 152.87    test's rmse: 178.462
[210]   train's rmse: 151.675   test's rmse: 178.196
[220]   train's rmse: 150.629   test's rmse: 177.846
[230]   train's rmse: 149.502   test's rmse: 177.476
[240]   train's rmse: 148.525   test's rmse: 177.16
[250]   train's rmse: 147.363   test's rmse: 176.79
[260]   train's rmse: 146.687   test's rmse: 176.628
[270]   train's rmse: 145.609   test's rmse: 176.37
[280]   train's rmse: 144.642   test's rmse: 176.205
[290]   train's rmse: 143.891   test's rmse: 175.986
[300]   train's rmse: 143.062   test's rmse: 175.733
[310]   train's rmse: 142.314   test's rmse: 175.533
[320]   train's rmse: 141.682   test's rmse: 175.375
[330]   train's rmse: 140.83    test's rmse: 175.258
[340]   train's rmse: 140.264   test's rmse: 175.13
[350]   train's rmse: 139.513   test's rmse: 174.845
[360]   train's rmse: 138.64    test's rmse: 174.657
[370]   train's rmse: 137.978   test's rmse: 174.389
[380]   train's rmse: 137.336   test's rmse: 174.302
[390]   train's rmse: 136.531   test's rmse: 174.34
[400]   train's rmse: 136.096   test's rmse: 174.267
[410]   train's rmse: 135.486   test's rmse: 174.057
[420]   train's rmse: 134.945   test's rmse: 173.967
[430]   train's rmse: 134.437   test's rmse: 173.8
[440]   train's rmse: 133.826   test's rmse: 173.722
[450]   train's rmse: 133.23    test's rmse: 173.654
[460]   train's rmse: 132.752   test's rmse: 173.466
[470]   train's rmse: 132.224   test's rmse: 173.182
[480]   train's rmse: 131.687   test's rmse: 173.196
[490]   train's rmse: 131.194   test's rmse: 173.149
[500]   train's rmse: 130.694   test's rmse: 173.145
Did not meet early stopping. Best iteration is:
[491]   train's rmse: 131.172   test's rmse: 173.145
Evaluation Metrics:
Mean Absolute Error (MAE): 92.3538
Mean Squared Error (MSE): 29979.0588
```

```
Root Mean Squared Error (RMSE): 173.1446
R^2 Score: 0.7515
```

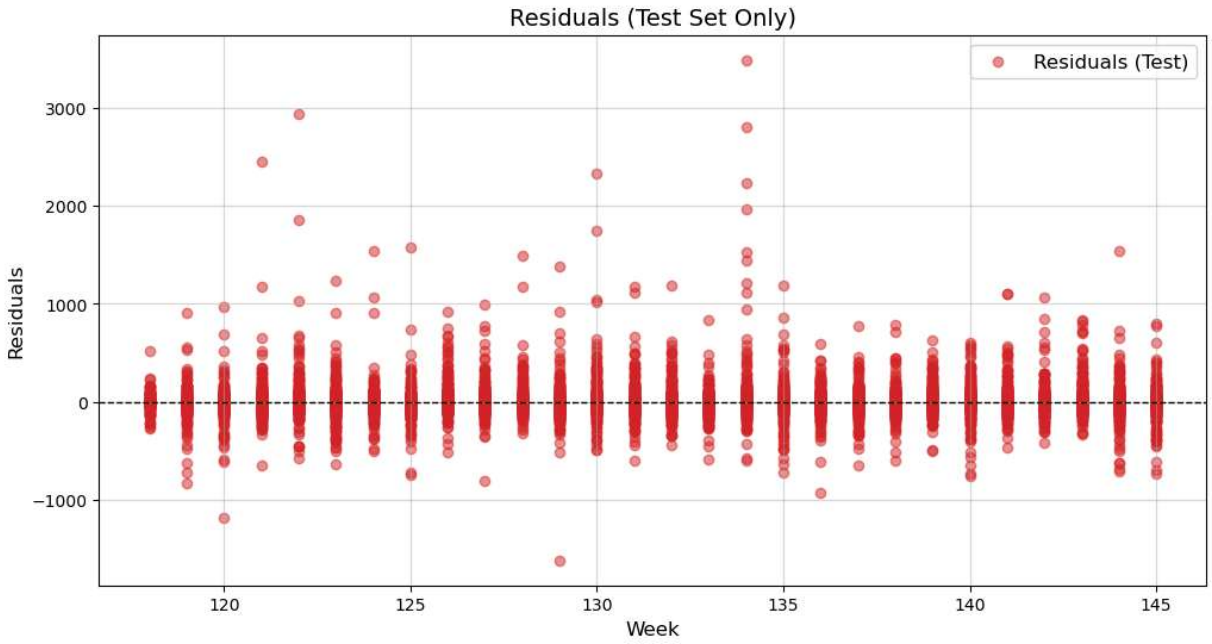
In [68]:
```
# Group by 'week' in the test set
test_weeks = X_test['week']
y_test_grouped = y_test.groupby(test_weeks).sum()
y_pred_grouped = pd.Series(y_pred.flatten(), index=X_test.index).groupby(test_weeks

# Plot Actual vs Predicted for the Test Set
plt.figure(figsize=(12, 6))
plt.plot(y_test_grouped.index, y_test_grouped, label = 'Actual (Test)', color = 'ta
plt.plot(y_pred_grouped.index, y_pred_grouped, label = 'Predicted (Test)', color =
plt.title("Actual vs Predicted Number of Orders (Test Set)", fontsize=14)
plt.xlabel("Week (Test Set Only)", fontsize = 12)
plt.ylabel("Total Number of Orders", fontsize = 12)
plt.legend(fontsize = 12)
plt.grid(alpha = 0.5)
plt.show()
```



In [69]:
```
# Residuals (Errors) for the Test Set
residuals = y_test - y_pred.flatten()

# Plot Residuals
plt.figure(figsize = (12, 6))
plt.scatter(test_weeks, residuals, alpha = 0.5, color = 'tab:red', label = 'Residua
plt.axhline(0, color = 'black', linestyle = '--', linewidth=1)
plt.title("Residuals (Test Set Only)", fontsize=14)
plt.xlabel("Week", fontsize = 12)
plt.ylabel("Residuals", fontsize = 12)
plt.legend(fontsize = 12)
plt.grid(alpha = 0.5)
plt.show()
```



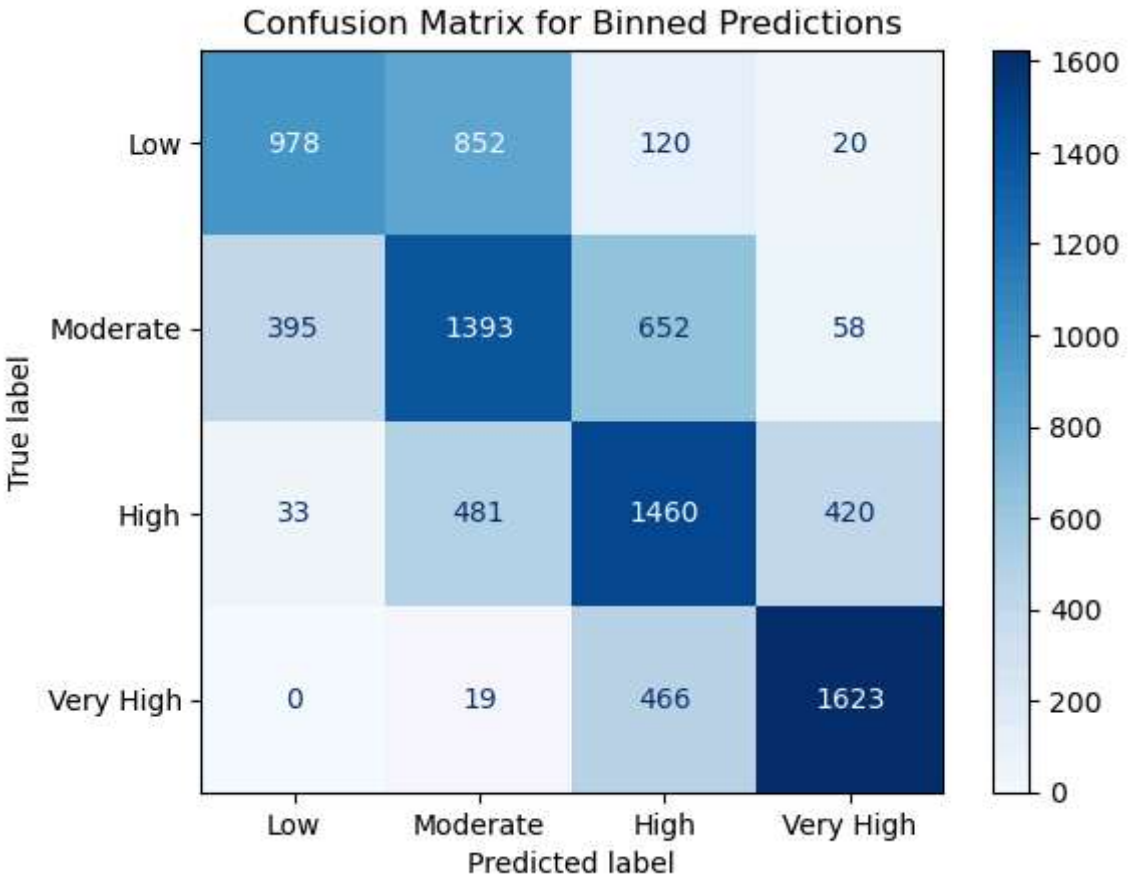
Confusion Matrix

In [70]:
```
# Define the bins and labels
bins = [0, 50, 136, 324, np.inf]
labels = ['Low', 'Moderate', 'High', 'Very High']

# Bin the actual and predicted values
y_test_binned = np.digitize(y_test, bins=bins) - 1
y_pred_binned = np.digitize(y_pred, bins=bins) - 1

# Generate confusion matrix
cm = confusion_matrix(y_test_binned, y_pred_binned, labels=range(len(labels)))

# Plot the confusion matrix
disp = ConfusionMatrixDisplay(confusion_matrix=cm, display_labels=labels)
disp.plot(cmap=plt.cm.Blues)
plt.title("Confusion Matrix for Binned Predictions")
plt.show()
```



Feature Importance

In [71]:
```
# Get feature importances from Booster
feature_importances = model.feature_importance(importance_type='split')

# Retrieve feature names
feature_names = model.feature_name()

# Create a DataFrame for feature importance
importance_df = pd.DataFrame({
    'Feature': feature_names,
    'Importance': feature_importances
}).sort_values(by='Importance', ascending=False)

# Display the top 15 features
print(importance_df.head(15))

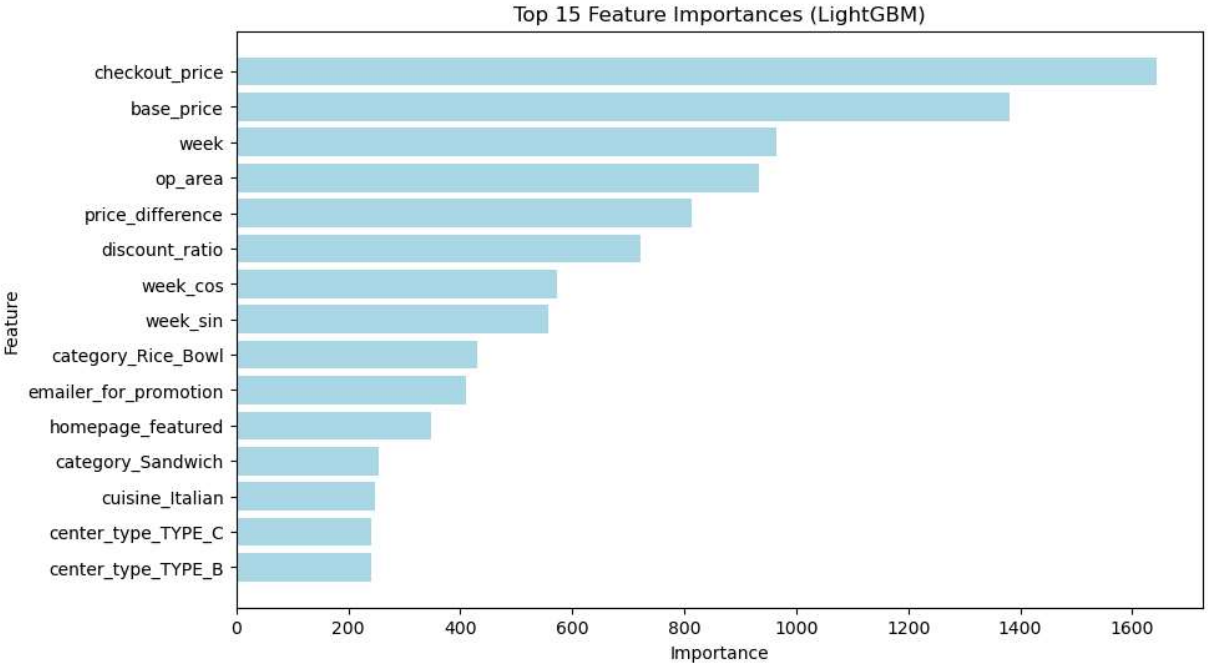

# Plot feature importances

# Get top 15 features
top_features = importance_df.head(15)

# Create a bar plot
plt.figure(figsize=(10, 6))
plt.barh(top_features['Feature'], top_features['Importance'], color='lightblue')
plt.gca().invert_yaxis()  # Invert y-axis for descending order
plt.title('Top 15 Feature Importances (LightGBM)')
```

```
plt.xlabel('Importance')
plt.ylabel('Feature')
plt.show()
```

	Feature	Importance
1	checkout_price	1643
2	base_price	1382
0	week	964
5	op_area	933
8	price_difference	814
9	discount_ratio	723
7	week_cos	572
6	week_sin	557
17	category_Rice_Bowl	431
3	emailer_for_promotion	410
4	homepage_featured	349
19	category_Sandwich	255
24	cuisine_Italian	248
27	center_type_TYPE_C	241
26	center_type_TYPE_B	241



Hypertuning

In [72]:
```
def objective(trial):
# Define the hyperparameters to tune
    params = {'objective': 'regression',
              'metric': 'rmse',
              'boosting_type': 'gbdt',
              'learning_rate': trial.suggest_float('learning_rate', 1e-4, 0.1, log=
              'num_leaves': trial.suggest_int('num_leaves', 16, 64),
              'max_depth': trial.suggest_int('max_depth', -1, 16),
              'min_child_samples': trial.suggest_int('min_child_samples', 5, 100),
              'min_child_weight': trial.suggest_float('min_child_weight', 1e-3, 1.0
              'subsample': trial.suggest_float('subsample', 0.5, 1.0),
              'colsample_bytree': trial.suggest_float('colsample_bytree', 0.5, 1.0)
              'reg_alpha': trial.suggest_float('reg_alpha', 1e-4, 10.0, log=True),
```

```
            'reg_lambda': trial.suggest_float('reg_lambda', 1e-4, 10.0, log=True)
            'n_estimators': trial.suggest_int('n_estimators', 100, 500),
        }

# Train LightGBM model using callbacks for early stopping
    model = lgb.LGBMRegressor(**params)
    model.fit(X_train,
              y_train,
              eval_set = [(X_test, y_test)],
              eval_metric = 'rmse',
              callbacks = [lgb.early_stopping(stopping_rounds=50),
                           lgb.log_evaluation(10)]
             )

# Predict on validation set
    y_pred = model.predict(X_test)

# Calculate metrics
    mse = mean_squared_error(y_test, y_pred)
    rmse = mean_squared_error(y_test, y_pred, squared=False)  # squared=False gives
    mae = mean_absolute_error(y_test, y_pred)
    r2 = r2_score(y_test, y_pred)

# Print metrics for each trial
    print(f"Trial Metrics: MAE={mae:.4f}, MSE={mse:.4f}, RMSE={rmse:.4f}, R^2={r2:.

# Return RMSE as the metric to minimize
    return rmse
```

In [73]:

```
# Create a study for optimization
study = optuna.create_study(direction = 'minimize')
study.optimize(objective, n_trials = 50)

# Print the best hyperparameters and their score
print("Best Trial:")
print(f"RMSE: {study.best_value:.4f}")
print("Best Hyperparameters:", study.best_params)
```

```
[I 2025-05-29 18:13:21,746] A new study created in memory with name: no-name-b493a3c
1-9b56-402d-a63c-2adb3092100d
[I 2025-05-29 18:13:22,025] Trial 0 finished with value: 306.5933395868258 and param
eters: {'learning_rate': 0.001744710350188766, 'num_leaves': 28, 'max_depth': 7, 'mi
n_child_samples': 46, 'min_child_weight': 0.02790855692021885, 'subsample': 0.866400
8667251544, 'colsample_bytree': 0.7701919237944993, 'reg_alpha': 0.3112606454370771,
'reg_lambda': 0.0008526481775253598, 'n_estimators': 172}. Best is trial 0 with valu
e: 306.5933395868258.
```

```
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 344.837
[20]    valid_0's rmse: 341.984
[30]    valid_0's rmse: 339.238
[40]    valid_0's rmse: 336.426
[50]    valid_0's rmse: 333.78
[60]    valid_0's rmse: 331.223
[70]    valid_0's rmse: 328.683
[80]    valid_0's rmse: 326.208
[90]    valid_0's rmse: 323.93
[100]   valid_0's rmse: 321.583
[110]   valid_0's rmse: 319.488
[120]   valid_0's rmse: 317.435
[130]   valid_0's rmse: 315.295
[140]   valid_0's rmse: 313.073
[150]   valid_0's rmse: 311.09
[160]   valid_0's rmse: 309.011
[170]   valid_0's rmse: 307.014
Did not meet early stopping. Best iteration is:
[172]   valid_0's rmse: 306.593
Trial Metrics: MAE=188.4547, MSE=93999.4759, RMSE=306.5933, R^2=0.2207
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 294.377
[20]    valid_0's rmse: 258.679
[30]    valid_0's rmse: 237.079
[40]    valid_0's rmse: 222.83
[50]    valid_0's rmse: 214.601
[60]    valid_0's rmse: 208.275
[70]    valid_0's rmse: 203.502
[80]    valid_0's rmse: 199.979
[90]    valid_0's rmse: 197.72
[100]   valid_0's rmse: 195.723
[110]   valid_0's rmse: 193.787
[120]   valid_0's rmse: 192.725
[130]   valid_0's rmse: 191.484
[140]   valid_0's rmse: 190.268
[150]   valid_0's rmse: 189.277
[160]   valid_0's rmse: 188.087
[170]   valid_0's rmse: 187.121
[180]   valid_0's rmse: 186.441
[190]   valid_0's rmse: 185.942
[200]   valid_0's rmse: 185.39
[210]   valid_0's rmse: 184.899
[220]   valid_0's rmse: 184.589
[230]   valid_0's rmse: 184.423
[240]   valid_0's rmse: 184.193
[250]   valid_0's rmse: 183.869
[260]   valid_0's rmse: 183.542
[270]   valid_0's rmse: 183.355
[280]   valid_0's rmse: 183.27
[290]   valid_0's rmse: 182.826
[300]   valid_0's rmse: 182.578
[310]   valid_0's rmse: 182.288
[320]   valid_0's rmse: 182.094
[330]   valid_0's rmse: 181.692
```

```
[I 2025-05-29 18:13:22,654] Trial 1 finished with value: 180.8274597826561 and param
eters: {'learning_rate': 0.03645490181695767, 'num_leaves': 64, 'max_depth': 13, 'mi
n_child_samples': 87, 'min_child_weight': 0.6915891787401482, 'subsample': 0.6958999
74747654, 'colsample_bytree': 0.7574782647145284, 'reg_alpha': 0.000298922106364585
2, 'reg_lambda': 0.022563293277696177, 'n_estimators': 370}. Best is trial 1 with va
lue: 180.8274597826561.
[340]   valid_0's rmse: 181.313
[350]   valid_0's rmse: 181.176
[360]   valid_0's rmse: 181.059
[370]   valid_0's rmse: 180.827
Did not meet early stopping. Best iteration is:
[370]   valid_0's rmse: 180.827
Trial Metrics: MAE=95.4201, MSE=32698.5702, RMSE=180.8275, R^2=0.7289
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 293.228
[I 2025-05-29 18:13:22,967] Trial 2 finished with value: 176.9722684009742 and param
eters: {'learning_rate': 0.036410171738729555, 'num_leaves': 49, 'max_depth': 9, 'mi
n_child_samples': 20, 'min_child_weight': 0.0675153241850288, 'subsample': 0.8595075
926980358, 'colsample_bytree': 0.9127529360596951, 'reg_alpha': 0.03280994279866109,
'reg_lambda': 0.025055524077789246, 'n_estimators': 178}. Best is trial 2 with valu
e: 176.9722684009742.
```

```
[20]    valid_0's rmse: 258.259
[30]    valid_0's rmse: 235.371
[40]    valid_0's rmse: 219.175
[50]    valid_0's rmse: 209.074
[60]    valid_0's rmse: 201.72
[70]    valid_0's rmse: 196.652
[80]    valid_0's rmse: 192.372
[90]    valid_0's rmse: 189.567
[100]   valid_0's rmse: 186.641
[110]   valid_0's rmse: 184.272
[120]   valid_0's rmse: 182.472
[130]   valid_0's rmse: 181.251
[140]   valid_0's rmse: 180.024
[150]   valid_0's rmse: 178.889
[160]   valid_0's rmse: 178.205
[170]   valid_0's rmse: 177.41
Did not meet early stopping. Best iteration is:
[178]   valid_0's rmse: 176.972
Trial Metrics: MAE=96.1142, MSE=31319.1838, RMSE=176.9723, R^2=0.7404
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 347.483
[20]    valid_0's rmse: 347.214
[30]    valid_0's rmse: 346.94
[40]    valid_0's rmse: 346.665
[50]    valid_0's rmse: 346.396
[60]    valid_0's rmse: 346.143
[70]    valid_0's rmse: 345.876
[80]    valid_0's rmse: 345.611
[90]    valid_0's rmse: 345.362
[100]   valid_0's rmse: 345.106
[110]   valid_0's rmse: 344.856
[120]   valid_0's rmse: 344.6
[130]   valid_0's rmse: 344.347
[140]   valid_0's rmse: 344.081
[150]   valid_0's rmse: 343.83
[I 2025-05-29 18:13:23,335] Trial 3 finished with value: 343.032343294509 and parame
ters: {'learning_rate': 0.00015042025635648044, 'num_leaves': 49, 'max_depth': 14,
'min_child_samples': 93, 'min_child_weight': 0.03054811778137601, 'subsample': 0.854
9999166873427, 'colsample_bytree': 0.7143361448390355, 'reg_alpha': 0.74261869278194
74, 'reg_lambda': 0.07046191448705372, 'n_estimators': 181}. Best is trial 2 with va
lue: 176.9722684009742.
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[160]   valid_0's rmse: 343.571
[170]   valid_0's rmse: 343.31
[180]   valid_0's rmse: 343.06
Did not meet early stopping. Best iteration is:
[181]   valid_0's rmse: 343.032
Trial Metrics: MAE=213.9633, MSE=117671.1885, RMSE=343.0323, R^2=0.0245
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 344.59
[20]    valid_0's rmse: 341.532
[30]    valid_0's rmse: 338.513
[40]    valid_0's rmse: 335.603
[50]    valid_0's rmse: 332.832
[60]    valid_0's rmse: 330.2
[70]    valid_0's rmse: 327.571
[80]    valid_0's rmse: 324.986
[90]    valid_0's rmse: 322.525
[100]   valid_0's rmse: 320.199
[110]   valid_0's rmse: 317.818
[120]   valid_0's rmse: 315.597
[130]   valid_0's rmse: 313.382
[140]   valid_0's rmse: 311.183
[150]   valid_0's rmse: 309.031
[160]   valid_0's rmse: 307.086
[170]   valid_0's rmse: 305.156
[180]   valid_0's rmse: 303.165
[190]   valid_0's rmse: 301.089
[200]   valid_0's rmse: 299.073
[210]   valid_0's rmse: 297.107
[220]   valid_0's rmse: 295.216
[230]   valid_0's rmse: 293.294
[240]   valid_0's rmse: 291.394
[250]   valid_0's rmse: 289.601
Did not meet early stopping. Best iteration is:
[255]   valid_0's rmse: 288.704
[I 2025-05-29 18:13:23,706] Trial 4 finished with value: 288.7040133549716 and param
eters: {'learning_rate': 0.001739691647939366, 'num_leaves': 35, 'max_depth': 16, 'm
in_child_samples': 22, 'min_child_weight': 0.8152390275676062, 'subsample': 0.666293
5573041977, 'colsample_bytree': 0.947671217527372, 'reg_alpha': 1.4980355587879037,
'reg_lambda': 0.0023105799126355523, 'n_estimators': 255}. Best is trial 2 with valu
e: 176.9722684009742.
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Trial Metrics: MAE=176.6258, MSE=83350.0073, RMSE=288.7040, R^2=0.3090
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 344.624
[20]    valid_0's rmse: 341.497
[30]    valid_0's rmse: 338.468
[40]    valid_0's rmse: 335.468
[50]    valid_0's rmse: 332.631
[60]    valid_0's rmse: 329.876
[70]    valid_0's rmse: 327.142
[80]    valid_0's rmse: 324.448
[90]    valid_0's rmse: 321.857
[100]   valid_0's rmse: 319.372
[110]   valid_0's rmse: 316.986
[120]   valid_0's rmse: 314.72
[130]   valid_0's rmse: 312.488
[140]   valid_0's rmse: 310.22
[150]   valid_0's rmse: 307.989
[160]   valid_0's rmse: 305.883
[170]   valid_0's rmse: 303.841
[180]   valid_0's rmse: 301.834
[190]   valid_0's rmse: 299.971
[200]   valid_0's rmse: 298.197
[210]   valid_0's rmse: 296.466
[220]   valid_0's rmse: 294.584
[230]   valid_0's rmse: 292.759
[240]   valid_0's rmse: 290.939
[250]   valid_0's rmse: 289.233
[260]   valid_0's rmse: 287.552
[270]   valid_0's rmse: 285.888
[280]   valid_0's rmse: 284.273
[290]   valid_0's rmse: 282.576
[300]   valid_0's rmse: 280.803
[I 2025-05-29 18:13:24,190] Trial 5 finished with value: 275.65126464955483 and para
meters: {'learning_rate': 0.0016920151399571605, 'num_leaves': 38, 'max_depth': 10,
'min_child_samples': 48, 'min_child_weight': 0.4379160443585348, 'subsample': 0.9037
111079361653, 'colsample_bytree': 0.9222955757966982, 'reg_alpha': 0.239650503137052
58, 'reg_lambda': 0.03624050387021901, 'n_estimators': 331}. Best is trial 2 with va
lue: 176.9722684009742.
[310]   valid_0's rmse: 279.09
[320]   valid_0's rmse: 277.418
[330]   valid_0's rmse: 275.774
Did not meet early stopping. Best iteration is:
[331]   valid_0's rmse: 275.651
Trial Metrics: MAE=167.1541, MSE=75983.6197, RMSE=275.6513, R^2=0.3701
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 347.084
[20]    valid_0's rmse: 346.402
[30]    valid_0's rmse: 345.665
[40]    valid_0's rmse: 344.934
[50]    valid_0's rmse: 344.223
[60]    valid_0's rmse: 343.542
[70]    valid_0's rmse: 342.835
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[I 2025-05-29 18:13:24,478] Trial 6 finished with value: 332.80295808725606 and para
meters: {'learning_rate': 0.00045658576295922343, 'num_leaves': 27, 'max_depth': 16,
'min_child_samples': 99, 'min_child_weight': 0.6876265886494846, 'subsample': 0.6375
918100819397, 'colsample_bytree': 0.6597895283731924, 'reg_alpha': 0.071053341473225
44, 'reg_lambda': 0.056250303981101174, 'n_estimators': 222}. Best is trial 2 with v
alue: 176.9722684009742.
[80]    valid_0's rmse: 342.143
[90]    valid_0's rmse: 341.516
[100]   valid_0's rmse: 340.842
[110]   valid_0's rmse: 340.186
[120]   valid_0's rmse: 339.526
[130]   valid_0's rmse: 338.899
[140]   valid_0's rmse: 338.227
[150]   valid_0's rmse: 337.593
[160]   valid_0's rmse: 336.909
[170]   valid_0's rmse: 336.273
[180]   valid_0's rmse: 335.621
[190]   valid_0's rmse: 334.9
[200]   valid_0's rmse: 334.215
[210]   valid_0's rmse: 333.567
[220]   valid_0's rmse: 332.936
Did not meet early stopping. Best iteration is:
[222]   valid_0's rmse: 332.803
Trial Metrics: MAE=206.4696, MSE=110757.8089, RMSE=332.8030, R^2=0.0818
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 307.474
[20]    valid_0's rmse: 276.076
[30]    valid_0's rmse: 253.602
[40]    valid_0's rmse: 237.865
[50]    valid_0's rmse: 227.634
[60]    valid_0's rmse: 220.762
[70]    valid_0's rmse: 214.914
[80]    valid_0's rmse: 209.377
[90]    valid_0's rmse: 206.552
[100]   valid_0's rmse: 203.254
[110]   valid_0's rmse: 200.804
[120]   valid_0's rmse: 199.327
[130]   valid_0's rmse: 197.859
[140]   valid_0's rmse: 196.728
[150]   valid_0's rmse: 195.469
[160]   valid_0's rmse: 194.559
[170]   valid_0's rmse: 193.4
[I 2025-05-29 18:13:24,845] Trial 7 finished with value: 189.61812463334596 and para
meters: {'learning_rate': 0.03127060028193703, 'num_leaves': 41, 'max_depth': 15, 'm
in_child_samples': 100, 'min_child_weight': 0.0011619914224389096, 'subsample': 0.55
53779892584346, 'colsample_bytree': 0.6536048799244214, 'reg_alpha': 1.2675774792648
227, 'reg_lambda': 2.2752827706537433, 'n_estimators': 224}. Best is trial 2 with va
lue: 176.9722684009742.
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[180]   valid_0's rmse: 192.901
[190]   valid_0's rmse: 191.649
[200]   valid_0's rmse: 190.836
[210]   valid_0's rmse: 190.383
[220]   valid_0's rmse: 189.854
Did not meet early stopping. Best iteration is:
[224]   valid_0's rmse: 189.618
Trial Metrics: MAE=100.3689, MSE=35955.0332, RMSE=189.6181, R^2=0.7019
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 347.59
[20]    valid_0's rmse: 347.432
[30]    valid_0's rmse: 347.277
[40]    valid_0's rmse: 347.117
[I 2025-05-29 18:13:25,069] Trial 8 finished with value: 345.3214648117581 and param
eters: {'learning_rate': 0.00013616215564998024, 'num_leaves': 42, 'max_depth': 4,
'min_child_samples': 56, 'min_child_weight': 0.0013983160115764036, 'subsample': 0.8
787373371795275, 'colsample_bytree': 0.516234272170619, 'reg_alpha': 1.1688058684379
439, 'reg_lambda': 0.0003789570956254573, 'n_estimators': 159}. Best is trial 2 with
value: 176.9722684009742.
[50]    valid_0's rmse: 346.951
[60]    valid_0's rmse: 346.794
[70]    valid_0's rmse: 346.644
[80]    valid_0's rmse: 346.481
[90]    valid_0's rmse: 346.336
[100]   valid_0's rmse: 346.185
[110]   valid_0's rmse: 346.036
[120]   valid_0's rmse: 345.895
[130]   valid_0's rmse: 345.751
[140]   valid_0's rmse: 345.6
[150]   valid_0's rmse: 345.457
Did not meet early stopping. Best iteration is:
[159]   valid_0's rmse: 345.321
Trial Metrics: MAE=215.7081, MSE=119246.9141, RMSE=345.3215, R^2=0.0114
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 326.881
[20]    valid_0's rmse: 309.956
[30]    valid_0's rmse: 296.25
[I 2025-05-29 18:13:25,285] Trial 9 finished with value: 216.63760955221488 and para
meters: {'learning_rate': 0.014582674671149523, 'num_leaves': 21, 'max_depth': 0, 'm
in_child_samples': 41, 'min_child_weight': 0.024838674061636132, 'subsample': 0.7620
040746720618, 'colsample_bytree': 0.7514178291062557, 'reg_alpha': 0.051071549020387
71, 'reg_lambda': 0.0008755574724865778, 'n_estimators': 153}. Best is trial 2 with
value: 176.9722684009742.
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[40]    valid_0's rmse: 282.411
[50]    valid_0's rmse: 270.644
[60]    valid_0's rmse: 261.232
[70]    valid_0's rmse: 253.225
[80]    valid_0's rmse: 246.013
[90]    valid_0's rmse: 240.549
[100]   valid_0's rmse: 235.091
[110]   valid_0's rmse: 230.793
[120]   valid_0's rmse: 227.284
[130]   valid_0's rmse: 223.463
[140]   valid_0's rmse: 220.188
[150]   valid_0's rmse: 217.598
Did not meet early stopping. Best iteration is:
[153]   valid_0's rmse: 216.638
Trial Metrics: MAE=126.4175, MSE=46931.8539, RMSE=216.6376, R^2=0.6109
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 246.809
[20]    valid_0's rmse: 208.493
[30]    valid_0's rmse: 191.385
[40]    valid_0's rmse: 183.629
[50]    valid_0's rmse: 179.607
[60]    valid_0's rmse: 176.619
[70]    valid_0's rmse: 175.252
[80]    valid_0's rmse: 174.071
[90]    valid_0's rmse: 172.204
[100]   valid_0's rmse: 171.541
[110]   valid_0's rmse: 170.881
[120]   valid_0's rmse: 170.799
[130]   valid_0's rmse: 170.331
[140]   valid_0's rmse: 169.774
[150]   valid_0's rmse: 169.261
[160]   valid_0's rmse: 168.837
[170]   valid_0's rmse: 168.745
[180]   valid_0's rmse: 168.547
[190]   valid_0's rmse: 168.452
[200]   valid_0's rmse: 168.332
[210]   valid_0's rmse: 168.044
[220]   valid_0's rmse: 167.892
[230]   valid_0's rmse: 167.744
[240]   valid_0's rmse: 167.431
[250]   valid_0's rmse: 167.154
[260]   valid_0's rmse: 166.973
[270]   valid_0's rmse: 166.813
[280]   valid_0's rmse: 166.681
[290]   valid_0's rmse: 166.303
[300]   valid_0's rmse: 166.359
[310]   valid_0's rmse: 166.213
[320]   valid_0's rmse: 166.105
[330]   valid_0's rmse: 166.051
[340]   valid_0's rmse: 165.778
[350]   valid_0's rmse: 165.397
[360]   valid_0's rmse: 165.424
[370]   valid_0's rmse: 165.265
[380]   valid_0's rmse: 165.285
[390]   valid_0's rmse: 165.215
[400]   valid_0's rmse: 165.068
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[410]   valid_0's rmse: 165.055
[420]   valid_0's rmse: 165.07
[I 2025-05-29 18:13:25,965] Trial 10 finished with value: 164.81826416748925 and parameters: {'learning_rate': 0.09536175509041732, 'num_leaves': 56, 'max_depth': 9, 'min_child_samples': 10, 'min_child_weight': 0.10385288662854704, 'subsample': 0.9953964889310776, 'colsample_bytree': 0.8534216758914224, 'reg_alpha': 0.002489386772326163, 'reg_lambda': 1.7050113832192717, 'n_estimators': 487}. Best is trial 10 with value: 164.81826416748925.
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[430]   valid_0's rmse: 165.022
[440]   valid_0's rmse: 164.841
[450]   valid_0's rmse: 164.876
[460]   valid_0's rmse: 164.932
[470]   valid_0's rmse: 164.897
[480]   valid_0's rmse: 164.936
Did not meet early stopping. Best iteration is:
[438]   valid_0's rmse: 164.818
Trial Metrics: MAE=86.9191, MSE=27165.0602, RMSE=164.8183, R^2=0.7748
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 252.696
[20]    valid_0's rmse: 213.46
[30]    valid_0's rmse: 196.777
[40]    valid_0's rmse: 188.191
[50]    valid_0's rmse: 183.574
[60]    valid_0's rmse: 180.005
[70]    valid_0's rmse: 177.649
[80]    valid_0's rmse: 176.287
[90]    valid_0's rmse: 174.79
[100]   valid_0's rmse: 173.776
[110]   valid_0's rmse: 172.93
[120]   valid_0's rmse: 172.334
[130]   valid_0's rmse: 171.548
[140]   valid_0's rmse: 170.805
[150]   valid_0's rmse: 170.26
[160]   valid_0's rmse: 169.823
[170]   valid_0's rmse: 169.337
[180]   valid_0's rmse: 169.29
[190]   valid_0's rmse: 168.84
[200]   valid_0's rmse: 168.452
[210]   valid_0's rmse: 168.058
[220]   valid_0's rmse: 167.736
[230]   valid_0's rmse: 167.585
[240]   valid_0's rmse: 167.457
[250]   valid_0's rmse: 167.195
[260]   valid_0's rmse: 166.978
[270]   valid_0's rmse: 166.662
[280]   valid_0's rmse: 166.669
[290]   valid_0's rmse: 166.436
[300]   valid_0's rmse: 166.207
[310]   valid_0's rmse: 166.061
[320]   valid_0's rmse: 166.203
[330]   valid_0's rmse: 166.039
[340]   valid_0's rmse: 165.911
[350]   valid_0's rmse: 165.762
[360]   valid_0's rmse: 165.69
[370]   valid_0's rmse: 165.678
[380]   valid_0's rmse: 165.591
[390]   valid_0's rmse: 165.517
[I 2025-05-29 18:13:26,641] Trial 11 finished with value: 165.03424058911483 and par
ameters: {'learning_rate': 0.08527052035578771, 'num_leaves': 56, 'max_depth': 9, 'm
in_child_samples': 6, 'min_child_weight': 0.13066571999630988, 'subsample': 0.999493
2155064045, 'colsample_bytree': 0.8678629527482138, 'reg_alpha': 0.00308973345289802
9, 'reg_lambda': 8.14565916971012, 'n_estimators': 482}. Best is trial 10 with valu
e: 164.81826416748925.
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[400]   valid_0's rmse: 165.458
[410]   valid_0's rmse: 165.35
[420]   valid_0's rmse: 165.369
[430]   valid_0's rmse: 165.216
[440]   valid_0's rmse: 165.159
[450]   valid_0's rmse: 165.172
[460]   valid_0's rmse: 165.034
[470]   valid_0's rmse: 165.129
[480]   valid_0's rmse: 165.079
Did not meet early stopping. Best iteration is:
[460]   valid_0's rmse: 165.034
Trial Metrics: MAE=87.7306, MSE=27236.3006, RMSE=165.0342, R^2=0.7742
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 256.12
[20]    valid_0's rmse: 214.144
[30]    valid_0's rmse: 197.95
[40]    valid_0's rmse: 189.614
[50]    valid_0's rmse: 185.231
[60]    valid_0's rmse: 182.419
[70]    valid_0's rmse: 180.665
[80]    valid_0's rmse: 179.216
[90]    valid_0's rmse: 178.25
[100]   valid_0's rmse: 177.056
[110]   valid_0's rmse: 175.955
[120]   valid_0's rmse: 175.101
[130]   valid_0's rmse: 174.219
[140]   valid_0's rmse: 173.523
[150]   valid_0's rmse: 173.133
[160]   valid_0's rmse: 172.412
[170]   valid_0's rmse: 172.027
[180]   valid_0's rmse: 171.553
[190]   valid_0's rmse: 171.004
[200]   valid_0's rmse: 170.477
[210]   valid_0's rmse: 170.17
[220]   valid_0's rmse: 169.695
[230]   valid_0's rmse: 169.49
[240]   valid_0's rmse: 169.225
[250]   valid_0's rmse: 168.985
[260]   valid_0's rmse: 168.713
[270]   valid_0's rmse: 168.466
[I 2025-05-29 18:13:27,159] Trial 12 finished with value: 165.89144757611353 and par
ameters: {'learning_rate': 0.09486705053419074, 'num_leaves': 64, 'max_depth': 6, 'm
in_child_samples': 7, 'min_child_weight': 0.16525992890765748, 'subsample': 0.998916
3978545986, 'colsample_bytree': 0.8518469007847504, 'reg_alpha': 0.00181642729176988
84, 'reg_lambda': 6.290834954063588, 'n_estimators': 500}. Best is trial 10 with val
ue: 164.81826416748925.
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[280]   valid_0's rmse: 168.14
[290]   valid_0's rmse: 168.081
[300]   valid_0's rmse: 168.009
[310]   valid_0's rmse: 167.921
[320]   valid_0's rmse: 167.821
[330]   valid_0's rmse: 167.753
[340]   valid_0's rmse: 167.545
[350]   valid_0's rmse: 167.373
[360]   valid_0's rmse: 167.203
[370]   valid_0's rmse: 167.058
[380]   valid_0's rmse: 166.934
[390]   valid_0's rmse: 166.884
[400]   valid_0's rmse: 167.046
[410]   valid_0's rmse: 166.865
[420]   valid_0's rmse: 166.734
[430]   valid_0's rmse: 166.617
[440]   valid_0's rmse: 166.62
[450]   valid_0's rmse: 166.607
[460]   valid_0's rmse: 166.397
[470]   valid_0's rmse: 166.449
[480]   valid_0's rmse: 166.24
[490]   valid_0's rmse: 166.012
[500]   valid_0's rmse: 165.891
Did not meet early stopping. Best iteration is:
[500]   valid_0's rmse: 165.891
Trial Metrics: MAE=87.5162, MSE=27519.9724, RMSE=165.8914, R^2=0.7719
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 241.41
[20]    valid_0's rmse: 205.823
[30]    valid_0's rmse: 193.586
[40]    valid_0's rmse: 185.872
[50]    valid_0's rmse: 181.514
[60]    valid_0's rmse: 178.901
[70]    valid_0's rmse: 176.785
[80]    valid_0's rmse: 175.816
[90]    valid_0's rmse: 175.048
[100]   valid_0's rmse: 174.2
[110]   valid_0's rmse: 173.879
[120]   valid_0's rmse: 173.627
[130]   valid_0's rmse: 173.321
[140]   valid_0's rmse: 173.078
[150]   valid_0's rmse: 172.845
[160]   valid_0's rmse: 172.572
[170]   valid_0's rmse: 172.489
[180]   valid_0's rmse: 172.174
[190]   valid_0's rmse: 171.725
[200]   valid_0's rmse: 171.605
[210]   valid_0's rmse: 171.467
[220]   valid_0's rmse: 171.196
[230]   valid_0's rmse: 170.993
[240]   valid_0's rmse: 170.622
[250]   valid_0's rmse: 170.202
[260]   valid_0's rmse: 170.307
[270]   valid_0's rmse: 170.122
[280]   valid_0's rmse: 169.963
[290]   valid_0's rmse: 169.719
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[300]   valid_0's rmse: 169.725
[310]   valid_0's rmse: 169.697
[320]   valid_0's rmse: 169.537
[330]   valid_0's rmse: 169.494
[340]   valid_0's rmse: 169.392
[350]   valid_0's rmse: 169.245
[360]   valid_0's rmse: 169.179
[370]   valid_0's rmse: 169.195
[380]   valid_0's rmse: 169.033
[390]   valid_0's rmse: 169.024
[400]   valid_0's rmse: 169.017
[410]   valid_0's rmse: 169.072
[420]   valid_0's rmse: 168.834
[I 2025-05-29 18:13:27,814] Trial 13 finished with value: 168.69958874556374 and parameters: {'learning_rate': 0.09653350272762597, 'num_leaves': 55, 'max_depth': 11, 'min_child_samples': 10, 'min_child_weight': 0.11069632971271677, 'subsample': 0.9942936506475348, 'colsample_bytree': 0.9992193798605723, 'reg_alpha': 0.0027982271053370684, 'reg_lambda': 0.5368359040495159, 'n_estimators': 479}. Best is trial 10 with value: 164.81826416748925.
```

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[430]   valid_0's rmse: 168.798
[440]   valid_0's rmse: 168.866
[450]   valid_0's rmse: 168.829
[460]   valid_0's rmse: 168.778
[470]   valid_0's rmse: 168.763
Did not meet early stopping. Best iteration is:
[479]   valid_0's rmse: 168.7
Trial Metrics: MAE=88.4214, MSE=28459.5512, RMSE=168.6996, R^2=0.7641
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 339.296
[20]    valid_0's rmse: 331.348
[30]    valid_0's rmse: 323.891
[40]    valid_0's rmse: 316.502
[50]    valid_0's rmse: 310.226
[60]    valid_0's rmse: 304.27
[70]    valid_0's rmse: 298.626
[80]    valid_0's rmse: 293.065
[90]    valid_0's rmse: 288.077
[100]   valid_0's rmse: 283.192
[110]   valid_0's rmse: 278.847
[120]   valid_0's rmse: 274.786
[130]   valid_0's rmse: 271.467
[140]   valid_0's rmse: 267.712
[150]   valid_0's rmse: 264.477
[160]   valid_0's rmse: 261.12
[170]   valid_0's rmse: 258.214
[180]   valid_0's rmse: 255.556
[190]   valid_0's rmse: 252.583
[200]   valid_0's rmse: 249.895
[210]   valid_0's rmse: 247.527
[220]   valid_0's rmse: 245.325
[230]   valid_0's rmse: 243.138
[240]   valid_0's rmse: 241.069
[250]   valid_0's rmse: 239.112
[260]   valid_0's rmse: 237.32
[270]   valid_0's rmse: 235.561
[280]   valid_0's rmse: 233.844
[290]   valid_0's rmse: 232.192
[300]   valid_0's rmse: 230.612
[310]   valid_0's rmse: 229.064
[320]   valid_0's rmse: 227.668
[330]   valid_0's rmse: 226.242
[340]   valid_0's rmse: 224.866
[350]   valid_0's rmse: 223.603
[360]   valid_0's rmse: 222.311
[370]   valid_0's rmse: 221.216
[380]   valid_0's rmse: 220.151
[390]   valid_0's rmse: 219.113
[400]   valid_0's rmse: 218.126
[410]   valid_0's rmse: 217.198
[420]   valid_0's rmse: 216.402
Did not meet early stopping. Best iteration is:
[426]   valid_0's rmse: 215.829
Trial Metrics: MAE=127.5780, MSE=46582.2200, RMSE=215.8291, R^2=0.6138
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[I 2025-05-29 18:13:28,149] Trial 14 finished with value: 215.82914535206874 and par
ameters: {'learning_rate': 0.007346666724528004, 'num_leaves': 56, 'max_depth': 4,
'min_child_samples': 27, 'min_child_weight': 0.009769057031127317, 'subsample': 0.95
5125523778002, 'colsample_bytree': 0.8352282358465627, 'reg_alpha': 0.00472328711049
41196, 'reg_lambda': 0.6897305471619931, 'n_estimators': 426}. Best is trial 10 with
value: 164.81826416748925.
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 336.781
[20]    valid_0's rmse: 326.837
[30]    valid_0's rmse: 317.942
[40]    valid_0's rmse: 309.397
[50]    valid_0's rmse: 302.356
[60]    valid_0's rmse: 295.895
[70]    valid_0's rmse: 289.133
[80]    valid_0's rmse: 282.538
[90]    valid_0's rmse: 276.763
[100]   valid_0's rmse: 271.03
[110]   valid_0's rmse: 266.052
[120]   valid_0's rmse: 261.118
[130]   valid_0's rmse: 257.045
[140]   valid_0's rmse: 253.204
[150]   valid_0's rmse: 249.779
[160]   valid_0's rmse: 246.465
[170]   valid_0's rmse: 243.51
[180]   valid_0's rmse: 240.98
[190]   valid_0's rmse: 238.398
[200]   valid_0's rmse: 236.159
[210]   valid_0's rmse: 234.035
[220]   valid_0's rmse: 232.194
[230]   valid_0's rmse: 230.227
[240]   valid_0's rmse: 228.432
[250]   valid_0's rmse: 226.671
[260]   valid_0's rmse: 224.954
[270]   valid_0's rmse: 223.356
[280]   valid_0's rmse: 221.956
[290]   valid_0's rmse: 220.602
[300]   valid_0's rmse: 219.361
[310]   valid_0's rmse: 218.237
[320]   valid_0's rmse: 216.985
[330]   valid_0's rmse: 215.736
[340]   valid_0's rmse: 214.611
[350]   valid_0's rmse: 213.599
[360]   valid_0's rmse: 212.721
[I 2025-05-29 18:13:28,561] Trial 15 finished with value: 207.6102863270712 and para
meters: {'learning_rate': 0.00817115499254775, 'num_leaves': 56, 'max_depth': 5, 'mi
n_child_samples': 72, 'min_child_weight': 0.2350189919657621, 'subsample': 0.7869974
522113643, 'colsample_bytree': 0.840682204204117, 'reg_alpha': 0.0001505771246390040
2, 'reg_lambda': 8.794457697596435, 'n_estimators': 423}. Best is trial 10 with valu
e: 164.81826416748925.
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[370]   valid_0's rmse: 211.872
[380]   valid_0's rmse: 211.02
[390]   valid_0's rmse: 210.142
[400]   valid_0's rmse: 209.315
[410]   valid_0's rmse: 208.503
[420]   valid_0's rmse: 207.777
Did not meet early stopping. Best iteration is:
[423]   valid_0's rmse: 207.61
Trial Metrics: MAE=118.2715, MSE=43102.0310, RMSE=207.6103, R^2=0.6427
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 315.673
[20]    valid_0's rmse: 291.63
[30]    valid_0's rmse: 273.509
[40]    valid_0's rmse: 256.639
[50]    valid_0's rmse: 244.382
[60]    valid_0's rmse: 234.889
[70]    valid_0's rmse: 226.975
[80]    valid_0's rmse: 220.086
[90]    valid_0's rmse: 214.461
[100]   valid_0's rmse: 209.897
[110]   valid_0's rmse: 206.174
[120]   valid_0's rmse: 203.371
[130]   valid_0's rmse: 200.813
[140]   valid_0's rmse: 198.049
[150]   valid_0's rmse: 195.897
[160]   valid_0's rmse: 193.858
[170]   valid_0's rmse: 192.156
[180]   valid_0's rmse: 190.7
[190]   valid_0's rmse: 189.447
[200]   valid_0's rmse: 188.045
[210]   valid_0's rmse: 187.014
[220]   valid_0's rmse: 185.897
[230]   valid_0's rmse: 185.238
[240]   valid_0's rmse: 184.189
[250]   valid_0's rmse: 183.437
[260]   valid_0's rmse: 182.782
[270]   valid_0's rmse: 182.21
[280]   valid_0's rmse: 181.782
[290]   valid_0's rmse: 181.392
[300]   valid_0's rmse: 181.024
[310]   valid_0's rmse: 180.689
[320]   valid_0's rmse: 180.286
[330]   valid_0's rmse: 179.815
[340]   valid_0's rmse: 179.364
[350]   valid_0's rmse: 179.081
[360]   valid_0's rmse: 178.923
[370]   valid_0's rmse: 178.557
[380]   valid_0's rmse: 178.285
[390]   valid_0's rmse: 178.21
[400]   valid_0's rmse: 177.887
[410]   valid_0's rmse: 177.811
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[I 2025-05-29 18:13:29,244] Trial 16 finished with value: 177.22371369443144 and par
ameters: {'learning_rate': 0.019004455443415558, 'num_leaves': 49, 'max_depth': 12,
'min_child_samples': 34, 'min_child_weight': 0.00947972360477638, 'subsample': 0.928
8127643792211, 'colsample_bytree': 0.8722957858419387, 'reg_alpha': 0.000736062373500
94802, 'reg_lambda': 0.42441486390387195, 'n_estimators': 445}. Best is trial 10 wit
h value: 164.81826416748925.
[420]   valid_0's rmse: 177.589
[430]   valid_0's rmse: 177.429
[440]   valid_0's rmse: 177.267
Did not meet early stopping. Best iteration is:
[444]   valid_0's rmse: 177.224
Trial Metrics: MAE=94.8601, MSE=31408.2447, RMSE=177.2237, R^2=0.7396
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 269.514
[20]    valid_0's rmse: 227.677
[30]    valid_0's rmse: 204.402
[40]    valid_0's rmse: 192.573
[50]    valid_0's rmse: 185.183
[60]    valid_0's rmse: 180.879
[70]    valid_0's rmse: 178.208
[80]    valid_0's rmse: 175.912
[90]    valid_0's rmse: 174.474
[100]   valid_0's rmse: 173.221
[110]   valid_0's rmse: 172.351
[120]   valid_0's rmse: 171.645
[130]   valid_0's rmse: 171.004
[140]   valid_0's rmse: 170.558
[150]   valid_0's rmse: 170.07
[160]   valid_0's rmse: 169.722
[170]   valid_0's rmse: 169.15
[180]   valid_0's rmse: 168.512
[190]   valid_0's rmse: 167.895
[200]   valid_0's rmse: 167.757
[I 2025-05-29 18:13:29,818] Trial 17 finished with value: 164.52444132146496 and par
ameters: {'learning_rate': 0.06619033090007496, 'num_leaves': 60, 'max_depth': 8, 'm
in_child_samples': 5, 'min_child_weight': 0.10560617678253516, 'subsample': 0.807556
8106358115, 'colsample_bytree': 0.8027750493803073, 'reg_alpha': 0.0086395141278435
6, 'reg_lambda': 2.173710512801541, 'n_estimators': 380}. Best is trial 17 with valu
e: 164.52444132146496.
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[210]   valid_0's rmse: 167.52
[220]   valid_0's rmse: 167.23
[230]   valid_0's rmse: 167.174
[240]   valid_0's rmse: 167.02
[250]   valid_0's rmse: 166.831
[260]   valid_0's rmse: 166.614
[270]   valid_0's rmse: 166.541
[280]   valid_0's rmse: 166.363
[290]   valid_0's rmse: 166.119
[300]   valid_0's rmse: 165.963
[310]   valid_0's rmse: 165.839
[320]   valid_0's rmse: 165.745
[330]   valid_0's rmse: 165.504
[340]   valid_0's rmse: 165.33
[350]   valid_0's rmse: 165.108
[360]   valid_0's rmse: 164.762
[370]   valid_0's rmse: 164.656
[380]   valid_0's rmse: 164.524
Did not meet early stopping. Best iteration is:
[380]   valid_0's rmse: 164.524
Trial Metrics: MAE=88.1950, MSE=27068.2918, RMSE=164.5244, R^2=0.7756
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 340.336
[20]    valid_0's rmse: 333.075
[30]    valid_0's rmse: 325.934
[40]    valid_0's rmse: 319.037
[50]    valid_0's rmse: 312.486
[60]    valid_0's rmse: 306.411
[70]    valid_0's rmse: 300.778
[80]    valid_0's rmse: 295.387
[90]    valid_0's rmse: 290.485
[100]   valid_0's rmse: 285.792
[110]   valid_0's rmse: 281.304
[120]   valid_0's rmse: 277.483
[130]   valid_0's rmse: 273.565
[140]   valid_0's rmse: 269.739
[150]   valid_0's rmse: 266.013
[160]   valid_0's rmse: 262.688
[170]   valid_0's rmse: 259.54
[180]   valid_0's rmse: 256.575
[190]   valid_0's rmse: 253.41
[200]   valid_0's rmse: 250.33
[210]   valid_0's rmse: 247.45
[220]   valid_0's rmse: 244.9
[230]   valid_0's rmse: 242.551
[240]   valid_0's rmse: 240.198
[250]   valid_0's rmse: 237.99
[260]   valid_0's rmse: 235.693
[270]   valid_0's rmse: 233.479
[280]   valid_0's rmse: 231.491
[290]   valid_0's rmse: 229.798
[300]   valid_0's rmse: 227.978
[310]   valid_0's rmse: 226.255
[320]   valid_0's rmse: 224.672
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[I 2025-05-29 18:13:30,473] Trial 18 finished with value: 217.23924087378575 and par
ameters: {'learning_rate': 0.004694844111229477, 'num_leaves': 61, 'max_depth': 8,
'min_child_samples': 62, 'min_child_weight': 0.07924490595101745, 'subsample': 0.512
1697828883263, 'colsample_bytree': 0.5824068356015702, 'reg_alpha': 7.19877809700605
2, 'reg_lambda': 0.1914576357476452, 'n_estimators': 370}. Best is trial 17 with val
ue: 164.52444132146496.
[330]   valid_0's rmse: 223.154
[340]   valid_0's rmse: 221.622
[350]   valid_0's rmse: 220.207
[360]   valid_0's rmse: 218.691
[370]   valid_0's rmse: 217.239
Did not meet early stopping. Best iteration is:
[370]   valid_0's rmse: 217.239
Trial Metrics: MAE=124.4541, MSE=47192.8878, RMSE=217.2392, R^2=0.6088
Training until validation scores don't improve for 50 rounds
[I 2025-05-29 18:13:30,625] Trial 19 finished with value: 283.9933584696995 and para
meters: {'learning_rate': 0.05206242132789606, 'num_leaves': 46, 'max_depth': 1, 'mi
n_child_samples': 16, 'min_child_weight': 0.011821790089023886, 'subsample': 0.80272
6163358476, 'colsample_bytree': 0.8023570190545962, 'reg_alpha': 0.00574483920567937
2, 'reg_lambda': 2.137901130353562, 'n_estimators': 100}. Best is trial 17 with valu
e: 164.52444132146496.
[10]    valid_0's rmse: 334.39
[20]    valid_0's rmse: 323.708
[30]    valid_0's rmse: 315.928
[40]    valid_0's rmse: 309.486
[50]    valid_0's rmse: 303.535
[60]    valid_0's rmse: 298.832
[70]    valid_0's rmse: 294.371
[80]    valid_0's rmse: 290.621
[90]    valid_0's rmse: 286.766
[100]   valid_0's rmse: 283.993
Did not meet early stopping. Best iteration is:
[100]   valid_0's rmse: 283.993
Trial Metrics: MAE=167.5138, MSE=80652.2277, RMSE=283.9934, R^2=0.3314
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 336.864
[20]    valid_0's rmse: 327.171
[30]    valid_0's rmse: 318.814
[40]    valid_0's rmse: 311.862
[50]    valid_0's rmse: 306.426
[60]    valid_0's rmse: 300.254
[70]    valid_0's rmse: 295.062
[80]    valid_0's rmse: 290.306
[90]    valid_0's rmse: 286.079
[100]   valid_0's rmse: 282.015
[110]   valid_0's rmse: 278.306
[120]   valid_0's rmse: 275.225
[130]   valid_0's rmse: 272.243
[140]   valid_0's rmse: 269.106
[150]   valid_0's rmse: 266.426
[160]   valid_0's rmse: 263.754
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[I 2025-05-29 18:13:30,874] Trial 20 finished with value: 234.86257770223165 and par
ameters: {'learning_rate': 0.01767853669011612, 'num_leaves': 60, 'max_depth': 2, 'm
in_child_samples': 32, 'min_child_weight': 0.3121724364339791, 'subsample': 0.719253
6000282939, 'colsample_bytree': 0.9773304602331402, 'reg_alpha': 0.01041238760952453
2, 'reg_lambda': 0.006281934019373776, 'n_estimators': 385}. Best is trial 17 with v
alue: 164.52444132146496.
```

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[170]   valid_0's rmse: 261.569
[180]   valid_0's rmse: 259.462
[190]   valid_0's rmse: 257.545
[200]   valid_0's rmse: 255.556
[210]   valid_0's rmse: 253.687
[220]   valid_0's rmse: 251.986
[230]   valid_0's rmse: 250.306
[240]   valid_0's rmse: 248.823
[250]   valid_0's rmse: 247.409
[260]   valid_0's rmse: 246.015
[270]   valid_0's rmse: 244.71
[280]   valid_0's rmse: 243.387
[290]   valid_0's rmse: 242.471
[300]   valid_0's rmse: 241.296
[310]   valid_0's rmse: 240.508
[320]   valid_0's rmse: 239.612
[330]   valid_0's rmse: 238.803
[340]   valid_0's rmse: 238.003
[350]   valid_0's rmse: 237.216
[360]   valid_0's rmse: 236.455
[370]   valid_0's rmse: 235.733
[380]   valid_0's rmse: 235.227
Did not meet early stopping. Best iteration is:
[385]   valid_0's rmse: 234.863
Trial Metrics: MAE=136.4945, MSE=55160.4304, RMSE=234.8626, R^2=0.5427
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 266.71
[20]    valid_0's rmse: 226.663
[30]    valid_0's rmse: 205.62
[40]    valid_0's rmse: 195.22
[50]    valid_0's rmse: 189.258
[60]    valid_0's rmse: 185.291
[70]    valid_0's rmse: 182.166
[80]    valid_0's rmse: 179.828
[90]    valid_0's rmse: 177.771
[100]   valid_0's rmse: 176.519
[110]   valid_0's rmse: 175.415
[120]   valid_0's rmse: 174.615
[130]   valid_0's rmse: 174.002
[140]   valid_0's rmse: 173.314
[150]   valid_0's rmse: 172.887
[160]   valid_0's rmse: 172.508
[170]   valid_0's rmse: 172.102
[180]   valid_0's rmse: 171.714
[190]   valid_0's rmse: 171.42
[200]   valid_0's rmse: 171.058
[210]   valid_0's rmse: 170.93
[220]   valid_0's rmse: 170.591
[230]   valid_0's rmse: 170.347
[240]   valid_0's rmse: 170.004
[250]   valid_0's rmse: 169.776
[260]   valid_0's rmse: 169.696
[270]   valid_0's rmse: 169.552
[280]   valid_0's rmse: 169.338
[290]   valid_0's rmse: 168.976
[300]   valid_0's rmse: 168.92
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[310]   valid_0's rmse: 168.828
[320]   valid_0's rmse: 168.804
[330]   valid_0's rmse: 168.592
[340]   valid_0's rmse: 168.389
[350]   valid_0's rmse: 168.356
[360]   valid_0's rmse: 168.225
[370]   valid_0's rmse: 168.067
[380]   valid_0's rmse: 167.934
[390]   valid_0's rmse: 167.863
[400]   valid_0's rmse: 167.748
[410]   valid_0's rmse: 167.708
[420]   valid_0's rmse: 167.49
[I 2025-05-29 18:13:31,545] Trial 21 finished with value: 167.21772336800035 and parameters: {'learning_rate': 0.06551058092291835, 'num_leaves': 54, 'max_depth': 9, 'min_child_samples': 5, 'min_child_weight': 0.06911639044179974, 'subsample': 0.9559560740571272, 'colsample_bytree': 0.8755538432348184, 'reg_alpha': 0.012871632776712246, 'reg_lambda': 3.415829904983946, 'n_estimators': 462}. Best is trial 17 with value: 164.52444132146496.
[430]   valid_0's rmse: 167.493
[440]   valid_0's rmse: 167.436
[450]   valid_0's rmse: 167.399
[460]   valid_0's rmse: 167.224
Did not meet early stopping. Best iteration is:
[462]   valid_0's rmse: 167.218
Trial Metrics: MAE=87.2099, MSE=27961.7670, RMSE=167.2177, R^2=0.7682
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 250.632
[20]    valid_0's rmse: 210.746
[30]    valid_0's rmse: 193.795
[40]    valid_0's rmse: 185.576
[50]    valid_0's rmse: 181.723
[60]    valid_0's rmse: 179.176
[70]    valid_0's rmse: 177.375
[80]    valid_0's rmse: 176.123
[90]    valid_0's rmse: 175.166
[100]   valid_0's rmse: 174.666
[110]   valid_0's rmse: 173.805
[120]   valid_0's rmse: 173.238
[130]   valid_0's rmse: 172.677
[140]   valid_0's rmse: 172.225
[150]   valid_0's rmse: 171.832
[160]   valid_0's rmse: 171.634
[170]   valid_0's rmse: 171.028
[180]   valid_0's rmse: 170.77
[190]   valid_0's rmse: 170.639
[200]   valid_0's rmse: 170.452
[210]   valid_0's rmse: 170.353
[220]   valid_0's rmse: 170.155
[230]   valid_0's rmse: 169.988
[I 2025-05-29 18:13:32,012] Trial 22 finished with value: 169.0205206096639 and parameters: {'learning_rate': 0.09380143078247151, 'num_leaves': 59, 'max_depth': 7, 'min_child_samples': 14, 'min_child_weight': 0.14414017717590086, 'subsample': 0.6131993565273209, 'colsample_bytree': 0.7929919338155632, 'reg_alpha': 0.0009636829389546111, 'reg_lambda': 1.6036273758473278, 'n_estimators': 317}. Best is trial 17 with value: 164.52444132146496.
```

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[240]   valid_0's rmse: 169.932
[250]   valid_0's rmse: 169.741
[260]   valid_0's rmse: 169.576
[270]   valid_0's rmse: 169.491
[280]   valid_0's rmse: 169.444
[290]   valid_0's rmse: 169.25
[300]   valid_0's rmse: 169.071
[310]   valid_0's rmse: 169.194
Did not meet early stopping. Best iteration is:
[296]   valid_0's rmse: 169.021
Trial Metrics: MAE=89.2994, MSE=28567.9364, RMSE=169.0205, R^2=0.7632
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 288.226
[20]    valid_0's rmse: 250.282
[30]    valid_0's rmse: 226.088
[40]    valid_0's rmse: 211.589
[50]    valid_0's rmse: 201.497
[60]    valid_0's rmse: 195.505
[70]    valid_0's rmse: 190.963
[80]    valid_0's rmse: 186.99
[90]    valid_0's rmse: 184.468
[100]   valid_0's rmse: 182.193
[110]   valid_0's rmse: 180.697
[120]   valid_0's rmse: 179.651
[130]   valid_0's rmse: 178.417
[140]   valid_0's rmse: 177.341
[150]   valid_0's rmse: 176.507
[160]   valid_0's rmse: 175.622
[170]   valid_0's rmse: 174.504
[180]   valid_0's rmse: 174.046
[190]   valid_0's rmse: 173.549
[200]   valid_0's rmse: 173.01
[210]   valid_0's rmse: 172.646
[220]   valid_0's rmse: 172.222
[230]   valid_0's rmse: 171.973
[240]   valid_0's rmse: 171.534
[250]   valid_0's rmse: 171.331
[260]   valid_0's rmse: 170.917
[270]   valid_0's rmse: 170.623
[280]   valid_0's rmse: 170.337
[290]   valid_0's rmse: 170.005
[300]   valid_0's rmse: 169.744
[310]   valid_0's rmse: 169.526
[320]   valid_0's rmse: 169.219
[330]   valid_0's rmse: 169.12
[340]   valid_0's rmse: 168.923
[350]   valid_0's rmse: 168.806
[360]   valid_0's rmse: 168.642
[370]   valid_0's rmse: 168.53
[380]   valid_0's rmse: 168.414
[390]   valid_0's rmse: 168.243
[400]   valid_0's rmse: 168.141
Did not meet early stopping. Best iteration is:
[401]   valid_0's rmse: 168.13
```

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[I 2025-05-29 18:13:32,626] Trial 23 finished with value: 168.13021136941364 and par
ameters: {'learning_rate': 0.04879067036918081, 'num_leaves': 52, 'max_depth': 11,
'min_child_samples': 5, 'min_child_weight': 0.23101573970350794, 'subsample': 0.8203
191907347338, 'colsample_bytree': 0.703622582386407, 'reg_alpha': 0.0133743026273462
14, 'reg_lambda': 9.124665788497097, 'n_estimators': 401}. Best is trial 17 with val
ue: 164.52444132146496.
```

```
Trial Metrics: MAE=89.6327, MSE=28267.7680, RMSE=168.1302, R^2=0.7657
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 311.455
[20]    valid_0's rmse: 285.3
[30]    valid_0's rmse: 263.865
[40]    valid_0's rmse: 247.113
[50]    valid_0's rmse: 234.635
[60]    valid_0's rmse: 224.949
[70]    valid_0's rmse: 216.657
[80]    valid_0's rmse: 210.376
[90]    valid_0's rmse: 205.536
[100]   valid_0's rmse: 201.536
[110]   valid_0's rmse: 198.305
[120]   valid_0's rmse: 195.645
[130]   valid_0's rmse: 193.305
[140]   valid_0's rmse: 191.535
[150]   valid_0's rmse: 189.384
[160]   valid_0's rmse: 187.521
[170]   valid_0's rmse: 186.195
[180]   valid_0's rmse: 184.925
[190]   valid_0's rmse: 183.75
[200]   valid_0's rmse: 182.902
[210]   valid_0's rmse: 181.978
[220]   valid_0's rmse: 181.328
[230]   valid_0's rmse: 180.729
[240]   valid_0's rmse: 180.013
[250]   valid_0's rmse: 179.347
[260]   valid_0's rmse: 178.844
[270]   valid_0's rmse: 178.468
[280]   valid_0's rmse: 178.082
[290]   valid_0's rmse: 177.746
[300]   valid_0's rmse: 177.463
[310]   valid_0's rmse: 177.219
[320]   valid_0's rmse: 176.975
[330]   valid_0's rmse: 176.527
[340]   valid_0's rmse: 176.33
[350]   valid_0's rmse: 176.123
[360]   valid_0's rmse: 175.818
[370]   valid_0's rmse: 175.574
[380]   valid_0's rmse: 175.431
[390]   valid_0's rmse: 175.209
[400]   valid_0's rmse: 174.953
[410]   valid_0's rmse: 174.838
[420]   valid_0's rmse: 174.624
[430]   valid_0's rmse: 174.469
[440]   valid_0's rmse: 174.292
[450]   valid_0's rmse: 174.237
[460]   valid_0's rmse: 174.214
[470]   valid_0's rmse: 174.084
[480]   valid_0's rmse: 173.974
Did not meet early stopping. Best iteration is:
[486]   valid_0's rmse: 173.906
```

```
[I 2025-05-29 18:13:33,289] Trial 24 finished with value: 173.90578560505978 and par
ameters: {'learning_rate': 0.023405495009073844, 'num_leaves': 45, 'max_depth': 9,
'min_child_samples': 24, 'min_child_weight': 0.055333372576508194, 'subsample': 0.94
72165823107087, 'colsample_bytree': 0.8898162112874696, 'reg_alpha': 0.0007682282617
254518, 'reg_lambda': 0.16302067029444578, 'n_estimators': 486}. Best is trial 17 wi
th value: 164.52444132146496.
Trial Metrics: MAE=93.4894, MSE=30243.2223, RMSE=173.9058, R^2=0.7493
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 328.94
[20]    valid_0's rmse: 312.154
[30]    valid_0's rmse: 297.855
[40]    valid_0's rmse: 284.806
[50]    valid_0's rmse: 273.812
[60]    valid_0's rmse: 264.114
[70]    valid_0's rmse: 255.283
[80]    valid_0's rmse: 247.639
[90]    valid_0's rmse: 240.65
[100]   valid_0's rmse: 234.098
[110]   valid_0's rmse: 228.64
[120]   valid_0's rmse: 224.106
[130]   valid_0's rmse: 220.036
[140]   valid_0's rmse: 216.126
[150]   valid_0's rmse: 212.767
[160]   valid_0's rmse: 209.794
[170]   valid_0's rmse: 207.113
[180]   valid_0's rmse: 204.676
[190]   valid_0's rmse: 202.458
[200]   valid_0's rmse: 200.683
[210]   valid_0's rmse: 199.001
[220]   valid_0's rmse: 197.515
[230]   valid_0's rmse: 195.837
[240]   valid_0's rmse: 194.445
[250]   valid_0's rmse: 193.198
[260]   valid_0's rmse: 192.071
[270]   valid_0's rmse: 191.006
[280]   valid_0's rmse: 189.989
[290]   valid_0's rmse: 188.974
[300]   valid_0's rmse: 188.164
[310]   valid_0's rmse: 187.182
[320]   valid_0's rmse: 186.547
[330]   valid_0's rmse: 185.984
[340]   valid_0's rmse: 185.429
Did not meet early stopping. Best iteration is:
[344]   valid_0's rmse: 185.286
[I 2025-05-29 18:13:33,757] Trial 25 finished with value: 185.28642515161144 and par
ameters: {'learning_rate': 0.01277018545628999, 'num_leaves': 59, 'max_depth': 6, 'm
in_child_samples': 15, 'min_child_weight': 0.01649887314371159, 'subsample': 0.91579
37682367205, 'colsample_bytree': 0.8091413960517212, 'reg_alpha': 0.0024812170272313
036, 'reg_lambda': 1.025679778830003, 'n_estimators': 344}. Best is trial 17 with va
lue: 164.52444132146496.
```

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Trial Metrics: MAE=105.0404, MSE=34331.0593, RMSE=185.2864, R^2=0.7154
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 274.546
[20]    valid_0's rmse: 234.989
[30]    valid_0's rmse: 214.886
[40]    valid_0's rmse: 203.148
[50]    valid_0's rmse: 196.199
[60]    valid_0's rmse: 192.036
[70]    valid_0's rmse: 188.994
[80]    valid_0's rmse: 185.982
[90]    valid_0's rmse: 184.268
[100]   valid_0's rmse: 182.495
[110]   valid_0's rmse: 181.317
[120]   valid_0's rmse: 180.569
[130]   valid_0's rmse: 179.961
[140]   valid_0's rmse: 179.391
[150]   valid_0's rmse: 178.566
[160]   valid_0's rmse: 178.195
[170]   valid_0's rmse: 177.884
[180]   valid_0's rmse: 177.215
[190]   valid_0's rmse: 176.868
[200]   valid_0's rmse: 176.892
[210]   valid_0's rmse: 176.674
[220]   valid_0's rmse: 176.379
[230]   valid_0's rmse: 176.042
[240]   valid_0's rmse: 175.791
[250]   valid_0's rmse: 175.603
[260]   valid_0's rmse: 175.346
[270]   valid_0's rmse: 175.098
[I 2025-05-29 18:13:34,217] Trial 26 finished with value: 174.81592218205628 and par
ameters: {'learning_rate': 0.054089258146952326, 'num_leaves': 51, 'max_depth': 11,
'min_child_samples': 39, 'min_child_weight': 0.004020428190462681, 'subsample': 0.96
86078010003522, 'colsample_bytree': 0.9441483250992366, 'reg_alpha': 0.0003255711642
0483303, 'reg_lambda': 3.8527069415917854, 'n_estimators': 289}. Best is trial 17 wi
th value: 164.52444132146496.
```

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[280]   valid_0's rmse: 174.92
Did not meet early stopping. Best iteration is:
[285]   valid_0's rmse: 174.816
Trial Metrics: MAE=93.6645, MSE=30560.6066, RMSE=174.8159, R^2=0.7466
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 307.772
[20]    valid_0's rmse: 275.882
[30]    valid_0's rmse: 253.642
[40]    valid_0's rmse: 236.306
[50]    valid_0's rmse: 224.401
[60]    valid_0's rmse: 215.278
[70]    valid_0's rmse: 207.897
[80]    valid_0's rmse: 202.26
[90]    valid_0's rmse: 198.069
[100]   valid_0's rmse: 194.081
[110]   valid_0's rmse: 191.244
[120]   valid_0's rmse: 189.407
[130]   valid_0's rmse: 187.475
[140]   valid_0's rmse: 185.736
[150]   valid_0's rmse: 184.18
[160]   valid_0's rmse: 183.299
[170]   valid_0's rmse: 182.2
[180]   valid_0's rmse: 181.368
[190]   valid_0's rmse: 180.698
[200]   valid_0's rmse: 180.059
[210]   valid_0's rmse: 179.363
[220]   valid_0's rmse: 178.96
[230]   valid_0's rmse: 178.523
[240]   valid_0's rmse: 178.186
[250]   valid_0's rmse: 177.817
[260]   valid_0's rmse: 177.411
[270]   valid_0's rmse: 177.181
[280]   valid_0's rmse: 176.834
[290]   valid_0's rmse: 176.605
[300]   valid_0's rmse: 176.309
[310]   valid_0's rmse: 176.129
[320]   valid_0's rmse: 176.03
[330]   valid_0's rmse: 175.924
[340]   valid_0's rmse: 175.759
[350]   valid_0's rmse: 175.614
[360]   valid_0's rmse: 175.415
[370]   valid_0's rmse: 175.178
[380]   valid_0's rmse: 174.928
[390]   valid_0's rmse: 174.816
[400]   valid_0's rmse: 174.688
[410]   valid_0's rmse: 174.537
[420]   valid_0's rmse: 174.384
[430]   valid_0's rmse: 174.261
[440]   valid_0's rmse: 174.169
[450]   valid_0's rmse: 174.066
Did not meet early stopping. Best iteration is:
[453]   valid_0's rmse: 174.042
```

[I 2025-05-29 18:13:34,866] Trial 27 finished with value: 174.04197677198655 and parameters: {'learning_rate': 0.027684547127659213, 'num_leaves': 63, 'max_depth': 8, 'min_child_samples': 29, 'min_child_weight': 0.10846979966458696, 'subsample': 0.9019688617480801, 'colsample_bytree': 0.7008316345013432, 'reg_alpha': 0.09896074839447205, 'reg_lambda': 0.2626519241973224, 'n_estimators': 454}. Best is trial 17 with value: 164.52444132146496.

Trial Metrics: MAE=93.3915, MSE=30290.6097, RMSE=174.0420, R^2=0.7489

Training until validation scores don't improve for 50 rounds

[10] valid_0's rmse: 339.459

[20] valid_0's rmse: 332.103

[30] valid_0's rmse: 325.924

[40] valid_0's rmse: 319.164

[50] valid_0's rmse: 313.302

[60] valid_0's rmse: 307.374

[70] valid_0's rmse: 302.577

[80] valid_0's rmse: 297.62

[90] valid_0's rmse: 292.878

[100] valid_0's rmse: 288.647

[110] valid_0's rmse: 284.593

[120] valid_0's rmse: 280.707

[130] valid_0's rmse: 276.912

[140] valid_0's rmse: 273.535

[150] valid_0's rmse: 270.672

[160] valid_0's rmse: 268.051

[170] valid_0's rmse: 265.704

[180] valid_0's rmse: 263.284

[190] valid_0's rmse: 260.922

[200] valid_0's rmse: 258.806

[210] valid_0's rmse: 256.912

[220] valid_0's rmse: 254.911

[230] valid_0's rmse: 252.633

[240] valid_0's rmse: 250.847

[I 2025-05-29 18:13:35,146] Trial 28 finished with value: 226.95104679508842 and parameters: {'learning_rate': 0.009312067425282906, 'num_leaves': 58, 'max_depth': 3, 'min_child_samples': 14, 'min_child_weight': 0.045096636409012215, 'subsample': 0.8260023991672848, 'colsample_bytree': 0.8238098350418733, 'reg_alpha': 0.02124560363422133, 'reg_lambda': 1.1092840961872366, 'n_estimators': 432}. Best is trial 17 with value: 164.52444132146496.

```
[250]   valid_0's rmse: 249.114
[260]   valid_0's rmse: 247.48
[270]   valid_0's rmse: 245.867
[280]   valid_0's rmse: 244.09
[290]   valid_0's rmse: 242.649
[300]   valid_0's rmse: 241.038
[310]   valid_0's rmse: 239.685
[320]   valid_0's rmse: 238.16
[330]   valid_0's rmse: 236.832
[340]   valid_0's rmse: 235.612
[350]   valid_0's rmse: 234.483
[360]   valid_0's rmse: 233.232
[370]   valid_0's rmse: 232.318
[380]   valid_0's rmse: 231.097
[390]   valid_0's rmse: 230.076
[400]   valid_0's rmse: 229.135
[410]   valid_0's rmse: 228.416
[420]   valid_0's rmse: 227.846
[430]   valid_0's rmse: 227.135
Did not meet early stopping. Best iteration is:
[432]   valid_0's rmse: 226.951
Trial Metrics: MAE=132.7788, MSE=51506.7776, RMSE=226.9510, R^2=0.5730
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 346.26
[20]    valid_0's rmse: 344.773
[30]    valid_0's rmse: 343.292
[40]    valid_0's rmse: 341.76
[50]    valid_0's rmse: 340.323
[60]    valid_0's rmse: 338.927
[70]    valid_0's rmse: 337.531
[80]    valid_0's rmse: 336.142
[90]    valid_0's rmse: 334.82
[100]   valid_0's rmse: 333.417
[110]   valid_0's rmse: 332.108
[120]   valid_0's rmse: 330.851
[130]   valid_0's rmse: 329.562
[140]   valid_0's rmse: 328.207
[150]   valid_0's rmse: 327.012
[160]   valid_0's rmse: 325.732
[170]   valid_0's rmse: 324.438
[180]   valid_0's rmse: 323.178
[190]   valid_0's rmse: 321.899
[200]   valid_0's rmse: 320.666
[210]   valid_0's rmse: 319.475
[220]   valid_0's rmse: 318.281
[230]   valid_0's rmse: 317.065
[240]   valid_0's rmse: 315.926
[250]   valid_0's rmse: 314.745
[260]   valid_0's rmse: 313.607
[I 2025-05-29 18:13:35,652] Trial 29 finished with value: 298.19889765769267 and par
ameters: {'learning_rate': 0.0009355633318590932, 'num_leaves': 33, 'max_depth': 7,
'min_child_samples': 76, 'min_child_weight': 0.03903093343566498, 'subsample': 0.744
5064122967952, 'colsample_bytree': 0.774894540404174, 'reg_alpha': 0.006313734452963
032, 'reg_lambda': 4.203344954877374, 'n_estimators': 407}. Best is trial 17 with va
lue: 164.52444132146496.
```

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[270]   valid_0's rmse: 312.431
[280]   valid_0's rmse: 311.342
[290]   valid_0's rmse: 310.21
[300]   valid_0's rmse: 309.123
[310]   valid_0's rmse: 308.042
[320]   valid_0's rmse: 307.017
[330]   valid_0's rmse: 305.96
[340]   valid_0's rmse: 304.908
[350]   valid_0's rmse: 303.834
[360]   valid_0's rmse: 302.816
[370]   valid_0's rmse: 301.742
[380]   valid_0's rmse: 300.795
[390]   valid_0's rmse: 299.83
[400]   valid_0's rmse: 298.866
Did not meet early stopping. Best iteration is:
[407]   valid_0's rmse: 298.199
Trial Metrics: MAE=181.4472, MSE=88922.5826, RMSE=298.1989, R^2=0.2628
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 341.676
[20]    valid_0's rmse: 335.595
[30]    valid_0's rmse: 329.78
[40]    valid_0's rmse: 323.968
[50]    valid_0's rmse: 318.524
[60]    valid_0's rmse: 313.664
[70]    valid_0's rmse: 309.026
[80]    valid_0's rmse: 304.363
[90]    valid_0's rmse: 300.129
[100]   valid_0's rmse: 295.789
[110]   valid_0's rmse: 291.964
[120]   valid_0's rmse: 288.277
[130]   valid_0's rmse: 284.624
[140]   valid_0's rmse: 280.967
[150]   valid_0's rmse: 277.589
[160]   valid_0's rmse: 274.416
[170]   valid_0's rmse: 271.382
[180]   valid_0's rmse: 268.44
[190]   valid_0's rmse: 265.46
[200]   valid_0's rmse: 262.591
[210]   valid_0's rmse: 260.01
[220]   valid_0's rmse: 257.363
[230]   valid_0's rmse: 254.895
[240]   valid_0's rmse: 252.496
[250]   valid_0's rmse: 250.003
[260]   valid_0's rmse: 247.625
[270]   valid_0's rmse: 245.396
[280]   valid_0's rmse: 243.469
[290]   valid_0's rmse: 241.555
[300]   valid_0's rmse: 239.367
[310]   valid_0's rmse: 237.403
[320]   valid_0's rmse: 235.583
[330]   valid_0's rmse: 233.827
[340]   valid_0's rmse: 232.004
[350]   valid_0's rmse: 230.297
[360]   valid_0's rmse: 228.704
```

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[I 2025-05-29 18:13:36,375] Trial 30 finished with value: 215.00002675367628 and parameters: {'learning_rate': 0.0036079172611285138, 'num_leaves': 53, 'max_depth': 10, 'min_child_samples': 21, 'min_child_weight': 0.42346115974015125, 'subsample': 0.9836444732623256, 'colsample_bytree': 0.7275521593538212, 'reg_alpha': 0.0013989963604351208, 'reg_lambda': 0.00013600459586873224, 'n_estimators': 463}. Best is trial 17 with value: 164.52444132146496.
[370]   valid_0's rmse: 227.116
[380]   valid_0's rmse: 225.711
[390]   valid_0's rmse: 224.175
[400]   valid_0's rmse: 222.768
[410]   valid_0's rmse: 221.443
[420]   valid_0's rmse: 220.097
[430]   valid_0's rmse: 218.904
[440]   valid_0's rmse: 217.596
[450]   valid_0's rmse: 216.422
[460]   valid_0's rmse: 215.333
Did not meet early stopping. Best iteration is:
[463]   valid_0's rmse: 215
Trial Metrics: MAE=124.1787, MSE=46225.0115, RMSE=215.0000, R^2=0.6168
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 256.77
[20]    valid_0's rmse: 217.42
[30]    valid_0's rmse: 199.255
[40]    valid_0's rmse: 191.598
[50]    valid_0's rmse: 185.682
[60]    valid_0's rmse: 182.714
[70]    valid_0's rmse: 180.888
[80]    valid_0's rmse: 179.496
[90]    valid_0's rmse: 178.245
[100]   valid_0's rmse: 177.437
[110]   valid_0's rmse: 176.666
[120]   valid_0's rmse: 175.915
[130]   valid_0's rmse: 174.964
[140]   valid_0's rmse: 174.368
[150]   valid_0's rmse: 173.88
[160]   valid_0's rmse: 173.116
[170]   valid_0's rmse: 172.585
[180]   valid_0's rmse: 172.002
[190]   valid_0's rmse: 171.559
[200]   valid_0's rmse: 171.324
[210]   valid_0's rmse: 170.889
[220]   valid_0's rmse: 170.567
[230]   valid_0's rmse: 170.301
[240]   valid_0's rmse: 169.938
[250]   valid_0's rmse: 169.613
[260]   valid_0's rmse: 169.307
[270]   valid_0's rmse: 169.232
[280]   valid_0's rmse: 168.95
[290]   valid_0's rmse: 168.774
[300]   valid_0's rmse: 168.549
```

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[I 2025-05-29 18:13:36,869] Trial 31 finished with value: 166.13516870159953 and par
ameters: {'learning_rate': 0.09275216635454793, 'num_leaves': 62, 'max_depth': 6, 'm
in_child_samples': 5, 'min_child_weight': 0.161557165262708, 'subsample': 0.99769875
86855688, 'colsample_bytree': 0.8607888842827215, 'reg_alpha': 0.001698086557437328
2, 'reg_lambda': 6.992276569560797, 'n_estimators': 482}. Best is trial 17 with valu
e: 164.52444132146496.
```

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[310]   valid_0's rmse: 168.324
[320]   valid_0's rmse: 168.176
[330]   valid_0's rmse: 168.068
[340]   valid_0's rmse: 167.806
[350]   valid_0's rmse: 167.614
[360]   valid_0's rmse: 167.381
[370]   valid_0's rmse: 167.395
[380]   valid_0's rmse: 167.317
[390]   valid_0's rmse: 167.029
[400]   valid_0's rmse: 166.844
[410]   valid_0's rmse: 166.733
[420]   valid_0's rmse: 166.697
[430]   valid_0's rmse: 166.641
[440]   valid_0's rmse: 166.678
[450]   valid_0's rmse: 166.468
[460]   valid_0's rmse: 166.253
[470]   valid_0's rmse: 166.198
[480]   valid_0's rmse: 166.241
Did not meet early stopping. Best iteration is:
[474]   valid_0's rmse: 166.135
Trial Metrics: MAE=87.7103, MSE=27600.8943, RMSE=166.1352, R^2=0.7712
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 276.284
[20]    valid_0's rmse: 235.306
[30]    valid_0's rmse: 214.647
[40]    valid_0's rmse: 203.082
[50]    valid_0's rmse: 195.206
[60]    valid_0's rmse: 190.788
[70]    valid_0's rmse: 187.701
[80]    valid_0's rmse: 185.659
[90]    valid_0's rmse: 184.051
[100]   valid_0's rmse: 182.725
[110]   valid_0's rmse: 181.614
[120]   valid_0's rmse: 180.833
[130]   valid_0's rmse: 179.894
[140]   valid_0's rmse: 179.227
[150]   valid_0's rmse: 178.551
[160]   valid_0's rmse: 177.834
[170]   valid_0's rmse: 177.24
[180]   valid_0's rmse: 176.776
[190]   valid_0's rmse: 175.912
[200]   valid_0's rmse: 175.574
[210]   valid_0's rmse: 175.191
[220]   valid_0's rmse: 174.952
[230]   valid_0's rmse: 174.52
[240]   valid_0's rmse: 174.213
[250]   valid_0's rmse: 173.867
[260]   valid_0's rmse: 173.682
[270]   valid_0's rmse: 173.475
[280]   valid_0's rmse: 173.158
[290]   valid_0's rmse: 172.653
```

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[I 2025-05-29 18:13:37,399] Trial 32 finished with value: 169.3450666908966 and para
meters: {'learning_rate': 0.0646559024356043, 'num_leaves': 63, 'max_depth': 6, 'min
_child_samples': 10, 'min_child_weight': 0.19618149519881523, 'subsample': 0.9320896
380588187, 'colsample_bytree': 0.9006837951543737, 'reg_alpha': 0.000305909049182715
5, 'reg_lambda': 5.007837612393021, 'n_estimators': 493}. Best is trial 17 with valu
e: 164.52444132146496.
```

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[300]   valid_0's rmse: 172.334
[310]   valid_0's rmse: 172.15
[320]   valid_0's rmse: 171.922
[330]   valid_0's rmse: 171.629
[340]   valid_0's rmse: 171.655
[350]   valid_0's rmse: 171.475
[360]   valid_0's rmse: 171.326
[370]   valid_0's rmse: 171.105
[380]   valid_0's rmse: 170.902
[390]   valid_0's rmse: 170.744
[400]   valid_0's rmse: 170.551
[410]   valid_0's rmse: 170.202
[420]   valid_0's rmse: 170.093
[430]   valid_0's rmse: 170.101
[440]   valid_0's rmse: 169.985
[450]   valid_0's rmse: 169.961
[460]   valid_0's rmse: 169.799
[470]   valid_0's rmse: 169.692
[480]   valid_0's rmse: 169.534
[490]   valid_0's rmse: 169.415
Did not meet early stopping. Best iteration is:
[493]   valid_0's rmse: 169.345
Trial Metrics: MAE=89.5421, MSE=28677.7516, RMSE=169.3451, R^2=0.7623
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 292.906
[20]    valid_0's rmse: 259.196
[30]    valid_0's rmse: 234.499
[40]    valid_0's rmse: 217.2
[50]    valid_0's rmse: 205.658
[60]    valid_0's rmse: 197.683
[70]    valid_0's rmse: 191.977
[80]    valid_0's rmse: 187.626
[90]    valid_0's rmse: 184.367
[100]   valid_0's rmse: 181.475
[110]   valid_0's rmse: 179.459
[120]   valid_0's rmse: 177.914
[130]   valid_0's rmse: 176.568
[140]   valid_0's rmse: 175.565
[150]   valid_0's rmse: 174.789
[160]   valid_0's rmse: 174.236
[170]   valid_0's rmse: 173.654
[180]   valid_0's rmse: 173.096
[190]   valid_0's rmse: 172.564
[200]   valid_0's rmse: 172.179
[210]   valid_0's rmse: 171.847
[220]   valid_0's rmse: 171.566
[230]   valid_0's rmse: 171.344
[240]   valid_0's rmse: 171.017
[250]   valid_0's rmse: 170.742
[260]   valid_0's rmse: 170.547
[270]   valid_0's rmse: 170.209
[280]   valid_0's rmse: 170.024
[290]   valid_0's rmse: 169.813
[300]   valid_0's rmse: 169.711
[310]   valid_0's rmse: 169.585
[320]   valid_0's rmse: 169.375
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[330]   valid_0's rmse: 169.189
[340]   valid_0's rmse: 169.084
[350]   valid_0's rmse: 168.918
[360]   valid_0's rmse: 168.861
[370]   valid_0's rmse: 168.736
[380]   valid_0's rmse: 168.592
[I 2025-05-29 18:13:38,099] Trial 33 finished with value: 167.59717578116087 and par
ameters: {'learning_rate': 0.038730817990641334, 'num_leaves': 64, 'max_depth': 8,
'min_child_samples': 9, 'min_child_weight': 0.09621488417833833, 'subsample': 0.8807
837501884365, 'colsample_bytree': 0.858860744043959, 'reg_alpha': 0.0032204688119773
783, 'reg_lambda': 1.7958359470885799, 'n_estimators': 500}. Best is trial 17 with v
alue: 164.52444132146496.
```

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[390]   valid_0's rmse: 168.523
[400]   valid_0's rmse: 168.411
[410]   valid_0's rmse: 168.277
[420]   valid_0's rmse: 168.175
[430]   valid_0's rmse: 168.085
[440]   valid_0's rmse: 168.099
[450]   valid_0's rmse: 167.946
[460]   valid_0's rmse: 167.892
[470]   valid_0's rmse: 167.783
[480]   valid_0's rmse: 167.664
[490]   valid_0's rmse: 167.609
[500]   valid_0's rmse: 167.677
Did not meet early stopping. Best iteration is:
[491]   valid_0's rmse: 167.597
Trial Metrics: MAE=87.8720, MSE=28088.8133, RMSE=167.5972, R^2=0.7671
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 258.43
[20]    valid_0's rmse: 220.679
[30]    valid_0's rmse: 202.769
[40]    valid_0's rmse: 193.407
[50]    valid_0's rmse: 186.864
[60]    valid_0's rmse: 183.744
[70]    valid_0's rmse: 180.82
[80]    valid_0's rmse: 177.917
[90]    valid_0's rmse: 176.449
[100]   valid_0's rmse: 175.201
[110]   valid_0's rmse: 174.196
[120]   valid_0's rmse: 173.643
[130]   valid_0's rmse: 173.04
[140]   valid_0's rmse: 172.529
[150]   valid_0's rmse: 171.881
[160]   valid_0's rmse: 171.529
[170]   valid_0's rmse: 171.214
[180]   valid_0's rmse: 170.906
[190]   valid_0's rmse: 170.734
[200]   valid_0's rmse: 170.524
[210]   valid_0's rmse: 170.323
[220]   valid_0's rmse: 170.189
[230]   valid_0's rmse: 169.884
[240]   valid_0's rmse: 169.505
[250]   valid_0's rmse: 169.302
[260]   valid_0's rmse: 169.156
[270]   valid_0's rmse: 169.004
[280]   valid_0's rmse: 168.748
[290]   valid_0's rmse: 168.456
[300]   valid_0's rmse: 168.463
[310]   valid_0's rmse: 168.412
[320]   valid_0's rmse: 168.165
[330]   valid_0's rmse: 168.047
[340]   valid_0's rmse: 168.168
[I 2025-05-29 18:13:38,720] Trial 34 finished with value: 167.93072672948452 and par
ameters: {'learning_rate': 0.0740224420219898, 'num_leaves': 57, 'max_depth': 13, 'm
in_child_samples': 18, 'min_child_weight': 0.40696799854839244, 'subsample': 0.99869
78025777327, 'colsample_bytree': 0.7756712808589097, 'reg_alpha': 0.0004156913005057
32, 'reg_lambda': 9.57021120960309, 'n_estimators': 366}. Best is trial 17 with valu
e: 164.52444132146496.
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[350]   valid_0's rmse: 168.109
[360]   valid_0's rmse: 168.077
Did not meet early stopping. Best iteration is:
[365]   valid_0's rmse: 167.931
Trial Metrics: MAE=89.7280, MSE=28200.7290, RMSE=167.9307, R^2=0.7662
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 290.257
[20]    valid_0's rmse: 254.501
[30]    valid_0's rmse: 231.707
[40]    valid_0's rmse: 216.088
[50]    valid_0's rmse: 206.506
[60]    valid_0's rmse: 199.69
[70]    valid_0's rmse: 194.466
[80]    valid_0's rmse: 190.352
[90]    valid_0's rmse: 187.443
[100]   valid_0's rmse: 184.494
[110]   valid_0's rmse: 182.382
[120]   valid_0's rmse: 180.535
[130]   valid_0's rmse: 178.914
[140]   valid_0's rmse: 177.762
[150]   valid_0's rmse: 176.867
[160]   valid_0's rmse: 175.979
[170]   valid_0's rmse: 175.437
[180]   valid_0's rmse: 174.835
[190]   valid_0's rmse: 174.369
[200]   valid_0's rmse: 173.993
[210]   valid_0's rmse: 173.62
[220]   valid_0's rmse: 173.281
[230]   valid_0's rmse: 173.099
[240]   valid_0's rmse: 172.899
[250]   valid_0's rmse: 172.672
[260]   valid_0's rmse: 172.352
[270]   valid_0's rmse: 172.297
[280]   valid_0's rmse: 171.995
[290]   valid_0's rmse: 171.864
[300]   valid_0's rmse: 171.759
[310]   valid_0's rmse: 171.488
[320]   valid_0's rmse: 171.347
[330]   valid_0's rmse: 171.058
[340]   valid_0's rmse: 170.929
[350]   valid_0's rmse: 170.748
[360]   valid_0's rmse: 170.608
[370]   valid_0's rmse: 170.302
[380]   valid_0's rmse: 170.314
[390]   valid_0's rmse: 170.165
[400]   valid_0's rmse: 169.912
[410]   valid_0's rmse: 169.783
[420]   valid_0's rmse: 169.802
[430]   valid_0's rmse: 169.665
[440]   valid_0's rmse: 169.53
[450]   valid_0's rmse: 169.36
[460]   valid_0's rmse: 169.153
```

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[I 2025-05-29 18:13:39,328] Trial 35 finished with value: 169.08881414018822 and par
ameters: {'learning_rate': 0.040638108205158154, 'num_leaves': 47, 'max_depth': 10,
'min_child_samples': 11, 'min_child_weight': 0.13624991837632008, 'subsample': 0.967
0371855328334, 'colsample_bytree': 0.932219484083372, 'reg_alpha': 0.000100682742201
10865, 'reg_lambda': 0.00987022567738636, 'n_estimators': 463}. Best is trial 17 wit
h value: 164.52444132146496.
Did not meet early stopping. Best iteration is:
[463]   valid_0's rmse: 169.089
Trial Metrics: MAE=89.2787, MSE=28591.0271, RMSE=169.0888, R^2=0.7630
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 308.875
[20]    valid_0's rmse: 279.353
[30]    valid_0's rmse: 257.965
[40]    valid_0's rmse: 242.333
[50]    valid_0's rmse: 231.46
[60]    valid_0's rmse: 223.376
[70]    valid_0's rmse: 216.068
[80]    valid_0's rmse: 210.698
[I 2025-05-29 18:13:39,690] Trial 36 finished with value: 180.00619580632957 and par
ameters: {'learning_rate': 0.031164271324260702, 'num_leaves': 64, 'max_depth': 5,
'min_child_samples': 21, 'min_child_weight': 0.023381460317960578, 'subsample': 0.84
23065078292463, 'colsample_bytree': 0.9037808736533908, 'reg_alpha': 0.0290775755349
6889, 'reg_lambda': 0.0979372313133126, 'n_estimators': 404}. Best is trial 17 with
value: 164.52444132146496.
```

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[90]    valid_0's rmse: 206.2
[100]   valid_0's rmse: 202.565
[110]   valid_0's rmse: 199.725
[120]   valid_0's rmse: 197.085
[130]   valid_0's rmse: 194.847
[140]   valid_0's rmse: 193.341
[150]   valid_0's rmse: 191.624
[160]   valid_0's rmse: 190.41
[170]   valid_0's rmse: 189.546
[180]   valid_0's rmse: 188.726
[190]   valid_0's rmse: 188.061
[200]   valid_0's rmse: 187.336
[210]   valid_0's rmse: 186.779
[220]   valid_0's rmse: 186.242
[230]   valid_0's rmse: 185.661
[240]   valid_0's rmse: 185.277
[250]   valid_0's rmse: 184.922
[260]   valid_0's rmse: 184.36
[270]   valid_0's rmse: 183.863
[280]   valid_0's rmse: 183.556
[290]   valid_0's rmse: 183.175
[300]   valid_0's rmse: 182.897
[310]   valid_0's rmse: 182.469
[320]   valid_0's rmse: 182.204
[330]   valid_0's rmse: 181.863
[340]   valid_0's rmse: 181.455
[350]   valid_0's rmse: 181.21
[360]   valid_0's rmse: 181.013
[370]   valid_0's rmse: 180.663
[380]   valid_0's rmse: 180.445
[390]   valid_0's rmse: 180.207
[400]   valid_0's rmse: 180.032
Did not meet early stopping. Best iteration is:
[403]   valid_0's rmse: 180.006
Trial Metrics: MAE=98.9061, MSE=32402.2305, RMSE=180.0062, R^2=0.7314
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 265.487
[20]    valid_0's rmse: 226.023
[30]    valid_0's rmse: 205.96
[40]    valid_0's rmse: 195.192
[50]    valid_0's rmse: 188.898
[60]    valid_0's rmse: 184.793
[70]    valid_0's rmse: 182.492
[80]    valid_0's rmse: 180.817
[90]    valid_0's rmse: 178.759
[100]   valid_0's rmse: 178.086
[110]   valid_0's rmse: 177.306
[120]   valid_0's rmse: 177.034
[130]   valid_0's rmse: 176.466
[140]   valid_0's rmse: 175.776
[150]   valid_0's rmse: 175.147
[160]   valid_0's rmse: 174.55
[170]   valid_0's rmse: 174.17
[180]   valid_0's rmse: 173.925
[190]   valid_0's rmse: 173.567
[200]   valid_0's rmse: 173.448
```

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[210]   valid_0's rmse: 173.326
[220]   valid_0's rmse: 173.098
[230]   valid_0's rmse: 172.946
[240]   valid_0's rmse: 172.883
[250]   valid_0's rmse: 172.973
[260]   valid_0's rmse: 172.807
[270]   valid_0's rmse: 172.798
[280]   valid_0's rmse: 172.627
[290]   valid_0's rmse: 172.551
[300]   valid_0's rmse: 172.336
[310]   valid_0's rmse: 172.389
[320]   valid_0's rmse: 172.376
[330]   valid_0's rmse: 172.093
[340]   valid_0's rmse: 172.111
[350]   valid_0's rmse: 172.045
[360]   valid_0's rmse: 172.084
[370]   valid_0's rmse: 172.134
[380]   valid_0's rmse: 172.039
[390]   valid_0's rmse: 171.928
[400]   valid_0's rmse: 171.879
[410]   valid_0's rmse: 171.896
[420]   valid_0's rmse: 171.699
[430]   valid_0's rmse: 171.605
Did not meet early stopping. Best iteration is:
[432]   valid_0's rmse: 171.592
[I 2025-05-29 18:13:40,299] Trial 37 finished with value: 171.59220958627336 and par
ameters: {'learning_rate': 0.069652075350372, 'num_leaves': 51, 'max_depth': 9, 'min
_child_samples': 26, 'min_child_weight': 0.2881573647935575, 'subsample': 0.69135983
42985882, 'colsample_bytree': 0.8375156623866008, 'reg_alpha': 0.007941274455380797,
'reg_lambda': 3.086911613898165, 'n_estimators': 439}. Best is trial 17 with value:
164.52444132146496.
Trial Metrics: MAE=91.2329, MSE=29443.8864, RMSE=171.5922, R^2=0.7559
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 347.337
[20]    valid_0's rmse: 346.944
[30]    valid_0's rmse: 346.556
[40]    valid_0's rmse: 346.164
[50]    valid_0's rmse: 345.777
[60]    valid_0's rmse: 345.39
[70]    valid_0's rmse: 345.005
[80]    valid_0's rmse: 344.62
[90]    valid_0's rmse: 344.24
[100]   valid_0's rmse: 343.859
[110]   valid_0's rmse: 343.483
[120]   valid_0's rmse: 343.108
[130]   valid_0's rmse: 342.733
[140]   valid_0's rmse: 342.356
[150]   valid_0's rmse: 341.978
[160]   valid_0's rmse: 341.604
[170]   valid_0's rmse: 341.232
[180]   valid_0's rmse: 340.86
[190]   valid_0's rmse: 340.489
[200]   valid_0's rmse: 340.119
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[I 2025-05-29 18:13:40,853] Trial 38 finished with value: 337.65738616881004 and parameters: {'learning_rate': 0.00021355553149351585, 'num_leaves': 60, 'max_depth': 12, 'min_child_samples': 5, 'min_child_weight': 0.562068928492527, 'subsample': 0.8867417113281747, 'colsample_bytree': 0.9649432106786071, 'reg_alpha': 0.001629398867901387, 'reg_lambda': 0.9968329011735665, 'n_estimators': 267}. Best is trial 17 with value: 164.52444132146496.
[210]   valid_0's rmse: 339.749
[220]   valid_0's rmse: 339.383
[230]   valid_0's rmse: 339.014
[240]   valid_0's rmse: 338.647
[250]   valid_0's rmse: 338.277
[260]   valid_0's rmse: 337.912
Did not meet early stopping. Best iteration is:
[267]   valid_0's rmse: 337.657
Trial Metrics: MAE=210.1788, MSE=114012.5104, RMSE=337.6574, R^2=0.0548
[I 2025-05-29 18:13:41,160] Trial 39 finished with value: 181.20341848897655 and parameters: {'learning_rate': 0.043990216057978024, 'num_leaves': 16, 'max_depth': 5, 'min_child_samples': 19, 'min_child_weight': 0.9473893172159794, 'subsample': 0.931118818079997, 'colsample_bytree': 0.7289034936635564, 'reg_alpha': 0.019498910564834146, 'reg_lambda': 0.4773496916751621, 'n_estimators': 353}. Best is trial 17 with value: 164.52444132146496.
```

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Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 301.533
[20]    valid_0's rmse: 269.722
[30]    valid_0's rmse: 248.427
[40]    valid_0's rmse: 233.761
[50]    valid_0's rmse: 224.102
[60]    valid_0's rmse: 217.028
[70]    valid_0's rmse: 210.747
[80]    valid_0's rmse: 206.195
[90]    valid_0's rmse: 202.824
[100]   valid_0's rmse: 200.352
[110]   valid_0's rmse: 198.355
[120]   valid_0's rmse: 196.81
[130]   valid_0's rmse: 195.233
[140]   valid_0's rmse: 193.351
[150]   valid_0's rmse: 192.188
[160]   valid_0's rmse: 191.374
[170]   valid_0's rmse: 190.313
[180]   valid_0's rmse: 189.501
[190]   valid_0's rmse: 188.732
[200]   valid_0's rmse: 188.179
[210]   valid_0's rmse: 187.662
[220]   valid_0's rmse: 186.916
[230]   valid_0's rmse: 186.254
[240]   valid_0's rmse: 185.647
[250]   valid_0's rmse: 184.928
[260]   valid_0's rmse: 184.563
[270]   valid_0's rmse: 183.858
[280]   valid_0's rmse: 183.432
[290]   valid_0's rmse: 183.003
[300]   valid_0's rmse: 182.689
[310]   valid_0's rmse: 182.333
[320]   valid_0's rmse: 182
[330]   valid_0's rmse: 181.685
[340]   valid_0's rmse: 181.407
[350]   valid_0's rmse: 181.264
Did not meet early stopping. Best iteration is:
[353]   valid_0's rmse: 181.203
Trial Metrics: MAE=99.9901, MSE=32834.6789, RMSE=181.2034, R^2=0.7278
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 311.359
[20]    valid_0's rmse: 283.575
[30]    valid_0's rmse: 262.153
[40]    valid_0's rmse: 245.656
[50]    valid_0's rmse: 233.651
[60]    valid_0's rmse: 224.354
[70]    valid_0's rmse: 217.294
[80]    valid_0's rmse: 211.677
[90]    valid_0's rmse: 207.516
[100]   valid_0's rmse: 203.82
[110]   valid_0's rmse: 200.499
[120]   valid_0's rmse: 198.465
[130]   valid_0's rmse: 196.337
[140]   valid_0's rmse: 193.893
[150]   valid_0's rmse: 192.408
[160]   valid_0's rmse: 190.606
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[170]   valid_0's rmse: 189.287
[180]   valid_0's rmse: 188.019
[190]   valid_0's rmse: 187.091
[200]   valid_0's rmse: 186.268
[210]   valid_0's rmse: 185.452
[220]   valid_0's rmse: 184.824
[230]   valid_0's rmse: 184.407
[240]   valid_0's rmse: 183.898
[250]   valid_0's rmse: 183.423
[260]   valid_0's rmse: 182.961
[270]   valid_0's rmse: 182.511
[280]   valid_0's rmse: 182.108
[290]   valid_0's rmse: 181.777
[300]   valid_0's rmse: 181.424
[310]   valid_0's rmse: 181.235
[320]   valid_0's rmse: 180.905
[330]   valid_0's rmse: 180.459
[340]   valid_0's rmse: 180.326
[350]   valid_0's rmse: 180.084
[360]   valid_0's rmse: 179.824
[370]   valid_0's rmse: 179.653
[380]   valid_0's rmse: 179.442
[390]   valid_0's rmse: 179.31
[400]   valid_0's rmse: 179.197
[410]   valid_0's rmse: 179.004
[420]   valid_0's rmse: 178.862
[430]   valid_0's rmse: 178.675
[440]   valid_0's rmse: 178.44
[450]   valid_0's rmse: 178.369
[460]   valid_0's rmse: 178.165
[470]   valid_0's rmse: 177.953
[I 2025-05-29 18:13:41,742] Trial 40 finished with value: 177.6948409850099 and para
meters: {'learning_rate': 0.025225973576369777, 'num_leaves': 38, 'max_depth': 8, 'm
in_child_samples': 36, 'min_child_weight': 0.05100993142728324, 'subsample': 0.86045
87794183584, 'colsample_bytree': 0.7875122146985201, 'reg_alpha': 0.129479931323116
7, 'reg_lambda': 5.349640192263056, 'n_estimators': 499}. Best is trial 17 with valu
e: 164.52444132146496.
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[480]   valid_0's rmse: 177.843
[490]   valid_0's rmse: 177.782
Did not meet early stopping. Best iteration is:
[499]   valid_0's rmse: 177.695
Trial Metrics: MAE=96.0434, MSE=31575.4565, RMSE=177.6948, R^2=0.7382
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 260.991
[20]    valid_0's rmse: 221.483
[30]    valid_0's rmse: 202.18
[40]    valid_0's rmse: 193.396
[50]    valid_0's rmse: 188.101
[60]    valid_0's rmse: 185.086
[70]    valid_0's rmse: 183.273
[80]    valid_0's rmse: 181.486
[90]    valid_0's rmse: 180.369
[100]   valid_0's rmse: 179.135
[110]   valid_0's rmse: 178.125
[120]   valid_0's rmse: 177.452
[130]   valid_0's rmse: 176.467
[140]   valid_0's rmse: 175.929
[150]   valid_0's rmse: 175.373
[160]   valid_0's rmse: 174.552
[170]   valid_0's rmse: 174.167
[180]   valid_0's rmse: 173.859
[190]   valid_0's rmse: 173.399
[200]   valid_0's rmse: 173.157
[210]   valid_0's rmse: 172.816
[220]   valid_0's rmse: 172.314
[230]   valid_0's rmse: 172.105
[240]   valid_0's rmse: 171.906
[250]   valid_0's rmse: 171.574
[260]   valid_0's rmse: 171.17
[270]   valid_0's rmse: 170.918
[280]   valid_0's rmse: 170.727
[290]   valid_0's rmse: 170.59
[300]   valid_0's rmse: 170.343
[310]   valid_0's rmse: 170.021
[320]   valid_0's rmse: 169.844
[I 2025-05-29 18:13:42,225] Trial 41 finished with value: 168.58710401987418 and par
ameters: {'learning_rate': 0.08801650374624885, 'num_leaves': 62, 'max_depth': 6, 'm
in_child_samples': 8, 'min_child_weight': 0.1614044822740112, 'subsample': 0.9827479
335753304, 'colsample_bytree': 0.8614203088029342, 'reg_alpha': 0.001714575647879536
8, 'reg_lambda': 5.955060782191625, 'n_estimators': 477}. Best is trial 17 with valu
e: 164.52444132146496.
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[330]   valid_0's rmse: 169.702
[340]   valid_0's rmse: 169.592
[350]   valid_0's rmse: 169.483
[360]   valid_0's rmse: 169.255
[370]   valid_0's rmse: 169.24
[380]   valid_0's rmse: 168.988
[390]   valid_0's rmse: 168.796
[400]   valid_0's rmse: 168.635
[410]   valid_0's rmse: 168.602
[420]   valid_0's rmse: 168.587
[430]   valid_0's rmse: 168.962
[440]   valid_0's rmse: 168.943
[450]   valid_0's rmse: 168.85
[460]   valid_0's rmse: 168.804
[470]   valid_0's rmse: 168.76
Early stopping, best iteration is:
[420]   valid_0's rmse: 168.587
Trial Metrics: MAE=88.7622, MSE=28421.6116, RMSE=168.5871, R^2=0.7644
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 256.143
[20]    valid_0's rmse: 215.583
[30]    valid_0's rmse: 197.056
[40]    valid_0's rmse: 188.571
[50]    valid_0's rmse: 184.86
[60]    valid_0's rmse: 181.916
[70]    valid_0's rmse: 179.895
[80]    valid_0's rmse: 178.302
[90]    valid_0's rmse: 177.143
[100]   valid_0's rmse: 176.133
[110]   valid_0's rmse: 175.195
[120]   valid_0's rmse: 174.392
[130]   valid_0's rmse: 173.786
[140]   valid_0's rmse: 173.175
[150]   valid_0's rmse: 172.816
[160]   valid_0's rmse: 172.198
[170]   valid_0's rmse: 171.669
[180]   valid_0's rmse: 171.281
[190]   valid_0's rmse: 170.731
[200]   valid_0's rmse: 170.48
[210]   valid_0's rmse: 170.104
[220]   valid_0's rmse: 169.962
[230]   valid_0's rmse: 169.91
[240]   valid_0's rmse: 169.701
[250]   valid_0's rmse: 169.344
[260]   valid_0's rmse: 169.123
[270]   valid_0's rmse: 168.638
[280]   valid_0's rmse: 168.393
[I 2025-05-29 18:13:42,715] Trial 42 finished with value: 165.67505473336095 and par
ameters: {'learning_rate': 0.09228843551642092, 'num_leaves': 61, 'max_depth': 6, 'm
in_child_samples': 12, 'min_child_weight': 0.08223459901360997, 'subsample': 0.99829
65338235401, 'colsample_bytree': 0.8538806099933325, 'reg_alpha': 0.0037122300041801
163, 'reg_lambda': 2.487163317472594, 'n_estimators': 473}. Best is trial 17 with va
lue: 164.52444132146496.
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[290]   valid_0's rmse: 168.253
[300]   valid_0's rmse: 168.016
[310]   valid_0's rmse: 167.767
[320]   valid_0's rmse: 167.489
[330]   valid_0's rmse: 167.247
[340]   valid_0's rmse: 167.094
[350]   valid_0's rmse: 166.962
[360]   valid_0's rmse: 166.905
[370]   valid_0's rmse: 166.819
[380]   valid_0's rmse: 166.575
[390]   valid_0's rmse: 166.414
[400]   valid_0's rmse: 166.275
[410]   valid_0's rmse: 166.233
[420]   valid_0's rmse: 166.015
[430]   valid_0's rmse: 166.08
[440]   valid_0's rmse: 166.052
[450]   valid_0's rmse: 166.078
[460]   valid_0's rmse: 165.879
[470]   valid_0's rmse: 165.696
Did not meet early stopping. Best iteration is:
[473]   valid_0's rmse: 165.675
Trial Metrics: MAE=88.9643, MSE=27448.2238, RMSE=165.6751, R^2=0.7725
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 279.155
[20]    valid_0's rmse: 241.356
[30]    valid_0's rmse: 218.294
[40]    valid_0's rmse: 203.205
[50]    valid_0's rmse: 194.855
[60]    valid_0's rmse: 188.895
[70]    valid_0's rmse: 185.064
[80]    valid_0's rmse: 182.288
[90]    valid_0's rmse: 180.19
[100]   valid_0's rmse: 178.862
[110]   valid_0's rmse: 177.908
[120]   valid_0's rmse: 177.208
[130]   valid_0's rmse: 176.171
[140]   valid_0's rmse: 175.34
[150]   valid_0's rmse: 174.793
[160]   valid_0's rmse: 174.276
[170]   valid_0's rmse: 173.562
[180]   valid_0's rmse: 173.024
[190]   valid_0's rmse: 172.659
[200]   valid_0's rmse: 172.473
[210]   valid_0's rmse: 172.223
[220]   valid_0's rmse: 171.891
[230]   valid_0's rmse: 171.57
[240]   valid_0's rmse: 171.424
[250]   valid_0's rmse: 171.014
[260]   valid_0's rmse: 170.82
[270]   valid_0's rmse: 170.528
[280]   valid_0's rmse: 170.278
[290]   valid_0's rmse: 169.986
[300]   valid_0's rmse: 169.807
[310]   valid_0's rmse: 169.618
[320]   valid_0's rmse: 169.511
[330]   valid_0's rmse: 169.402
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[340]   valid_0's rmse: 169.431
[350]   valid_0's rmse: 169.37
[360]   valid_0's rmse: 169.17
[370]   valid_0's rmse: 169.124
[380]   valid_0's rmse: 169.006
[390]   valid_0's rmse: 168.787
[400]   valid_0's rmse: 168.574
[410]   valid_0's rmse: 168.459
[420]   valid_0's rmse: 168.303
[430]   valid_0's rmse: 168.334
[440]   valid_0's rmse: 168.248
[450]   valid_0's rmse: 168.267
[460]   valid_0's rmse: 168.235
[470]   valid_0's rmse: 168.257
Did not meet early stopping. Best iteration is:
[459]   valid_0's rmse: 168.185
[I 2025-05-29 18:13:43,299] Trial 43 finished with value: 168.18472681557287 and par
ameters: {'learning_rate': 0.05496818362089986, 'num_leaves': 57, 'max_depth': 7, 'm
in_child_samples': 13, 'min_child_weight': 0.06469317244879612, 'subsample': 0.94589
01970831775, 'colsample_bytree': 0.8167909064597421, 'reg_alpha': 0.0041555129923839
9, 'reg_lambda': 2.4434335399894813, 'n_estimators': 472}. Best is trial 17 with val
ue: 164.52444132146496.
Trial Metrics: MAE=89.3981, MSE=28286.1023, RMSE=168.1847, R^2=0.7655
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 282.471
[20]    valid_0's rmse: 248.205
[30]    valid_0's rmse: 229.467
[40]    valid_0's rmse: 217.712
[50]    valid_0's rmse: 210.657
[60]    valid_0's rmse: 206.054
[70]    valid_0's rmse: 202.85
[80]    valid_0's rmse: 200.454
[90]    valid_0's rmse: 198.713
[100]   valid_0's rmse: 197.084
[110]   valid_0's rmse: 195.462
[120]   valid_0's rmse: 194.145
[130]   valid_0's rmse: 193.324
[140]   valid_0's rmse: 192.546
[150]   valid_0's rmse: 191.489
[160]   valid_0's rmse: 190.549
[170]   valid_0's rmse: 189.768
[180]   valid_0's rmse: 189.096
[190]   valid_0's rmse: 188.337
[200]   valid_0's rmse: 188.014
[210]   valid_0's rmse: 187.631
[220]   valid_0's rmse: 187.261
[230]   valid_0's rmse: 186.837
[I 2025-05-29 18:13:43,618] Trial 44 finished with value: 182.07538442157545 and par
ameters: {'learning_rate': 0.0734271658817153, 'num_leaves': 54, 'max_depth': 4, 'mi
n_child_samples': 51, 'min_child_weight': 0.09218287463124569, 'subsample': 0.975483
88733828, 'colsample_bytree': 0.9243461791108065, 'reg_alpha': 0.000594270145934835
9, 'reg_lambda': 1.3539095472149907, 'n_estimators': 444}. Best is trial 17 with val
ue: 164.52444132146496.
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[240]   valid_0's rmse: 186.531
[250]   valid_0's rmse: 186.231
[260]   valid_0's rmse: 186
[270]   valid_0's rmse: 185.689
[280]   valid_0's rmse: 185.428
[290]   valid_0's rmse: 185.132
[300]   valid_0's rmse: 184.776
[310]   valid_0's rmse: 184.296
[320]   valid_0's rmse: 183.994
[330]   valid_0's rmse: 183.835
[340]   valid_0's rmse: 183.684
[350]   valid_0's rmse: 183.568
[360]   valid_0's rmse: 183.319
[370]   valid_0's rmse: 183.235
[380]   valid_0's rmse: 183.1
[390]   valid_0's rmse: 182.861
[400]   valid_0's rmse: 182.71
[410]   valid_0's rmse: 182.726
[420]   valid_0's rmse: 182.391
[430]   valid_0's rmse: 182.203
[440]   valid_0's rmse: 182.137
Did not meet early stopping. Best iteration is:
[444]   valid_0's rmse: 182.075
Trial Metrics: MAE=98.3506, MSE=33151.4456, RMSE=182.0754, R^2=0.7252
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 242.248
[20]    valid_0's rmse: 205.173
[30]    valid_0's rmse: 192.562
[40]    valid_0's rmse: 185.079
[50]    valid_0's rmse: 180.232
[60]    valid_0's rmse: 177.892
[70]    valid_0's rmse: 176.87
[80]    valid_0's rmse: 176.062
[90]    valid_0's rmse: 175.54
[100]   valid_0's rmse: 174.944
[110]   valid_0's rmse: 174.735
[120]   valid_0's rmse: 174.146
[130]   valid_0's rmse: 173.967
[140]   valid_0's rmse: 173.821
[150]   valid_0's rmse: 173.389
[160]   valid_0's rmse: 173.497
[170]   valid_0's rmse: 173.639
[180]   valid_0's rmse: 173.605
[190]   valid_0's rmse: 173.375
[200]   valid_0's rmse: 173.082
[210]   valid_0's rmse: 172.876
[220]   valid_0's rmse: 172.959
[230]   valid_0's rmse: 172.843
[240]   valid_0's rmse: 172.989
[250]   valid_0's rmse: 172.861
[260]   valid_0's rmse: 172.63
[270]   valid_0's rmse: 172.561
[280]   valid_0's rmse: 172.51
[290]   valid_0's rmse: 172.055
[300]   valid_0's rmse: 171.824
[310]   valid_0's rmse: 171.828
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[320]   valid_0's rmse: 171.78
[330]   valid_0's rmse: 171.603
[340]   valid_0's rmse: 171.67
[350]   valid_0's rmse: 171.395
[I 2025-05-29 18:13:44,268] Trial 45 finished with value: 171.39239305275987 and par
ameters: {'learning_rate': 0.09645512453169304, 'num_leaves': 61, 'max_depth': -1,
'min_child_samples': 18, 'min_child_weight': 0.03425236548750207, 'subsample': 0.909
7733999807023, 'colsample_bytree': 0.8911267833428045, 'reg_alpha': 0.03861217483066
739, 'reg_lambda': 0.7173661484809413, 'n_estimators': 415}. Best is trial 17 with v
alue: 164.52444132146496.
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[360]   valid_0's rmse: 171.488
[370]   valid_0's rmse: 171.497
[380]   valid_0's rmse: 171.709
[390]   valid_0's rmse: 171.818
[400]   valid_0's rmse: 171.775
Early stopping, best iteration is:
[351]   valid_0's rmse: 171.392
Trial Metrics: MAE=89.3622, MSE=29375.3524, RMSE=171.3924, R^2=0.7565
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 294.274
[20]    valid_0's rmse: 260.305
[30]    valid_0's rmse: 236.07
[40]    valid_0's rmse: 218.833
[50]    valid_0's rmse: 207.83
[60]    valid_0's rmse: 199.596
[70]    valid_0's rmse: 193.45
[80]    valid_0's rmse: 188.896
[90]    valid_0's rmse: 185.587
[100]   valid_0's rmse: 182.916
[110]   valid_0's rmse: 180.716
[120]   valid_0's rmse: 179.29
[130]   valid_0's rmse: 177.977
[140]   valid_0's rmse: 176.269
[150]   valid_0's rmse: 175.349
[160]   valid_0's rmse: 174.543
[170]   valid_0's rmse: 173.759
[180]   valid_0's rmse: 173.168
[190]   valid_0's rmse: 172.514
[200]   valid_0's rmse: 172.111
[210]   valid_0's rmse: 171.648
[220]   valid_0's rmse: 171.309
[230]   valid_0's rmse: 170.995
[240]   valid_0's rmse: 170.557
[250]   valid_0's rmse: 170.355
[260]   valid_0's rmse: 169.965
[270]   valid_0's rmse: 169.67
[280]   valid_0's rmse: 169.446
[290]   valid_0's rmse: 169.18
[300]   valid_0's rmse: 168.968
[310]   valid_0's rmse: 168.866
[320]   valid_0's rmse: 168.84
[330]   valid_0's rmse: 168.619
[340]   valid_0's rmse: 168.53
[350]   valid_0's rmse: 168.361
[360]   valid_0's rmse: 168.283
[370]   valid_0's rmse: 168.245
[380]   valid_0's rmse: 168.123
[390]   valid_0's rmse: 168.052
[400]   valid_0's rmse: 167.88
[I 2025-05-29 18:13:44,924] Trial 46 finished with value: 167.3780556193042 and para
meters: {'learning_rate': 0.03656186918963119, 'num_leaves': 58, 'max_depth': 9, 'mi
n_child_samples': 10, 'min_child_weight': 0.1191211193822301, 'subsample': 0.6279942
233775722, 'colsample_bytree': 0.7516438349707458, 'reg_alpha': 0.002714066846167937
6, 'reg_lambda': 0.29960995682813396, 'n_estimators': 433}. Best is trial 17 with va
lue: 164.52444132146496.
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[410]   valid_0's rmse: 167.801
[420]   valid_0's rmse: 167.645
[430]   valid_0's rmse: 167.432
Did not meet early stopping. Best iteration is:
[433]   valid_0's rmse: 167.378
Trial Metrics: MAE=89.2609, MSE=28015.4135, RMSE=167.3781, R^2=0.7677
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 346.578
[20]    valid_0's rmse: 345.426
[30]    valid_0's rmse: 344.251
[40]    valid_0's rmse: 343.066
[50]    valid_0's rmse: 341.931
[60]    valid_0's rmse: 340.835
[70]    valid_0's rmse: 339.739
[80]    valid_0's rmse: 338.628
[90]    valid_0's rmse: 337.576
[100]   valid_0's rmse: 336.483
[110]   valid_0's rmse: 335.414
[120]   valid_0's rmse: 334.364
[130]   valid_0's rmse: 333.333
[140]   valid_0's rmse: 332.286
[150]   valid_0's rmse: 331.265
[160]   valid_0's rmse: 330.224
[170]   valid_0's rmse: 329.205
[180]   valid_0's rmse: 328.195
[190]   valid_0's rmse: 327.173
[200]   valid_0's rmse: 326.179
[210]   valid_0's rmse: 325.232
[220]   valid_0's rmse: 324.285
[230]   valid_0's rmse: 323.32
[240]   valid_0's rmse: 322.405
[250]   valid_0's rmse: 321.448
[260]   valid_0's rmse: 320.517
[270]   valid_0's rmse: 319.586
[I 2025-05-29 18:13:45,404] Trial 47 finished with value: 309.2451695924989 and para
meters: {'learning_rate': 0.0007129692798304032, 'num_leaves': 29, 'max_depth': 10,
'min_child_samples': 25, 'min_child_weight': 0.29915950663367163, 'subsample': 0.961
4534398462093, 'colsample_bytree': 0.8491958591448074, 'reg_alpha': 0.00115784681572
09627, 'reg_lambda': 2.3855810861954643, 'n_estimators': 393}. Best is trial 17 with
value: 164.52444132146496.
[280]   valid_0's rmse: 318.684
[290]   valid_0's rmse: 317.797
[300]   valid_0's rmse: 316.937
[310]   valid_0's rmse: 316.07
[320]   valid_0's rmse: 315.243
[330]   valid_0's rmse: 314.412
[340]   valid_0's rmse: 313.566
[350]   valid_0's rmse: 312.726
[360]   valid_0's rmse: 311.897
[370]   valid_0's rmse: 311.03
[380]   valid_0's rmse: 310.233
[390]   valid_0's rmse: 309.469
Did not meet early stopping. Best iteration is:
[393]   valid_0's rmse: 309.245
Trial Metrics: MAE=189.9681, MSE=95632.5749, RMSE=309.2452, R^2=0.2072
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[I 2025-05-29 18:13:45,693] Trial 48 finished with value: 193.47877401902443 and par
ameters: {'learning_rate': 0.060840990797981075, 'num_leaves': 55, 'max_depth': 3,
'min_child_samples': 83, 'min_child_weight': 0.18712290286886119, 'subsample': 0.994
9528098459529, 'colsample_bytree': 0.8267173391479739, 'reg_alpha': 0.00868590852716
7514, 'reg_lambda': 0.027050766365345553, 'n_estimators': 477}. Best is trial 17 wit
h value: 164.52444132146496.
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Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 302.131
[20]    valid_0's rmse: 275.175
[30]    valid_0's rmse: 258.735
[40]    valid_0's rmse: 245.353
[50]    valid_0's rmse: 235.972
[60]    valid_0's rmse: 228.558
[70]    valid_0's rmse: 223.446
[80]    valid_0's rmse: 219.516
[90]    valid_0's rmse: 216.635
[100]   valid_0's rmse: 213.855
[110]   valid_0's rmse: 212.224
[120]   valid_0's rmse: 210.553
[130]   valid_0's rmse: 208.784
[140]   valid_0's rmse: 207.51
[150]   valid_0's rmse: 206.23
[160]   valid_0's rmse: 205.554
[170]   valid_0's rmse: 204.531
[180]   valid_0's rmse: 203.724
[190]   valid_0's rmse: 202.891
[200]   valid_0's rmse: 202.432
[210]   valid_0's rmse: 201.927
[220]   valid_0's rmse: 201.187
[230]   valid_0's rmse: 200.567
[240]   valid_0's rmse: 200.097
[250]   valid_0's rmse: 199.702
[260]   valid_0's rmse: 199.221
[270]   valid_0's rmse: 198.841
[280]   valid_0's rmse: 198.418
[290]   valid_0's rmse: 197.971
[300]   valid_0's rmse: 197.604
[310]   valid_0's rmse: 197.301
[320]   valid_0's rmse: 197.077
[330]   valid_0's rmse: 196.683
[340]   valid_0's rmse: 196.512
[350]   valid_0's rmse: 196.266
[360]   valid_0's rmse: 196.042
[370]   valid_0's rmse: 195.556
[380]   valid_0's rmse: 195.393
[390]   valid_0's rmse: 195.26
[400]   valid_0's rmse: 195.022
[410]   valid_0's rmse: 194.8
[420]   valid_0's rmse: 194.627
[430]   valid_0's rmse: 194.536
[440]   valid_0's rmse: 194.211
[450]   valid_0's rmse: 193.987
[460]   valid_0's rmse: 193.826
[470]   valid_0's rmse: 193.722
Did not meet early stopping. Best iteration is:
[477]   valid_0's rmse: 193.479
Trial Metrics: MAE=106.1214, MSE=37434.0360, RMSE=193.4788, R^2=0.6897
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 313.563
[20]    valid_0's rmse: 288.211
[30]    valid_0's rmse: 266.546
[40]    valid_0's rmse: 250.16
```

```
[50]    valid_0's rmse: 238.83
[60]    valid_0's rmse: 229.531
[70]    valid_0's rmse: 221.691
[80]    valid_0's rmse: 215.559
[90]    valid_0's rmse: 210.628
[100]   valid_0's rmse: 206.448
[110]   valid_0's rmse: 203.132
[120]   valid_0's rmse: 200.378
[130]   valid_0's rmse: 197.715
[140]   valid_0's rmse: 195.736
[150]   valid_0's rmse: 193.888
[160]   valid_0's rmse: 192.298
[170]   valid_0's rmse: 191.19
[180]   valid_0's rmse: 189.81
[190]   valid_0's rmse: 188.711
[200]   valid_0's rmse: 187.924
[210]   valid_0's rmse: 187.048
[220]   valid_0's rmse: 186.146
[230]   valid_0's rmse: 185.605
[240]   valid_0's rmse: 185.173
[250]   valid_0's rmse: 184.67
[260]   valid_0's rmse: 184.137
[270]   valid_0's rmse: 183.676
[280]   valid_0's rmse: 183.258
[290]   valid_0's rmse: 182.924
[300]   valid_0's rmse: 182.613
[310]   valid_0's rmse: 182.353
[320]   valid_0's rmse: 182.046
[330]   valid_0's rmse: 181.735
[340]   valid_0's rmse: 181.449
[350]   valid_0's rmse: 181.232
[360]   valid_0's rmse: 180.977
[370]   valid_0's rmse: 180.793
[380]   valid_0's rmse: 180.523
[390]   valid_0's rmse: 180.292
[400]   valid_0's rmse: 180.014
[410]   valid_0's rmse: 179.894
[420]   valid_0's rmse: 179.567
[430]   valid_0's rmse: 179.417
[440]   valid_0's rmse: 179.297
Did not meet early stopping. Best iteration is:
[449]   valid_0's rmse: 179.041
[I 2025-05-29 18:13:46,266] Trial 49 finished with value: 179.04089055248988 and par
ameters: {'learning_rate': 0.02145554443568913, 'num_leaves': 50, 'max_depth': 7, 'm
in_child_samples': 43, 'min_child_weight': 0.07664230365964152, 'subsample': 0.77420
5553208178, 'colsample_bytree': 0.8785185164460645, 'reg_alpha': 0.00408788835609310
6, 'reg_lambda': 0.7270709917468694, 'n_estimators': 449}. Best is trial 17 with val
ue: 164.52444132146496.
Trial Metrics: MAE=97.3657, MSE=32055.6405, RMSE=179.0409, R^2=0.7343
Best Trial:
RMSE: 164.5244
Best Hyperparameters: {'learning_rate': 0.06619033090007496, 'num_leaves': 60, 'max_
depth': 8, 'min_child_samples': 5, 'min_child_weight': 0.10560617678253516, 'subsamp
le': 0.8075568106358115, 'colsample_bytree': 0.8027750493803073, 'reg_alpha': 0.0086
39514127843586, 'reg_lambda': 2.173710512801541, 'n_estimators': 380}
```

In [74]:

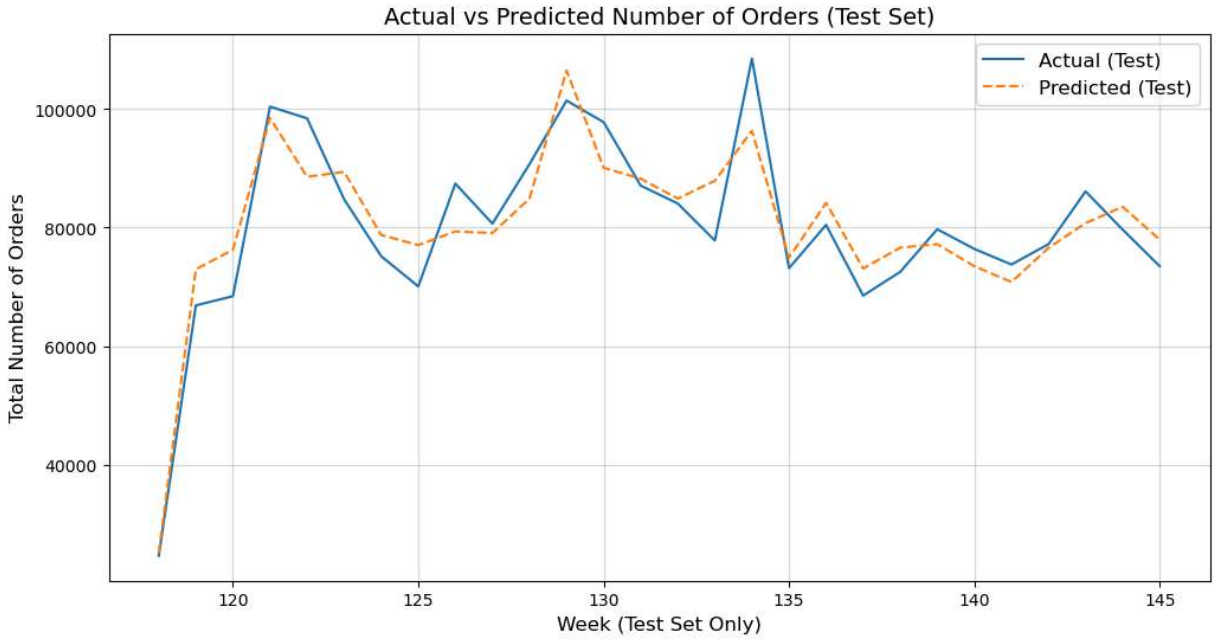
```python
# Train the final model with the best parameters
best_params = study.best_params
final_model = lgb.LGBMRegressor(**best_params)
final_model.fit(X_train,
                y_train,
                eval_set = [(X_test, y_test)],
                eval_metric = 'rmse',
                callbacks = [lgb.early_stopping(stopping_rounds=50),
                             lgb.log_evaluation(10)]
               )

# Make predictions
y_pred = final_model.predict(X_test)

# Calculate metrics
mse = mean_squared_error(y_test, y_pred)
rmse = mean_squared_error(y_test, y_pred, squared=False)
mae = mean_absolute_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

# Print the final metrics
print("\nFinal Model Metrics:")
print(f"MAE: {mae:.4f}")
print(f"MSE: {mse:.4f}")
print(f"RMSE: {rmse:.4f}")
print(f"R^2: {r2:.4f}")
```

```
Training until validation scores don't improve for 50 rounds
[10]    valid_0's rmse: 269.514 valid_0's l2: 72638
[20]    valid_0's rmse: 227.677 valid_0's l2: 51836.9
[30]    valid_0's rmse: 204.402 valid_0's l2: 41780.2
[40]    valid_0's rmse: 192.573 valid_0's l2: 37084.3
[50]    valid_0's rmse: 185.183 valid_0's l2: 34292.8
[60]    valid_0's rmse: 180.879 valid_0's l2: 32717.2
[70]    valid_0's rmse: 178.208 valid_0's l2: 31758
[80]    valid_0's rmse: 175.912 valid_0's l2: 30945.1
[90]    valid_0's rmse: 174.474 valid_0's l2: 30441.3
[100]   valid_0's rmse: 173.221 valid_0's l2: 30005.5
[110]   valid_0's rmse: 172.351 valid_0's l2: 29705
[120]   valid_0's rmse: 171.645 valid_0's l2: 29462
[130]   valid_0's rmse: 171.004 valid_0's l2: 29242.4
[140]   valid_0's rmse: 170.558 valid_0's l2: 29090
[150]   valid_0's rmse: 170.07  valid_0's l2: 28923.7
[160]   valid_0's rmse: 169.722 valid_0's l2: 28805.6
[170]   valid_0's rmse: 169.15  valid_0's l2: 28611.7
[180]   valid_0's rmse: 168.512 valid_0's l2: 28396.2
[190]   valid_0's rmse: 167.895 valid_0's l2: 28188.6
[200]   valid_0's rmse: 167.757 valid_0's l2: 28142.4
[210]   valid_0's rmse: 167.52  valid_0's l2: 28062.8
[220]   valid_0's rmse: 167.23  valid_0's l2: 27965.8
[230]   valid_0's rmse: 167.174 valid_0's l2: 27947
[240]   valid_0's rmse: 167.02  valid_0's l2: 27895.7
[250]   valid_0's rmse: 166.831 valid_0's l2: 27832.7
[260]   valid_0's rmse: 166.614 valid_0's l2: 27760.3
[270]   valid_0's rmse: 166.541 valid_0's l2: 27736
[280]   valid_0's rmse: 166.363 valid_0's l2: 27676.6
[290]   valid_0's rmse: 166.119 valid_0's l2: 27595.6
[300]   valid_0's rmse: 165.963 valid_0's l2: 27543.7
[310]   valid_0's rmse: 165.839 valid_0's l2: 27502.6
[320]   valid_0's rmse: 165.745 valid_0's l2: 27471.3
[330]   valid_0's rmse: 165.504 valid_0's l2: 27391.6
[340]   valid_0's rmse: 165.33  valid_0's l2: 27334
[350]   valid_0's rmse: 165.108 valid_0's l2: 27260.7
[360]   valid_0's rmse: 164.762 valid_0's l2: 27146.5
[370]   valid_0's rmse: 164.656 valid_0's l2: 27111.7
[380]   valid_0's rmse: 164.524 valid_0's l2: 27068.3
Did not meet early stopping. Best iteration is:
[380]   valid_0's rmse: 164.524 valid_0's l2: 27068.3

Final Model Metrics:
MAE: 88.1950
MSE: 27068.2918
RMSE: 164.5244
R^2: 0.7756
```

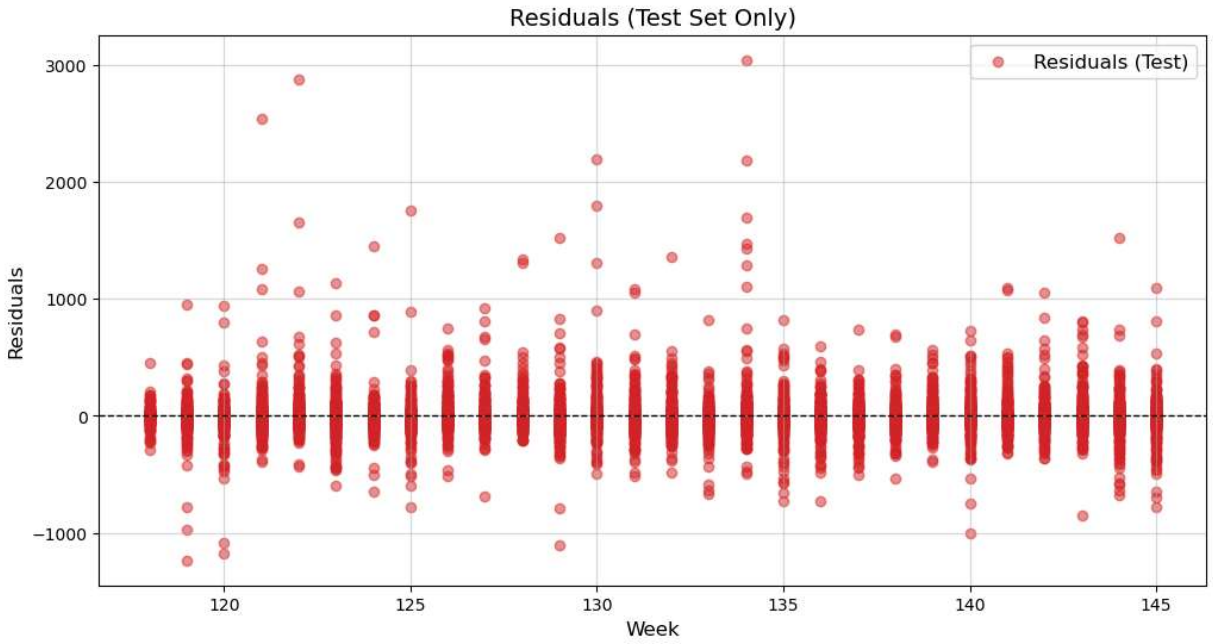
In [75]:

```
# Group by 'week' in the test set
test_weeks = X_test['week']
y_test_grouped = y_test.groupby(test_weeks).sum()
y_pred_grouped = pd.Series(y_pred.flatten(), index=X_test.index).groupby(test_weeks

# Plot Actual vs Predicted for the Test Set
plt.figure(figsize=(12, 6))
plt.plot(y_test_grouped.index, y_test_grouped, label = 'Actual (Test)', color = 'ta
```

```
plt.plot(y_pred_grouped.index, y_pred_grouped, label = 'Predicted (Test)', color =
plt.title("Actual vs Predicted Number of Orders (Test Set)", fontsize=14)
plt.xlabel("Week (Test Set Only)", fontsize = 12)
plt.ylabel("Total Number of Orders", fontsize = 12)
plt.legend(fontsize = 12)
plt.grid(alpha = 0.5)
plt.show()
```



In [76]:
```
# Residuals (Errors) for the Test Set
residuals = y_test - y_pred.flatten()

# Plot Residuals
plt.figure(figsize = (12, 6))
plt.scatter(test_weeks, residuals, alpha = 0.5, color = 'tab:red', label = 'Residua
plt.axhline(0, color = 'black', linestyle = '--', linewidth=1)
plt.title("Residuals (Test Set Only)", fontsize=14)
plt.xlabel("Week", fontsize = 12)
plt.ylabel("Residuals", fontsize = 12)
plt.legend(fontsize = 12)
plt.grid(alpha = 0.5)
plt.show()
```



Conclusions & Future Work

Key Findings:

- Machine-learning models substantially outperform traditional methods in MAE and R^2.
- Neural networks offer flexibility but may require more tuning and data.

Practical Implications:

- Organizations can adopt LightGBM or Neural Network for reliable weekly demand forecasts.
- Better forecasts lead to optimized inventory, lower waste, and improved service levels.

Limitations & Next Steps:

- Explore hyperparameter tuning and ensembling to further boost accuracy.
- Incorporate external factors (e.g., promotions, holidays).
- Test on different product categories or longer time horizons.

In [ ]: