data preprocessing

New notebook

In [1]:

```python
# Welcome to your new notebook
# Type here in the cell editor to add code!
```

```
StatementMeta(, f97326c7-9162-4aa4-9db2-d03770cad977, 3, Finished, Available, Finish
ed)
SynapseWidget(Synapse.DataFrame, 0352b249-c254-4c05-8938-63b3ec068f1f)
```

In [1]:

```python
df = spark.read.format("csv").option("header","true").load("Files/Merged_Company_Ta
# df now is a Spark DataFrame containing CSV data from "Files/Merged_Company_Table.
display(df)
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 3, Finished, Available, Finish
ed)
SynapseWidget(Synapse.DataFrame, b988e687-0d3e-41ab-992e-0545b53e21d3)
```

In [5]:

```python
# Import necessary libraries
from pyspark.sql import SparkSession
from pyspark.sql.functions import col, mean, stddev
from pyspark.ml.feature import VectorAssembler, StandardScaler
from pyspark.ml.stat import Correlation
from pyspark.ml.regression import RandomForestRegressor, GBTRegressor
from pyspark.ml.evaluation import RegressionEvaluator
from pyspark.ml.tuning import CrossValidator, ParamGridBuilder
from pyspark.sql.types import DoubleType
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 7, Finished, Available, Finish
ed)
```

In [6]:

```python
# Replace missing values with default values
df = df.fillna({
    "DistanceKM": 0,
    "UnitsProduced": 0,
    "DeliveryCount": 0,
    "AverageCO2PerKM": 0,
    "AvgCO2PerUnit": 0,
    "AvgCO2PerDelivery": 0
})
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 8, Finished, Available, Finish
ed)
```

In [7]:

```python
# Detect and remove outliers using z-scores
mean_distance = df.select(mean(col("DistanceKM"))).collect()[0][0]
std_distance = df.select(stddev(col("DistanceKM"))).collect()[0][0]
z_score_threshold = 3

df = df.filter((col("DistanceKM") - mean_distance) / std_distance < z_score_thresho
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 9, Finished, Available, Finish
ed)
```

In [9]:

```
from pyspark.sql.types import DoubleType

# Convert columns to numeric (double) type
df = df.withColumn("DistanceKM", col("DistanceKM").cast(DoubleType()))
df = df.withColumn("UnitsProduced", col("UnitsProduced").cast(DoubleType()))
df = df.withColumn("DeliveryCount", col("DeliveryCount").cast(DoubleType()))

# Check the schema to confirm the type changes
df.printSchema()
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 11, Finished, Available, Finis
hed)
root
 |-- _c0: string (nullable = true)
 |-- TransactionID: string (nullable = true)
 |-- TransportID: string (nullable = true)
 |-- ProductionID: string (nullable = true)
 |-- SupplierID: string (nullable = true)
 |-- DistanceKM: double (nullable = true)
 |-- UnitsProduced: double (nullable = true)
 |-- DeliveryCount: double (nullable = true)
 |-- Mode: string (nullable = true)
 |-- FuelType: string (nullable = true)
 |-- AverageCO2PerKM: string (nullable = false)
 |-- Material: string (nullable = true)
 |-- EnergySource: string (nullable = true)
 |-- AvgCO2PerUnit: string (nullable = false)
 |-- SupplierName: string (nullable = true)
 |-- Location: string (nullable = true)
 |-- AvgCO2PerDelivery: string (nullable = false)
```

In [10]:

```
# Assemble features for scaling
assembler = VectorAssembler(inputCols=["DistanceKM", "UnitsProduced", "DeliveryCoun
df = assembler.transform(df)

# Normalize features
scaler = StandardScaler(inputCol="features", outputCol="scaled_features", withMean=
scaler_model = scaler.fit(df)
df = scaler_model.transform(df)

# Show the transformed data
df.select("DistanceKM", "UnitsProduced", "DeliveryCount", "scaled_features").show(5
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 12, Finished, Available, Finis
hed)
```

```
+----------+-------------+-------------+--------------------+
|DistanceKM|UnitsProduced|DeliveryCount|     scaled_features|
+----------+-------------+-------------+--------------------+
|    1638.0|       1270.0|          5.0|[0.95636182468682...|
|    1860.0|        399.0|          6.0|[1.28216912167213...|
|     779.0|       4019.0|          1.0|[-0.3043069505851...|
|    1489.0|       2049.0|          7.0|[0.73768935959308...|
|     153.0|       2714.0|          9.0|[-1.2230248240662...|
+----------+-------------+-------------+--------------------+
only showing top 5 rows
```

Exploratory Data Analysis (EDA)

In [11]:

```python
# Show basic statistics
df.describe(["DistanceKM", "UnitsProduced", "DeliveryCount"]).show()
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 13, Finished, Available, Finis
hed)
+-------+-----------------+------------------+------------------+
|summary|       DistanceKM|     UnitsProduced|     DeliveryCount|
+-------+-----------------+------------------+------------------+
|  count|               20|                20|                20|
|   mean|           986.35|            2632.3|              4.75|
| stddev|681.3843706208088|1553.8462668657512|2.5313819816144116|
|    min|             53.0|             212.0|               1.0|
|    max|           1982.0|            4893.0|               9.0|
+-------+-----------------+------------------+------------------+
```

In [13]:

```python
# Drop the existing 'features' column if it exists
if "features" in df.columns:
    df = df.drop("features")

# Assemble features for scaling
assembler = VectorAssembler(inputCols=["DistanceKM", "UnitsProduced", "DeliveryCoun
df = assembler.transform(df)

# Compute the correlation matrix
from pyspark.ml.stat import Correlation
correlation_matrix = Correlation.corr(df, "features").head()[0]
print("Correlation Matrix:\n", correlation_matrix)
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 15, Finished, Available, Finis
hed)
Correlation Matrix:
 DenseMatrix([[ 1.        , -0.38620208, -0.19773717],
             [-0.38620208,  1.        , -0.24233219],
             [-0.19773717, -0.24233219,  1.        ]])
```

4. Train Machine Learning Model

In [14]:

```python
# Split data into training and test sets
train_df, test_df = df.randomSplit([0.8, 0.2], seed=42)
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 16, Finished, Available, Finis
hed)
```

In [16]:

```python
from pyspark.sql.types import DoubleType

# Cast the AverageCO2PerKM column to a numeric type
df = df.withColumn("AverageCO2PerKM", col("AverageCO2PerKM").cast(DoubleType()))

# Verify the schema to ensure the column is now numeric
df.printSchema()
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 18, Finished, Available, Finis
hed)
root
 |-- _c0: string (nullable = true)
 |-- TransactionID: string (nullable = true)
 |-- TransportID: string (nullable = true)
 |-- ProductionID: string (nullable = true)
 |-- SupplierID: string (nullable = true)
 |-- DistanceKM: double (nullable = true)
 |-- UnitsProduced: double (nullable = true)
 |-- DeliveryCount: double (nullable = true)
 |-- Mode: string (nullable = true)
 |-- FuelType: string (nullable = true)
 |-- AverageCO2PerKM: double (nullable = true)
 |-- Material: string (nullable = true)
 |-- EnergySource: string (nullable = true)
 |-- AvgCO2PerUnit: string (nullable = false)
 |-- SupplierName: string (nullable = true)
 |-- Location: string (nullable = true)
 |-- AvgCO2PerDelivery: string (nullable = false)
 |-- scaled_features: vector (nullable = true)
 |-- features: vector (nullable = true)
```

In [20]:

```python
# Split data into training and test sets
train_df, test_df = df.randomSplit([0.8, 0.2], seed=42)

# Define the Random Forest model
rf = RandomForestRegressor(featuresCol="scaled_features", labelCol="AverageCO2PerKM

# Define parameter grid
param_grid = ParamGridBuilder().addGrid(rf.numTrees, [10, 20, 50]).build()

# Cross-validator
evaluator = RegressionEvaluator(labelCol="AverageCO2PerKM", predictionCol="predicti
crossval = CrossValidator(estimator=rf, estimatorParamMaps=param_grid, evaluator=ev

# Train models and select the best one
cv_model = crossval.fit(train_df)
best_model = cv_model.bestModel

# Evaluate the model
predictions = best_model.transform(test_df)
rmse = evaluator.evaluate(predictions)
```

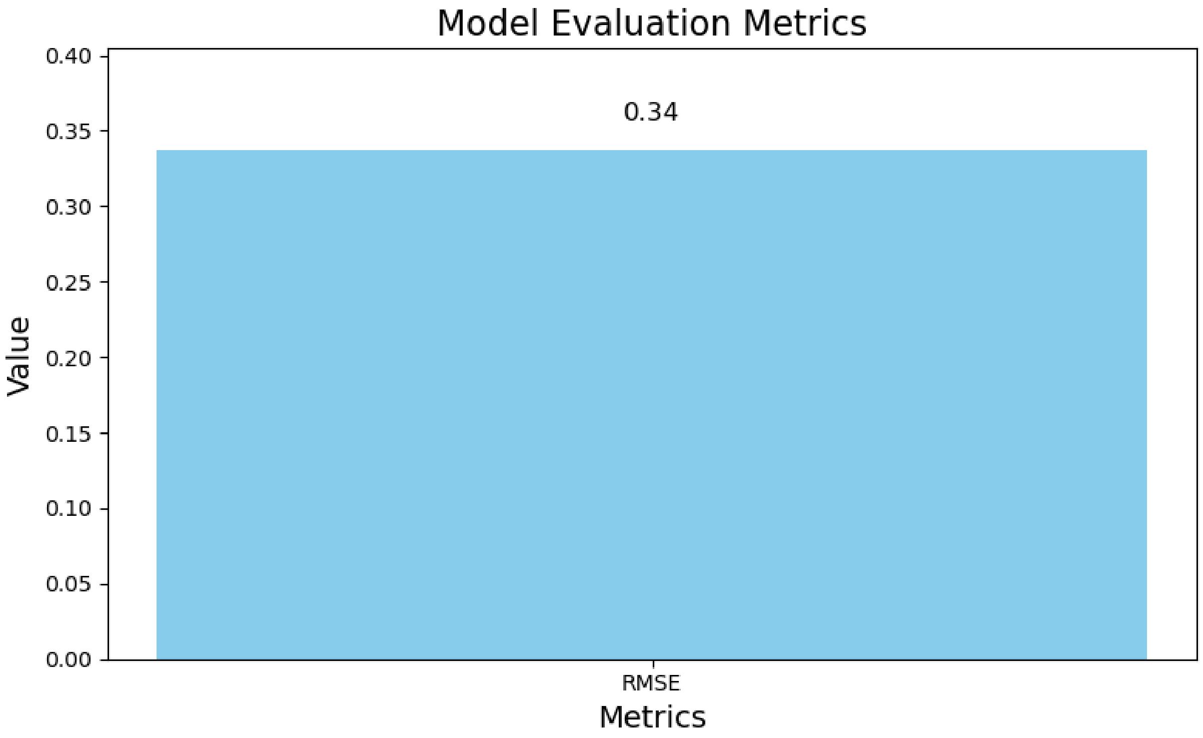
```
print(f"Best Model: {type(best_model).__name__}")
print(f"RMSE: {rmse}")
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 22, Finished, Available, Finis
hed)
Best Model: RandomForestRegressionModel
RMSE: 0.33692692679570774
```

In [21]:

```
import matplotlib.pyplot as plt

# Ensure the metrics are within a reasonable range
metrics = {
    "RMSE": rmse if rmse < 1e6 else 0,  # Check for large/unreasonable values
}

# Plot the metrics
plt.figure(figsize=(8, 5))
plt.bar(metrics.keys(), metrics.values(), color='skyblue')
plt.title("Model Evaluation Metrics", fontsize=16)
plt.ylabel("Value", fontsize=14)
plt.xlabel("Metrics", fontsize=14)
plt.ylim(0, max(metrics.values()) * 1.2)  # Add space above bars

# Annotate the values on top of the bars
for metric, value in metrics.items():
    plt.text(metric, value + 0.02, f"{value:.2f}", ha='center', fontsize=12)

plt.tight_layout()
plt.show()
```

```
StatementMeta(, b6b4b1c6-804e-4454-90a5-766ef1f4124b, 23, Finished, Available, Finis
hed)
```


Model Evaluation Metrics
Value
RMSE
Metrics