Mini Project on CO2 Emission Data Using PySpark

Dataset : CO2 Emissions_Canada.csv

Source : https://www.kaggle.com/datasets/debajyotipodder/co2-emission-by-vehicles

```python
import os
import findspark

# Point to Java & Spark
os.environ["JAVA_HOME"] = "C:/Progra~1/Java/jdk1.8"
os.environ["SPARK_HOME"] = "C:/spark/spark-3.5.7-bin-hadoop3-scala2.13"
os.environ["HADOOP_HOME"] = "C:/hadoop"   # if you installed winutils here
os.environ["PATH"] += ";C:/spark/spark-3.5.7-bin-hadoop3-scala2.13/bin;C:/hadoop/bin"

# Initialize findspark
findspark.init(os.environ["SPARK_HOME"])

from pyspark.sql import SparkSession

# Now build SparkSession
spark = SparkSession.builder \
    .appName("BDA_MINI_PROJECT") \
    .master("local[*]") \
    .getOrCreate()

sc = spark.sparkContext

sc
```

```
<SparkContext master=local[*] appName=BDA_MINI_PROJECT>
```

Dataset Insights

The dataset provided contains details of 7,385 vehicles across different makes, models, classes, and fuel types in Canada. It has 12 columns: Make, Model, Vehicle Class, Engine Size(L), Cylinders, Transmission, Fuel Type, Fuel Consumption (City, Hwy, Comb), Fuel Consumption Comb (mpg), and CO2 Emissions(g/km). There are no missing values, ensuring data consistency and completeness, which is advantageous for analysis. Below are the detailed insights:

1. Structure and Uniqueness

The dataset comprises 7,385 rows and 12 columns. Each vehicle is uniquely identified by the combination of Make and Model. There are 42 unique makes (e.g., Ford, Toyota, BMW), and over 2,000 unique models. The dataset captures a wide range of vehicle types, including 16 vehicle classes (from two-seaters to large SUVs and pickups). This diversity provides a strong foundation for analyzing the automotive market in terms of fuel efficiency and emissions.

1. Vehicle Class Distribution

The dataset spans 16 vehicle classes, such as Compact, Midsize, SUV, Pickup Truck, and Station Wagon. SUVs and Pickup Trucks appear with higher representation, reflecting their popularity in the Canadian market. Smaller classes like Two-Seater and Subcompact also exist but in smaller numbers. Such distribution helps analyze the impact of vehicle type on CO2 emissions and fuel economy.

1. Transmission and Engine Configurations

There are 27 unique transmission types ranging from manual to automatic with varying gears, and 8 unique cylinder configurations (from 3 to 12 cylinders). Vehicles with higher cylinder counts generally correspond to larger engines and higher emissions. This allows comparative analysis of drivetrain efficiency.

1. CO2 Emissions Insights

The CO2 Emissions(g/km) variable ranges widely, with values as low as ~100 g/km for efficient hybrids to well above 400 g/km for large, less efficient vehicles. The average CO2 emission across all vehicles is around ~250 g/km, showing significant variation. This indicates the presence of both eco-friendly cars and high-emission performance vehicles.

1. Fuel Consumption Distribution

Fuel consumption is provided for city, highway, and combined driving in liters per 100 km. City consumption values are generally higher than highway, reflecting real-world driving conditions. The combined fuel consumption ranges from ~4 L/100 km (very efficient hybrids) to over 20 L/100 km (large SUVs and pickups), indicating major differences in fuel economy across vehicle classes.

1. Fuel Type Patterns

The dataset includes 5 fuel types: Regular gasoline, Premium gasoline, Diesel, Ethanol (E85), and Natural Gas. Regular and Premium gasoline vehicles dominate the dataset, while Diesel and alternative fuels have a smaller share. Average CO2 emissions vary by fuel type, with gasoline vehicles contributing higher emissions on average compared to hybrid/alternative fuel options.

1. Key Relationships

Engine Size vs. CO2: Larger engine sizes (L) generally correlate with higher CO2 emissions.

Cylinders vs. Fuel Consumption: Vehicles with more cylinders show higher city and highway fuel consumption.

Transmission vs. Efficiency: Vehicles with newer automatic transmissions often achieve better combined fuel economy compared to older manual configurations.

Fuel Type vs. Emissions: Alternative fuels (E85, Hybrid, CNG) generally report lower CO2 than traditional gasoline.

1. Market Characteristics

Overall, the dataset portrays a diverse Canadian automotive market with a wide mix of vehicles across size, power, and efficiency. The absence of missing data makes this dataset reliable for environmental policy analysis, automotive research, and predictive modeling of emissions. It highlights key industry trends: strong SUV and pickup representation, dominance of gasoline fuel types, and the growing presence of fuel-efficient models.

```python
import pandas as pd
import matplotlib.pyplot as plt

# Load dataset
df = pd.read_csv("CO2 Emissions_Canada.csv")
df
```

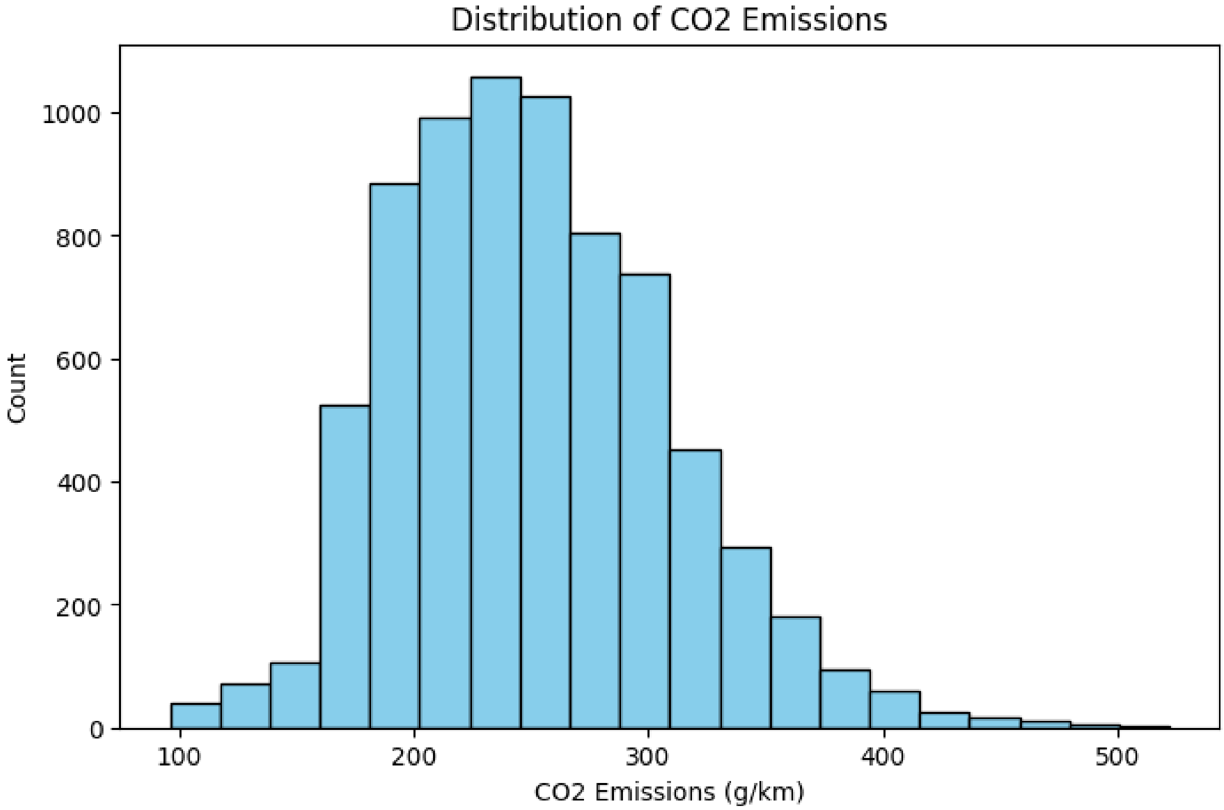
```
       Make        Model   Vehicle Class  Engine Size(L)  Cylinders  \
0     ACURA          ILX         COMPACT             2.0          4
1     ACURA          ILX         COMPACT             2.4          4
2     ACURA   ILX HYBRID         COMPACT             1.5          4
3     ACURA      MDX 4WD     SUV - SMALL             3.5          6
4     ACURA      RDX AWD     SUV - SMALL             3.5          6
...     ...          ...             ...             ...        ...
7380  VOLVO  XC40 T5 AWD     SUV - SMALL             2.0          4
7381  VOLVO  XC60 T5 AWD     SUV - SMALL             2.0          4
7382  VOLVO  XC60 T6 AWD     SUV - SMALL             2.0          4
7383  VOLVO  XC90 T5 AWD  SUV - STANDARD             2.0          4
7384  VOLVO  XC90 T6 AWD  SUV - STANDARD             2.0          4

     Transmission Fuel Type  Fuel Consumption City (L/100 km)  \
0             AS5         Z                               9.9
1              M6         Z                              11.2
2             AV7         Z                               6.0
3             AS6         Z                              12.7
4             AS6         Z                              12.1
...           ...       ...                               ...
7380          AS8         Z                              10.7
7381          AS8         Z                              11.2
7382          AS8         Z                              11.7
7383          AS8         Z                              11.2
7384          AS8         Z                              12.2

      Fuel Consumption Hwy (L/100 km)  Fuel Consumption Comb (L/100
km)  \
0                                 6.7
8.5
1                                 7.7
9.6
2                                 5.8
5.9
3                                 9.1
11.1
4                                 8.7
10.6
...                               ...                               ..
```

```
.
7380                              7.7
9.4
7381                              8.3
9.9
7382                              8.6
10.3
7383                              8.3
9.9
7384                              8.7
10.7

      Fuel Consumption Comb (mpg)  CO2 Emissions(g/km)
0                              33                  196
1                              29                  221
2                              48                  136
3                              25                  255
4                              27                  244
...                           ...                  ...
7380                           30                  219
7381                           29                  232
7382                           27                  240
7383                           29                  232
7384                           26                  248

[7385 rows x 12 columns]
```

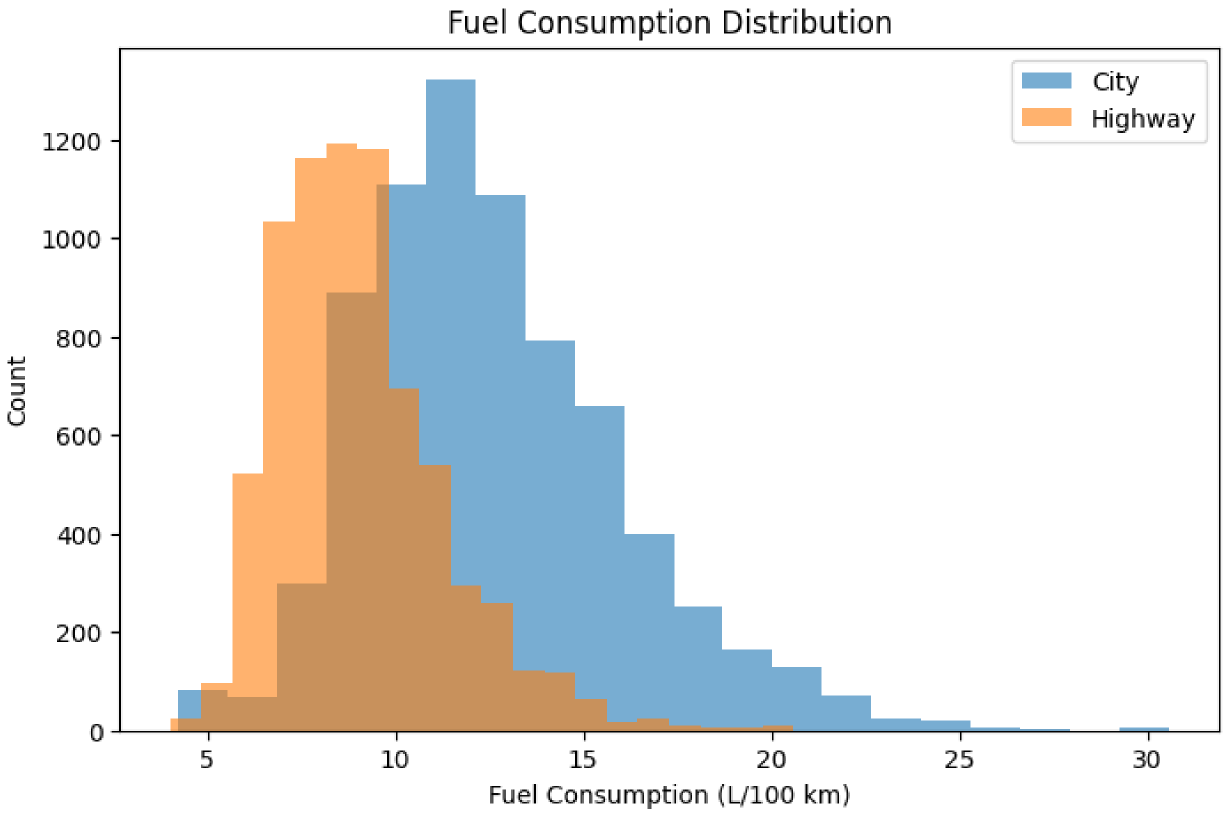
```python
# Dataset Insights
print("Dataset Shape:", df.shape)
print("Columns:", df.columns.tolist())
print("Missing Values:\n", df.isnull().sum())
print("Unique values per column:\n", df.nunique())
print(df.describe())
```

```
Dataset Shape: (7385, 12)
Columns: ['Make', 'Model', 'Vehicle Class', 'Engine Size(L)',
'Cylinders', 'Transmission', 'Fuel Type', 'Fuel Consumption City
(L/100 km)', 'Fuel Consumption Hwy (L/100 km)', 'Fuel Consumption Comb
(L/100 km)', 'Fuel Consumption Comb (mpg)', 'CO2 Emissions(g/km)']
Missing Values:
 Make                                0
Model                               0
Vehicle Class                       0
Engine Size(L)                      0
Cylinders                           0
Transmission                        0
Fuel Type                           0
Fuel Consumption City (L/100 km)    0
Fuel Consumption Hwy (L/100 km)     0
Fuel Consumption Comb (L/100 km)    0
Fuel Consumption Comb (mpg)         0
CO2 Emissions(g/km)                 0
dtype: int64
Unique values per column:
 Make                                  42
Model                               2053
Vehicle Class                         16
Engine Size(L)                        51
Cylinders                              8
Transmission                          27
Fuel Type                              5
Fuel Consumption City (L/100 km)     211
Fuel Consumption Hwy (L/100 km)      143
Fuel Consumption Comb (L/100 km)     181
Fuel Consumption Comb (mpg)           54
CO2 Emissions(g/km)                  331
dtype: int64
       Engine Size(L)    Cylinders  Fuel Consumption City (L/100
km)  \
count     7385.000000  7385.000000                       7385.000000

mean         3.160068     5.615030                         12.556534

std          1.354170     1.828307                          3.500274

min          0.900000     3.000000                          4.200000

25%          2.000000     4.000000                         10.100000

50%          3.000000     6.000000                         12.100000

75%          3.700000     6.000000                         14.600000

max          8.400000    16.000000                         30.600000


       Fuel Consumption Hwy (L/100 km)  Fuel Consumption Comb (L/100
km)  \
count                       7385.000000
7385.000000
mean                           9.041706
10.975071
std                            2.224456
2.892506
min                            4.000000
4.100000
25%                            7.500000
8.900000
50%                            8.700000
10.600000
```

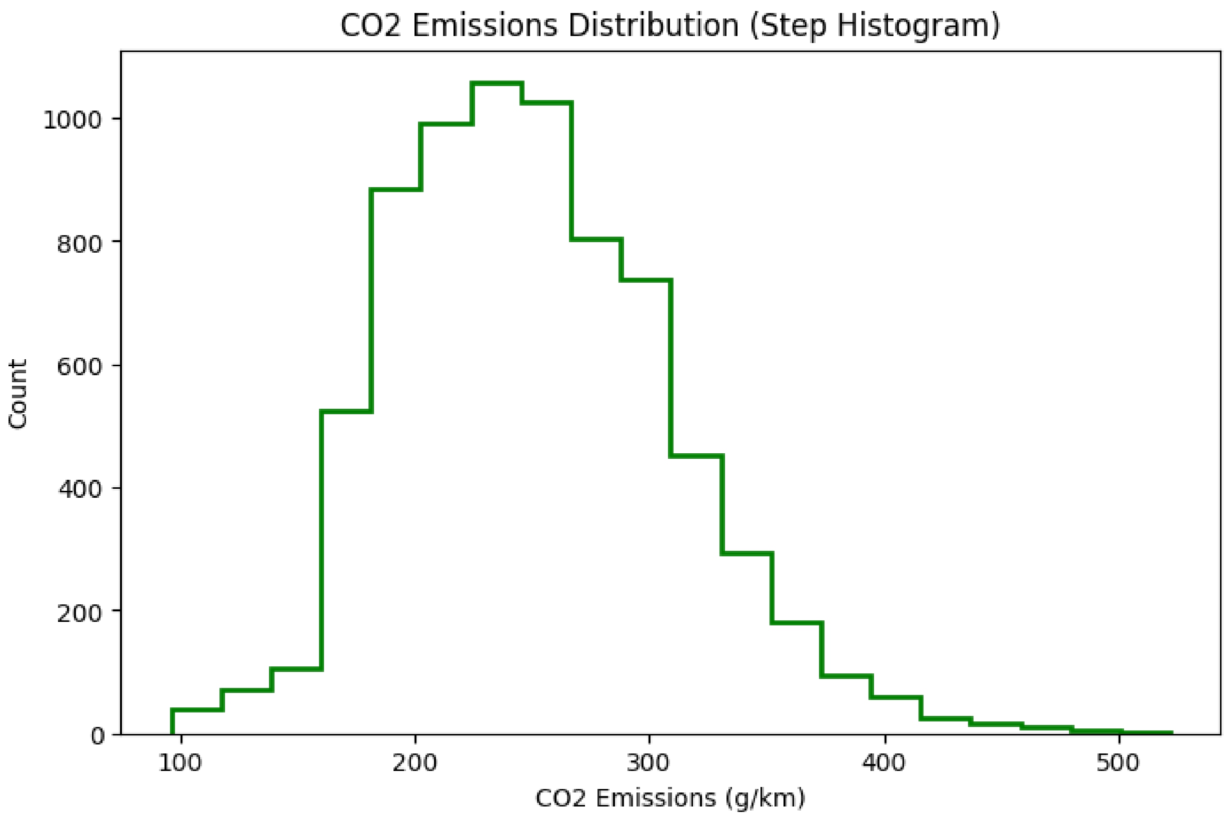
```
75%                          10.200000
12.600000
max                          20.600000
26.100000

       Fuel Consumption Comb (mpg)  CO2 Emissions(g/km)
count                  7385.000000          7385.000000
mean                     27.481652           250.584699
std                       7.231879            58.512679
min                      11.000000            96.000000
25%                      22.000000           208.000000
50%                      27.000000           246.000000
75%                      32.000000           288.000000
max                      69.000000           522.000000

#1.Distribution of CO2 Emissions
plt.figure(figsize=(8,5))
plt.hist(df['CO2 Emissions(g/km)'], bins=20, color="skyblue",
edgecolor="black")
plt.title("Distribution of CO2 Emissions")
plt.xlabel("CO2 Emissions (g/km)")
plt.ylabel("Count")
plt.show()
```



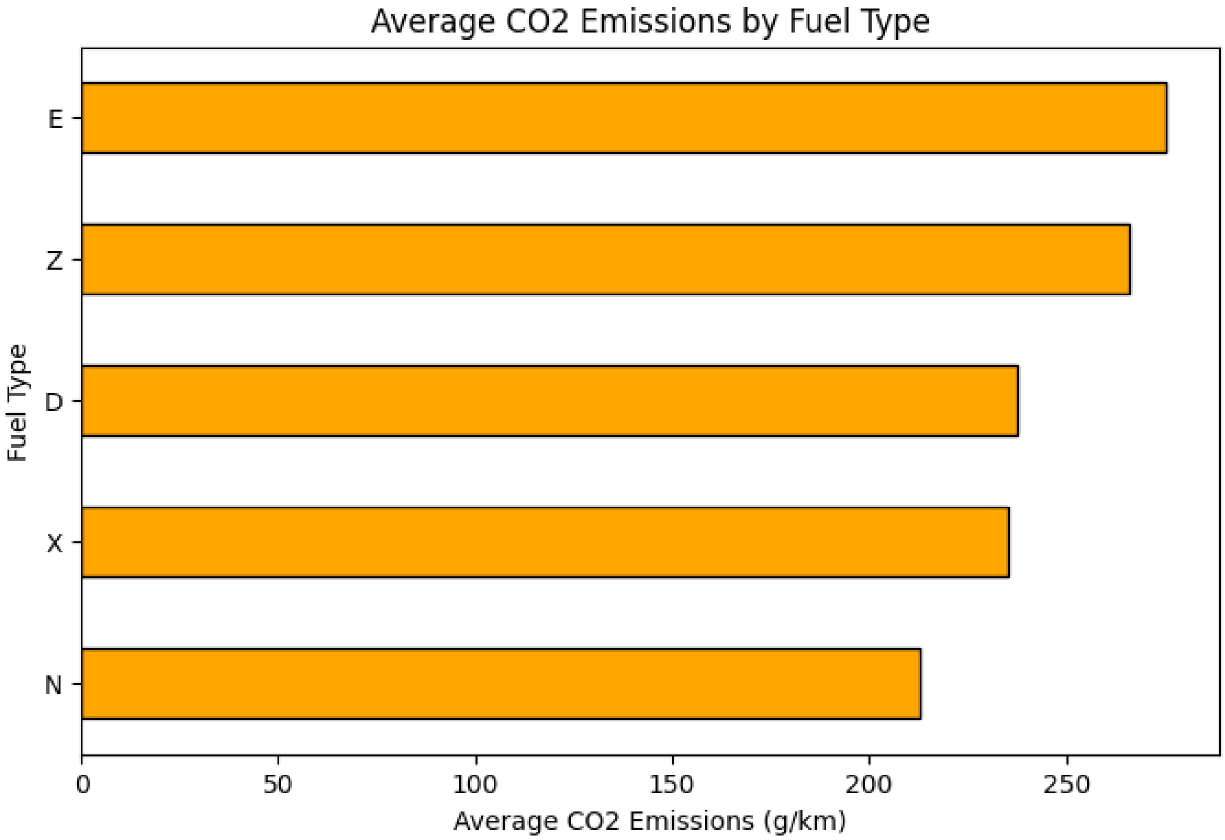
```python
#2. Fuel Consumption Distribution (City vs Highway)
plt.figure(figsize=(8,5))
plt.hist(df['Fuel Consumption City (L/100 km)'], bins=20, alpha=0.6,
label="City")
plt.hist(df['Fuel Consumption Hwy (L/100 km)'], bins=20, alpha=0.6,
label="Highway")
plt.title("Fuel Consumption Distribution")
plt.xlabel("Fuel Consumption (L/100 km)")
plt.ylabel("Count")
plt.legend()
plt.show()
```



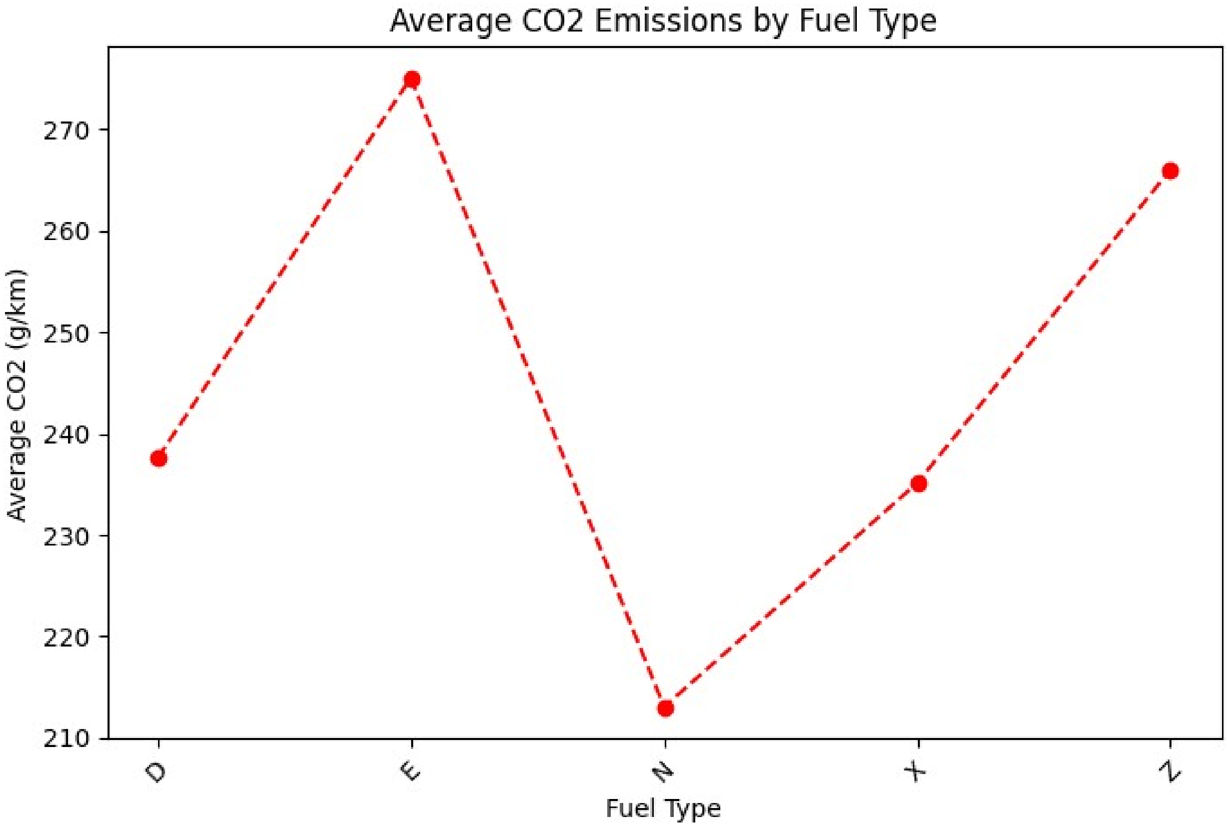
```python
#3.CO2 Emissions Distribution → Step Histogram
plt.figure(figsize=(8,5))
plt.hist(df['CO2 Emissions(g/km)'], bins=20, color="green",
histtype="step", linewidth=2)
plt.title("CO2 Emissions Distribution (Step Histogram)")
plt.xlabel("CO2 Emissions (g/km)")
plt.ylabel("Count")
plt.show()
```



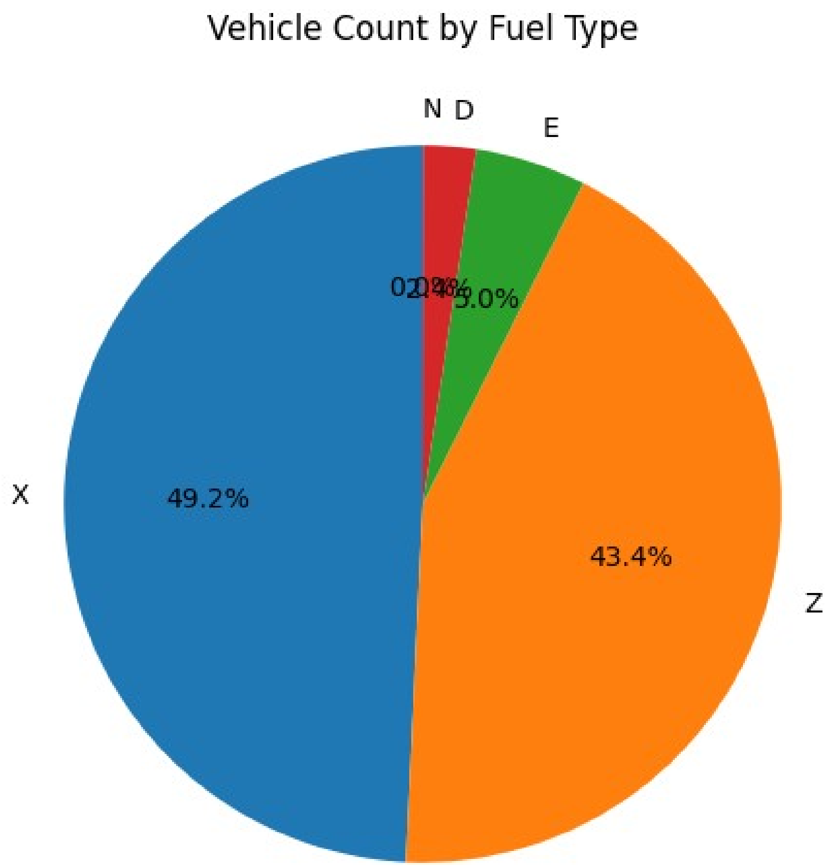
```
#4. Average CO2 Emissions by Fuel Type
avg_co2_fuel = df.groupby("Fuel Type")["CO2 Emissions(g/km)"].mean().sort_values()
plt.figure(figsize=(8,5))
avg_co2_fuel.plot(kind="barh", color="orange", edgecolor="black")
plt.title("Average CO2 Emissions by Fuel Type")
plt.xlabel("Average CO2 Emissions (g/km)")
plt.ylabel("Fuel Type")
plt.show()
```



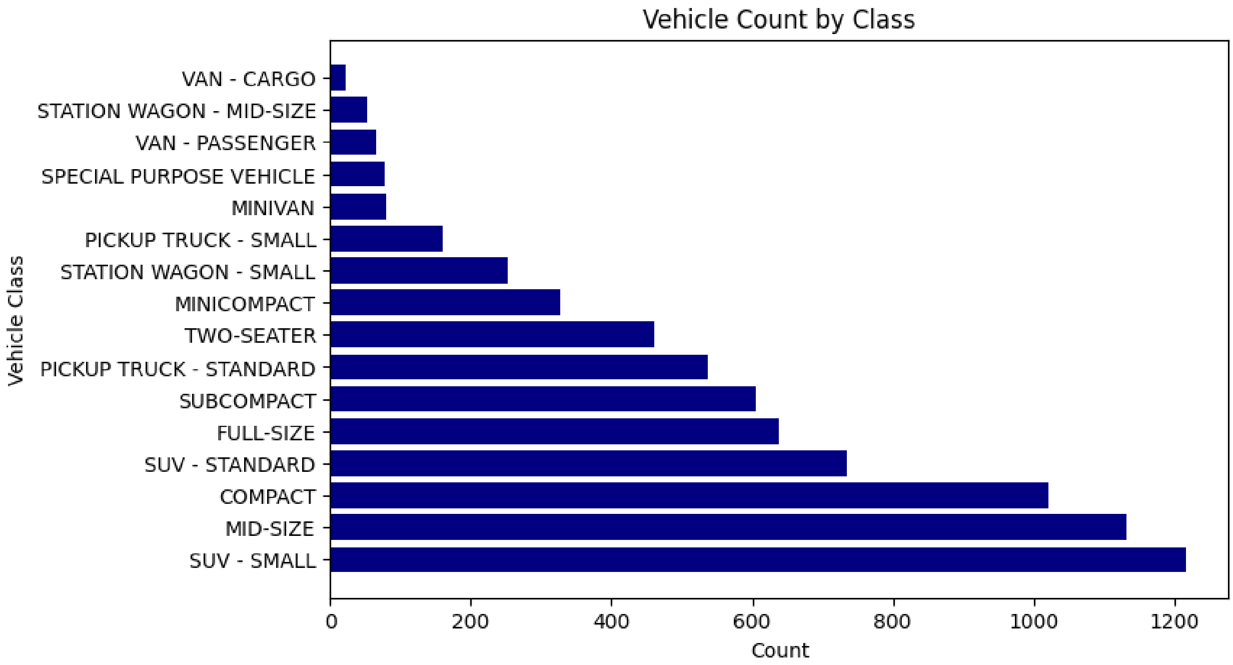
```
#5.Average CO2 Emissions by Fuel Type
avg_co2 = df.groupby("Fuel Type")["CO2 Emissions(g/km)"].mean()
plt.figure(figsize=(8,5))
plt.plot(avg_co2.index, avg_co2.values, marker="o", linestyle="--",
color="red")
plt.title("Average CO2 Emissions by Fuel Type")
plt.xlabel("Fuel Type")
plt.ylabel("Average CO2 (g/km)")
plt.xticks(rotation=45)
plt.show()
```



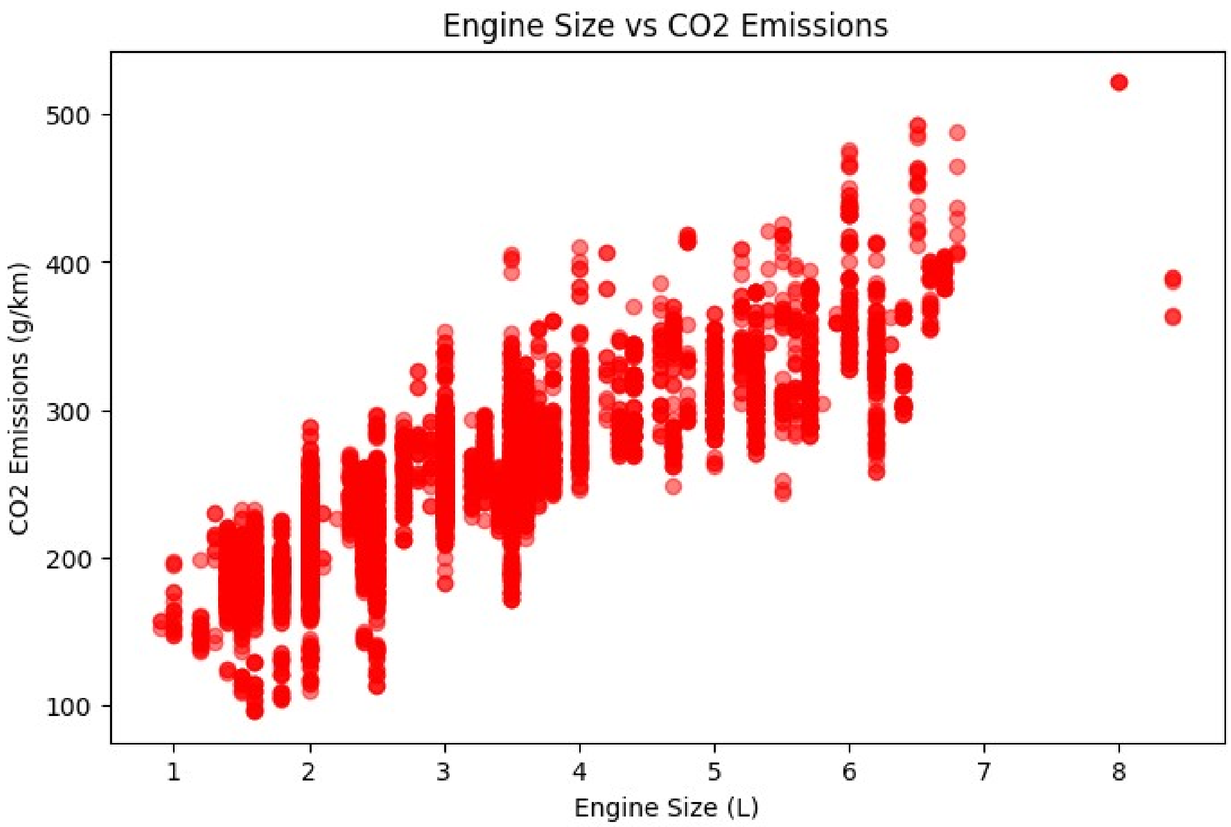
```
#6. Vehicle Count by Fuel Type
fuel_count = df["Fuel Type"].value_counts()
plt.figure(figsize=(6,6))
plt.pie(fuel_count, labels=fuel_count.index, autopct="%1.1f%%",
startangle=90)
plt.title("Vehicle Count by Fuel Type")
plt.show()
```



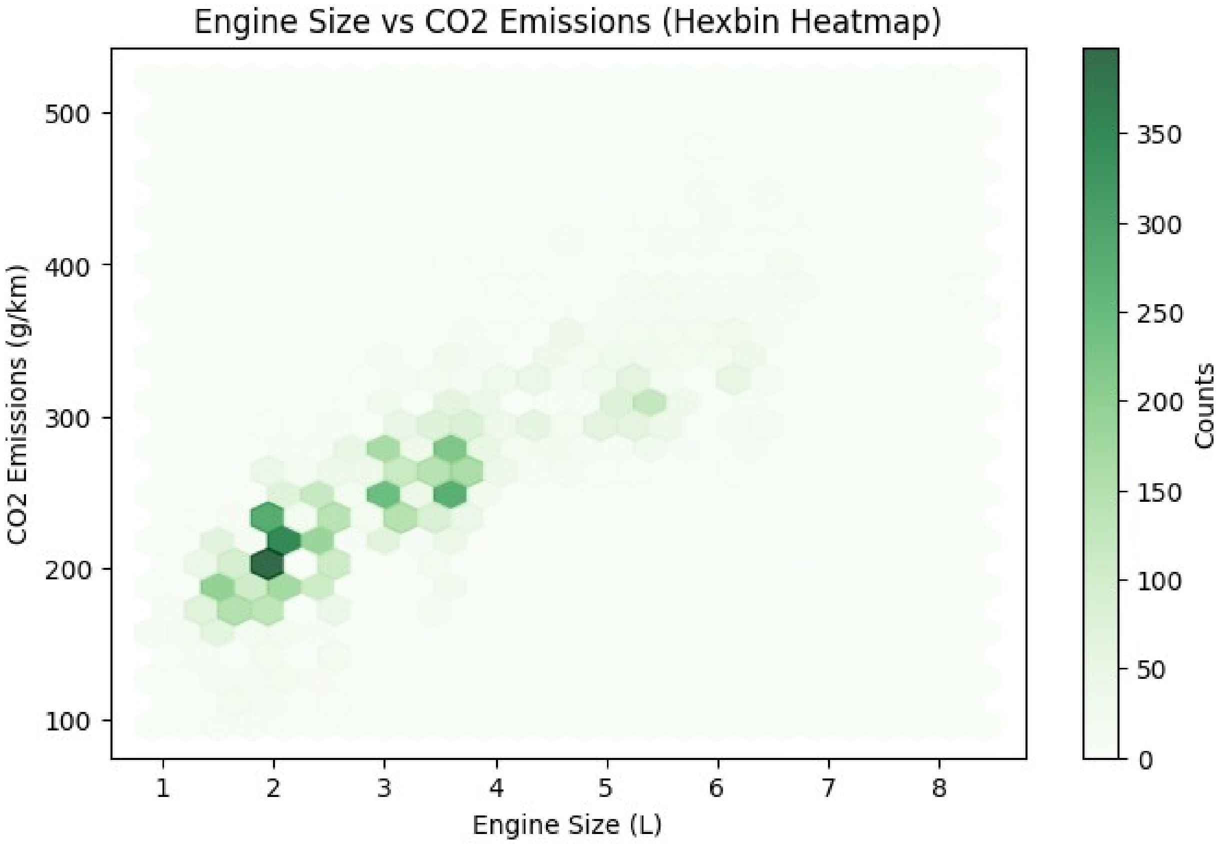
```
#7.Vehicle Count by Vehicle Class
class_count = df["Vehicle Class"].value_counts()
plt.figure(figsize=(8,5))
plt.barh(class_count.index, class_count.values, color="navy")
plt.title("Vehicle Count by Class")
plt.xlabel("Count")
plt.ylabel("Vehicle Class")
plt.show()
```



```
#8. Scatter Plot → Engine Size vs CO2 Emissions
plt.figure(figsize=(8,5))
plt.scatter(df['Engine Size(L)'], df['CO2 Emissions(g/km)'],
alpha=0.5, c='red')
plt.title("Engine Size vs CO2 Emissions")
plt.xlabel("Engine Size (L)")
plt.ylabel("CO2 Emissions (g/km)")
plt.show()
```

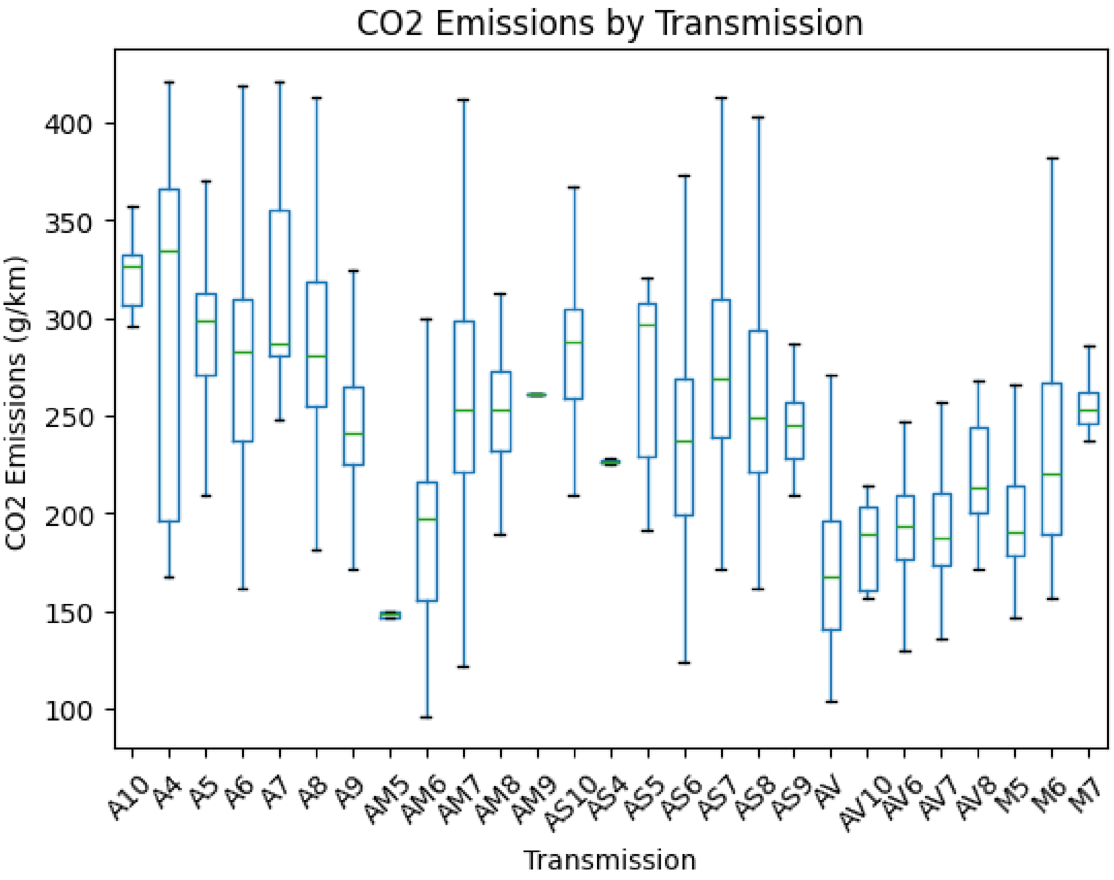


```
#9.Engine Size vs CO2 Emissions (Hexbin Heatmap)
plt.figure(figsize=(8,5))
plt.hexbin(df['Engine Size(L)'], df['CO2 Emissions(g/km)'],
gridsize=25, cmap="Greens", alpha=0.8)
plt.colorbar(label="Counts")
plt.title("Engine Size vs CO2 Emissions (Hexbin Heatmap)")
plt.xlabel("Engine Size (L)")
plt.ylabel("CO2 Emissions (g/km)")
plt.show()
```



```
#10. Boxplot → CO2 by Transmission
plt.figure(figsize=(10,6))
df.boxplot(column="CO2 Emissions(g/km)", by="Transmission",
grid=False, showfliers=False)
plt.title("CO2 Emissions by Transmission")
plt.suptitle("")
plt.xlabel("Transmission")
plt.ylabel("CO2 Emissions (g/km)")
plt.xticks(rotation=45)
plt.show()
```

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



```
from pyspark.sql import SparkSession
from pyspark.sql.functions import col, avg, min, max

# Start Spark session
spark =
SparkSession.builder.appName("CO2EmissionsCanada").getOrCreate()

# Load the dataset
df = spark.read.option("header", True).option("inferSchema",
True).csv("CO2 Emissions_Canada.csv")

#1. Total number of vehicles---------------------
print("Total number of vehicles:", df.count())

Total number of vehicles: 7385

#2. Total number of fuel types------------------
print("Total number of fuel types:", df.select("Fuel
Type").distinct().count())

Total number of fuel types: 5
```

```
#3. Fuel Type Names----------------------------
print("Fuel Types:")
df.select("Fuel Type").distinct().show()
```

```
Fuel Types:
+---------+
|Fuel Type|
+---------+
|        E|
|        D|
|        Z|
|        N|
|        X|
+---------+
```

```
#4. Total number of vehicles by fuel type----------
print("Vehicles by Fuel Type:")
df.groupBy("Fuel Type").count().show()
```

```
Vehicles by Fuel Type:
+---------+-----+
|Fuel Type|count|
+---------+-----+
|        E|  370|
|        D|  175|
|        Z| 3202|
|        N|    1|
|        X| 3637|
+---------+-----+
```

```
#5. Total number of vehicles by vehicle class-------
print("Vehicles by Vehicle Class:")
df.groupBy("Vehicle Class").count().show()
```

```
Vehicles by Vehicle Class:
+--------------------+-----+
|       Vehicle Class|count|
+--------------------+-----+
|         MINICOMPACT|  326|
|SPECIAL PURPOSE V...|   77|
|             COMPACT| 1022|
|         VAN - CARGO|   22|
|      SUV - STANDARD|  735|
|         SUV - SMALL| 1217|
|PICKUP TRUCK - ST...|  538|
|STATION WAGON - M...|   53|
|          TWO-SEATER|  460|
|          SUBCOMPACT|  606|
|            MID-SIZE| 1133|
|PICKUP TRUCK - SMALL|  159|
|           FULL-SIZE|  639|
|STATION WAGON - S...|  252|
|             MINIVAN|   80|
|     VAN - PASSENGER|   66|
+--------------------+-----+
```

```
#6. Vehicles grouped by Fuel Type & Transmission----
print("Vehicles by Fuel Type and Transmission:")
df.groupBy("Fuel Type", "Transmission").count().show()
```

```
Vehicles by Fuel Type and Transmission:
+---------+------------+-----+
|Fuel Type|Transmission|count|
+---------+------------+-----+
|        Z|         AV6|    9|
|        D|         AM6|    6|
|        X|          A5|   76|
|        X|        AV10|    4|
|        Z|          A6|   55|
|        E|         AS8|   18|
|        Z|         AS5|    4|
|        X|          A8|  234|
|        Z|          M6|  465|
|        D|        AS10|   14|
|        X|         AS9|   24|
|        Z|         AS9|   53|
|        Z|         AS8|  946|
|        Z|         AM8|   62|
|        Z|          A7|   53|
|        Z|          AV|    6|
|        X|         AS5|   22|
|        D|          A6|   36|
|        E|          A6|  166|
|        Z|         AV7|   30|
+---------+------------+-----+
only showing top 20 rows
```

```
#7. Min and Max CO2 emissions per vehicle class----
print("Minimum and maximum CO2 emissions in each vehicle class:")
df.groupBy("Vehicle Class").agg(
    min("CO2 Emissions(g/km)").alias("min_co2"),
    max("CO2 Emissions(g/km)").alias("max_co2")
).show()
```

```
Minimum and maximum CO2 emissions in each vehicle class:
+--------------------+-------+-------+
|       Vehicle Class|min_co2|max_co2|
+--------------------+-------+-------+
|         MINICOMPACT|    143|    365|
|SPECIAL PURPOSE V...|    208|    298|
|             COMPACT|    106|    404|
|         VAN - CARGO|    334|    396|
|      SUV - STANDARD|    156|    476|
|         SUV - SMALL|    128|    353|
|PICKUP TRUCK - ST...|    238|    414|
|STATION WAGON - M...|    126|    386|
|          TWO-SEATER|    145|    522|
|          SUBCOMPACT|    152|    392|
|            MID-SIZE|    104|    465|
|PICKUP TRUCK - SMALL|    235|    331|
|           FULL-SIZE|     96|    404|
|STATION WAGON - S...|    110|    382|
|             MINIVAN|    221|    296|
|     VAN - PASSENGER|    315|    488|
+--------------------+-------+-------+
```

```
#8. Vehicles with CO2 > average----------
avg_co2_val = df.agg(avg("CO2
Emissions(g/km)").alias("avg_co2")).collect()[0]["avg_co2"]

print("Vehicles with CO2 Emissions greater than average:")
df.filter(col("CO2 Emissions(g/km)") > avg_co2_val) \
  .select("Make", "Model", "Fuel Type", "CO2 Emissions(g/km)") \
  .show(20, truncate=False)
```

```
Vehicles with CO2 Emissions greater than average:
+------------+-----------------+---------+-------------------+
|Make        |Model            |Fuel Type|CO2 Emissions(g/km)|
+------------+-----------------+---------+-------------------+
|ACURA       |MDX 4WD          |Z        |255                |
|ACURA       |TL AWD           |Z        |255                |
|ACURA       |TL AWD           |Z        |267                |
|ASTON MARTIN|DB9              |Z        |359                |
|ASTON MARTIN|RAPIDE           |Z        |359                |
|ASTON MARTIN|V8 VANTAGE       |Z        |338                |
|ASTON MARTIN|V8 VANTAGE       |Z        |354                |
|ASTON MARTIN|V8 VANTAGE S     |Z        |338                |
|ASTON MARTIN|V8 VANTAGE S     |Z        |354                |
|ASTON MARTIN|VANQUISH         |Z        |359                |
|AUDI        |A6 QUATTRO       |Z        |251                |
|AUDI        |A7 QUATTRO       |Z        |262                |
|AUDI        |A8               |Z        |258                |
|AUDI        |A8               |Z        |265                |
|AUDI        |A8L              |Z        |258                |
|AUDI        |A8L              |Z        |288                |
|AUDI        |A8L              |Z        |363                |
|AUDI        |Q5               |Z        |258                |
|AUDI        |Q7               |Z        |304                |
|AUDI        |Q7 TDI (modified)|D        |290                |
+------------+-----------------+---------+-------------------+
only showing top 20 rows
```

```
#9. Increase CO2 by +10 for vehicles with Engine Size > 5.0L---
df_updated = df.withColumn("CO2 Emissions(g/km)",
                           col("CO2 Emissions(g/km)") +
                           (10 * (col("Engine Size(L)") >
5.0).cast("int")))

print("Updated CO2 values for vehicles with Engine Size > 5.0L:")
df_updated.filter(col("Engine Size(L)") > 5.0).select("Make", "Engine
Size(L)", "CO2 Emissions(g/km)").show(20, truncate=False)
```

```
Updated CO2 values for vehicles with Engine Size > 5.0L:
+------------+--------------+-------------------+
|Make        |Engine Size(L)|CO2 Emissions(g/km)|
+------------+--------------+-------------------+
|ASTON MARTIN|5.9           |369                |
|ASTON MARTIN|5.9           |369                |
|ASTON MARTIN|5.9           |369                |
|AUDI        |6.3           |373                |
|AUDI        |5.2           |357                |
|AUDI        |5.2           |419                |
|AUDI        |5.2           |357                |
|AUDI        |5.2           |419                |
|BENTLEY     |6.0           |366                |
|BENTLEY     |6.0           |390                |
|BENTLEY     |6.0           |390                |
|BENTLEY     |6.0           |398                |
|BENTLEY     |6.8           |447                |
|BMW         |6.0           |366                |
|CADILLAC    |6.2           |392                |
|CADILLAC    |6.2           |350                |
|CADILLAC    |6.2           |392                |
|CADILLAC    |6.2           |350                |
|CADILLAC    |6.2           |392                |
|CADILLAC    |6.2           |350                |
+------------+--------------+-------------------+
only showing top 20 rows
```

```
#10. Save vehicles with CO2 > 300 into CSV----------
import os, shutil

# Change paths to your location
output_dir = r"C:\Users\sathw\High_CO2_Vehicles_temp"
```

```python
final_file = r"C:\Users\sathw\High_CO2_Vehicles.csv"

high_co2_df = df.filter(col("CO2 Emissions(g/km)") > 300)

try:
    # Write Spark output to temp folder
    high_co2_df.coalesce(1) \
        .write.option("header", True) \
        .mode("overwrite") \
        .csv(output_dir)

    # Find the part file Spark created
    for file in os.listdir(output_dir):
        if file.startswith("part-") and file.endswith(".csv"):
            part_file = os.path.join(output_dir, file)
            # Move and rename to desired file
            shutil.move(part_file, final_file)
            break

    # Clean up temp directory
    shutil.rmtree(output_dir)

    print(f"□ Saved vehicles with CO2 > 300 into: {final_file}")

except Exception as e:
    print("⚠ Spark CSV write failed, using Pandas fallback...", e)
    high_co2_df.toPandas().to_csv(final_file, index=False)
    print("□ Saved vehicles with CO2 > 300 using Pandas fallback.")
```

```
□ Saved vehicles with CO2 > 300 into: C:\Users\sathw\
High_CO2_Vehicles.csv
```

Conclusion

--Overall, the dataset portrays a diverse Canadian automotive market with a wide mix of vehicles across size, power, and efficiency. The absence of missing data makes this dataset reliable for environmental policy analysis, automotive research, and predictive modeling of emissions. It highlights key industry trends: strong SUV and pickup representation, dominance of gasoline fuel types, and the growing presence of fuel-efficient models.