assignment_1

April 8, 2024

Data Mining and Machine Learning - Assignment 1

1 Question 1 - NOx Study

Modelling of $LNOx$ concentration as function of other variables

[8]:
```
# Import of used libraries
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
import scipy.stats as stats
import statsmodels.api as sm
```

[9]:
```
# Import of the dataset
q1_pd = pd.read_csv('NOxEmissions.csv')
q1_pd
```

[9]:

	rownames	julday	LNOx	LNOxEm	sqrtWS
0	193	373	4.457250	5.536489	0.856446
1	194	373	4.151827	5.513000	1.016612
2	195	373	3.834061	4.886994	1.095445
3	196	373	4.172848	5.138912	1.354068
4	197	373	4.322807	5.666518	1.204159
…	…	…	…	…	…
8083	8779	730	5.000585	6.730993	1.396424
8084	8780	730	4.669552	6.165086	1.466288
8085	8781	730	4.380776	5.855493	1.559808
8086	8782	730	4.284276	5.691445	1.449138
8087	8783	730	4.143928	5.505866	1.466288

[8088 rows x 5 columns]

1.1 (a) - Data Pre-processing

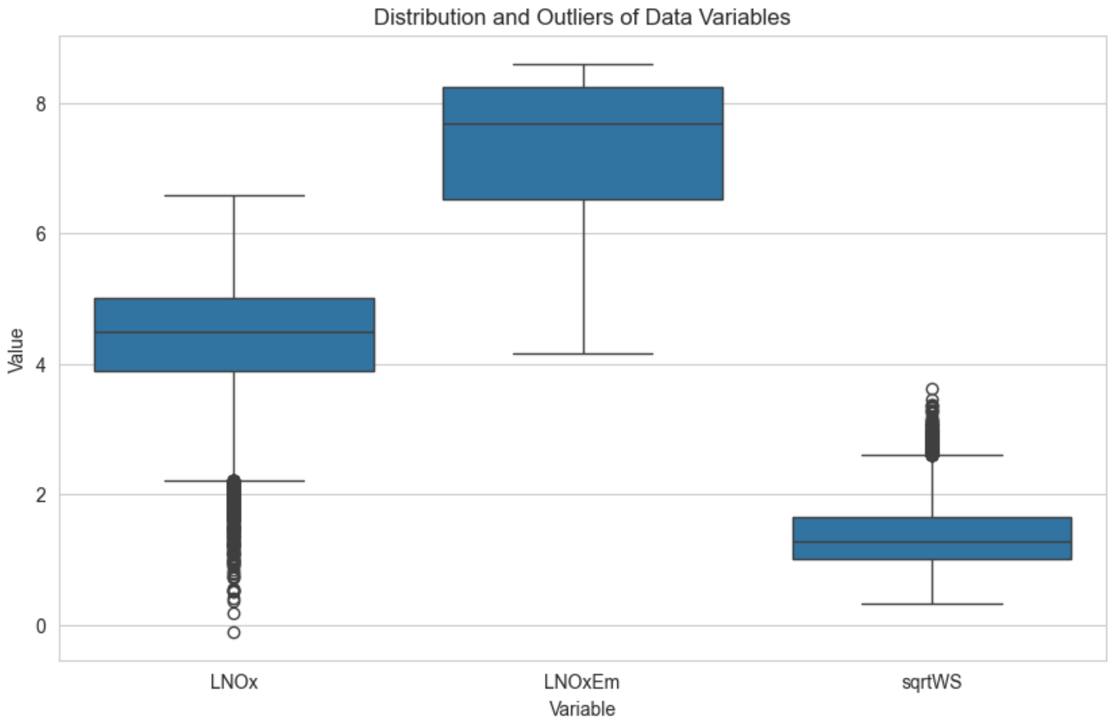
In the pre-processing we want to address data quality problems like Incorrect Data, Missing Values, duplicate data, outliers…

- **Missing data:** No missing data found in the dataset
- **Duplicates:** No duplicates were found.

[10]:
```python
# (a) - Pre-processing

# Check if missing/duplicated/Invalid data is present in the dataset

## Missing data
print(f"Number of missing data: {q1_pd.isnull().sum().sum()}")
## Duplicated data
print(f"Number of duplicated data: {q1_pd.duplicated().sum()}")

## Statistical Summary
print(f"===Statistical Summary===\n{q1_pd.describe()}")
```

```
Number of missing data: 0
Number of duplicated data: 0
===Statistical Summary===
          rownames       julday         LNOx       LNOxEm       sqrtWS
count  8088.000000  8088.000000  8088.000000  8088.000000  8088.000000
mean   4597.584570   556.078882     4.378691     7.338244     1.365253
std    2464.686179   102.706509     0.937389     1.016658     0.466280
min     193.000000   373.000000    -0.105361     4.157866     0.316228
25%    2507.750000   469.000000     3.891820     6.514982     1.016612
50%    4681.500000   560.000000     4.497028     7.692495     1.284523
75%    6709.250000   644.000000     5.012134     8.239159     1.648181
max    8783.000000   730.000000     6.576121     8.600040     3.624017
```

[11]:
```python
# Check for outliers

melted_data = pd.melt(q1_pd, value_vars=['LNOx', 'LNOxEm', 'sqrtWS'],␣
 ↪var_name='Variable', value_name='Value')
sns.set_style("whitegrid")

plt.figure(figsize=(10, 6))
boxplot = sns.boxplot(x='Variable', y='Value', data=melted_data)
boxplot.set_title('Distribution and Outliers of Data Variables')
boxplot.set_ylabel('Value')
boxplot.set_xlabel('Variable')

plt.show()
```



1.2 (b) - Distribution of LNOx variable

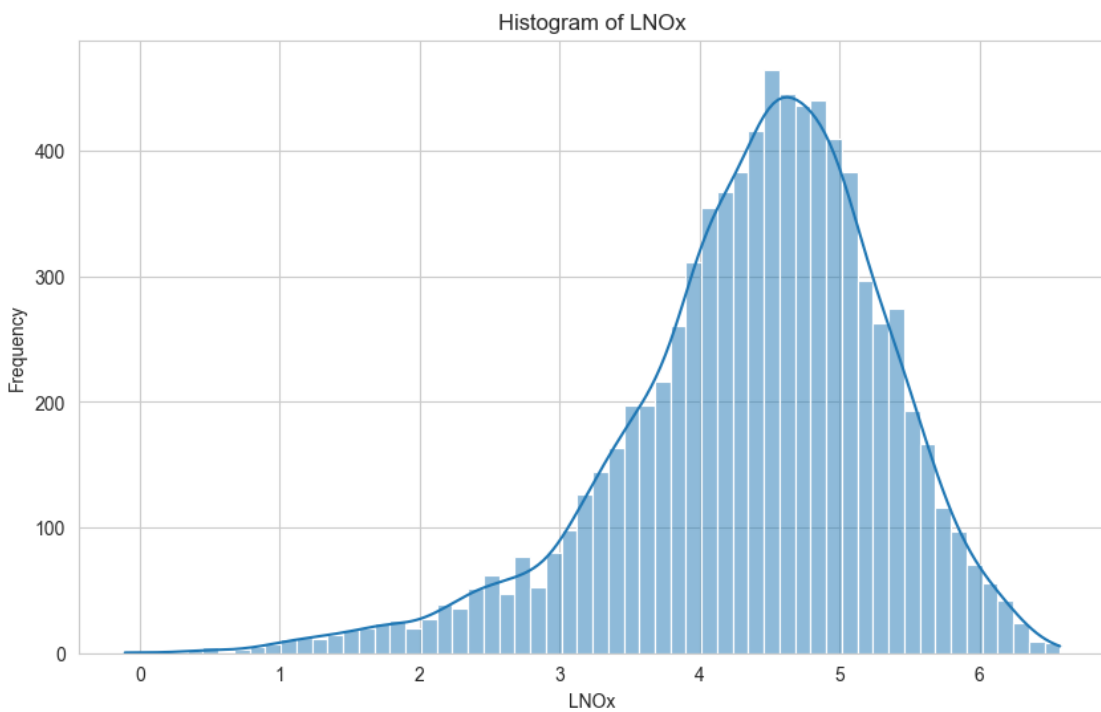
To describe the distribution of the *LNOx* variable we are going to use descriptive statistics indicators along with diagrams for visualization.

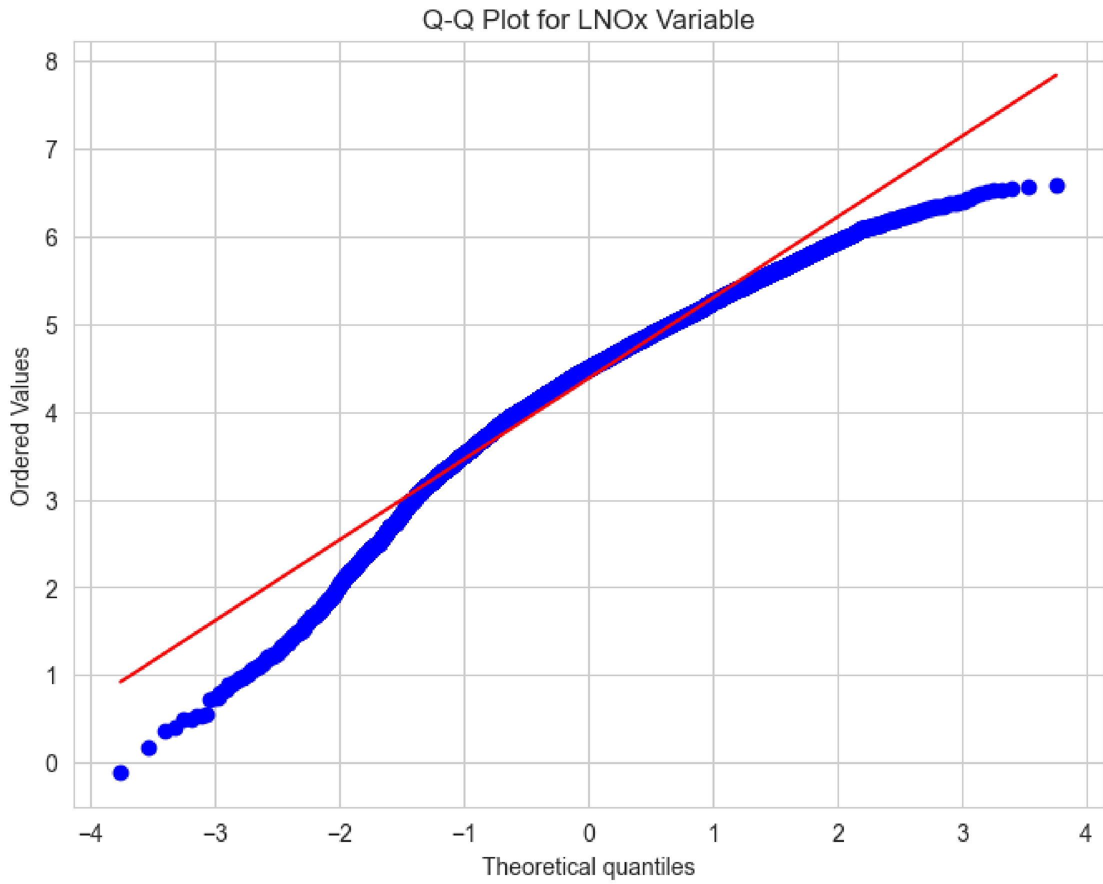
LNOx appears to have a normal distribution with a significant number of outliers on the left side (as shown by the previous box-plot. Also a left (negative) skew is evident in the graph and by using the descriptive statistics.

[12]:
```python
# (b) - LNOx distribution

lnox = q1_pd['LNOx']

## Descriptive Stats
range_lnox = lnox.max() - lnox.min()
print(f"Mean: {lnox.mean()}\nMedian: {lnox.median()}\nStandard Deviation: {lnox.
↪std()}\nVariance: {lnox.var()}\nRange: {range_lnox}\nSkewness: {lnox.
↪skew()}\nKurtosis: {lnox.kurt()}")

## Histogram plot
plt.figure(figsize=(10, 6))
sns.histplot(q1_pd['LNOx'], kde=True)
plt.title('Histogram of LNOx')
plt.xlabel('LNOx')
```

```
plt.ylabel('Frequency')
plt.show()

# Q-Q plot
fig = plt.figure(figsize=(8, 6))
ax = fig.add_subplot(111)
stats.probplot(q1_pd['LNOx'], dist="norm", plot=ax)
ax.set_title("Q-Q Plot for LNOx Variable")
plt.show()
```

```
Mean: 4.378690810185019
Median: 4.49702802736839
Standard Deviation: 0.9373885825025527
Variance: 0.8786973546060968
Range: 6.681481834658996
Skewness: -0.8244320335510329
Kurtosis: 1.1307787937580986
```





1.3 (c) - Linear Model of LNOx as fn. of LNOxEm, sqrtWS

The $LNOx$ linear model is fitted below using a multiple linear regression, $LNOx$ is the dependent variable, $LNOxEm$ and $sqrtWS$ are the independent variables as requested by the question.

The OLS-regression results from the model shows that:

- $R^2 = 0.663$, that means that the independent variables can explain about 66% of variability of $LNOx$.
- The coefficients of the independent variables explains:
  - $LNOxEm$: When this variables increase, $LNOx$ **increases** too by a factor of ≈ 0.06.
  - $sqrtWS$: When the square root of wind speed increases, $LNOx$ get **decreased** by a factor of ≈ 1.01

[13]:
```
# (c) - LNOx linear model

X = q1_pd[['LNOxEm', 'sqrtWS']]
X = sm.add_constant(X)
y = q1_pd['LNOx']
model = sm.OLS(y, X).fit()
```

```python
# Print model summary
model.summary()
```

[13]:

Dep. Variable:	LNOx	**R-squared:**	0.663
Model:	OLS	**Adj. R-squared:**	0.663
Method:	Least Squares	**F-statistic:**	7952.
Date:	Mon, 08 Apr 2024	**Prob (F-statistic):**	0.00
Time:	17:54:09	**Log-Likelihood:**	-6554.7
No. Observations:	8088	**AIC:**	1.312e+04
Df Residuals:	8085	**BIC:**	1.314e+04
Df Model:	2		
Covariance Type:	nonrobust		

	coef	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**
const	1.0619	0.046	23.097	0.000	0.972	1.152
LNOxEm	0.6414	0.006	107.092	0.000	0.630	0.653
sqrtWS	-1.0182	0.013	-77.969	0.000	-1.044	-0.993

Omnibus:	28.937	**Durbin-Watson:**	0.497
Prob(Omnibus):	0.000	**Jarque-Bera (JB):**	30.943
Skew:	-0.115	**Prob(JB):**	1.91e-07
Kurtosis:	3.198	**Cond. No.**	58.3

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.

1.4 (d) - Relationship between dependent and independent variables

In the Linear Regression model created above, we analyzed how the concentration of nitrogen close to a motorway ($LNOx$, the dependent variable) is influenced by:

- The emission of NOx of cars on the motorway ($LNOxEm$)
- The square root of wind speed ($sqrtWS$)

The results of the model shows that both (independent) variables are significant in determining the concentration of NOx. An increase of the wind speed ($sqrtWS$) tends to lower the concentration of NOx, probably because it would disperse the NOx present in the air. On the other hand $LNOxEm$ has a positive impact on the concentration of NOx, this probably means that when the volume of emissions of car in the motorway increases so does the NOx concentration close the motorway. However, this affects the concentration of nitrogen less than the wind does.

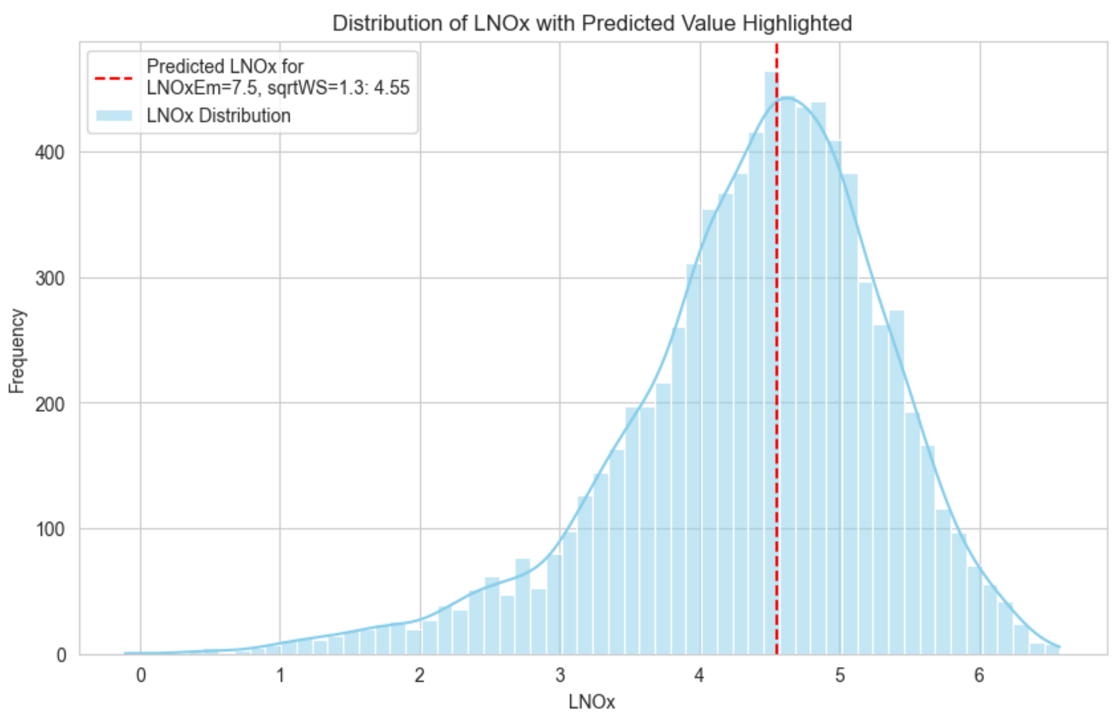
1.5 (e) - Prediction of LNOx given the indp. variables values.

Given the value of the emission of cars in the motorway ($LNOxEm = 7.5$) and wind speed ($sqrtWS = 1.3$) the estimated value for the concentration of pollution close to the motorway is $LNOx \approx 4.55$. This means that given the amount of pollution the cars are making (7.5) and how fast the wind is blowing (1.3) the air pollution is expected to be around 4.55.

By consulting the data available the prediction in close to the average concentration of pollution, suggesting that the prediction is within reasonable ranges.

[20]:
```
# (e) - prediction using pre-defined values

# LNOxEm = 7.5, sqrtWS = 1.3
new_data = pd.DataFrame({'const': 1, 'LNOxEm': [7.5], 'sqrtWS': [1.3]})
predicted_LNOx = model.predict(new_data)

print(f"The predicted LNOx value is: {predicted_LNOx[0]:.2f}")

# Visualization
plt.figure(figsize=(10, 6))
sns.histplot(q1_pd['LNOx'], kde=True, color="skyblue", label='LNOx␣
↪Distribution')
plt.axvline(x=predicted_LNOx[0], color='red', linestyle='--', label=f'Predicted␣
↪LNOx for\nLNOxEm=7.5, sqrtWS=1.3: {predicted_LNOx.iloc[0]:.2f}')
plt.legend()
plt.title('Distribution of LNOx with Predicted Value Highlighted')
plt.xlabel('LNOx')
plt.ylabel('Frequency')
plt.show()
```

```
The predicted LNOx value is: 4.55
```



2 Question 2 - Airbag study