Benzene Emissions at Asphalt Plants: A Statistical Analysis Based on a Dutch Case Study

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Introduction

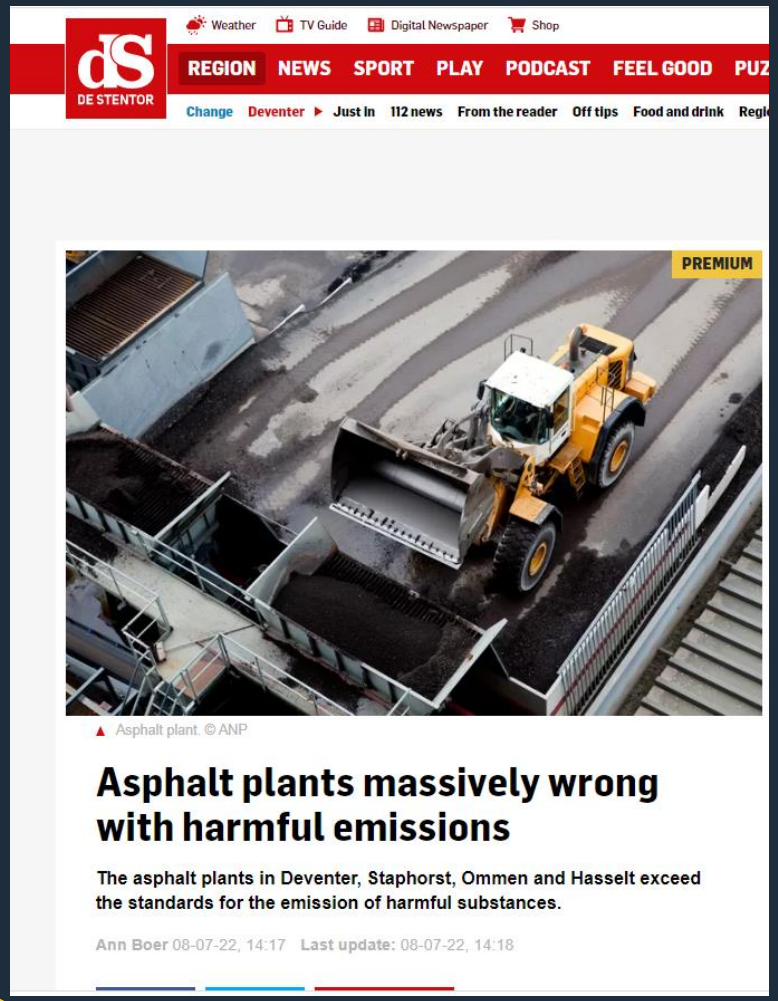
- Dutch sustainability ambitions:
  - Reduce GHGs emissions by 49% by 2030
  - Reduce GHGs emissions by 95% by 2050
  - Reduce primary material use by 50% by 2030

- The use of reclaimed asphalt (RA) is new asphalt mixtures is key for the asphalt paving sector to help achieving these targets

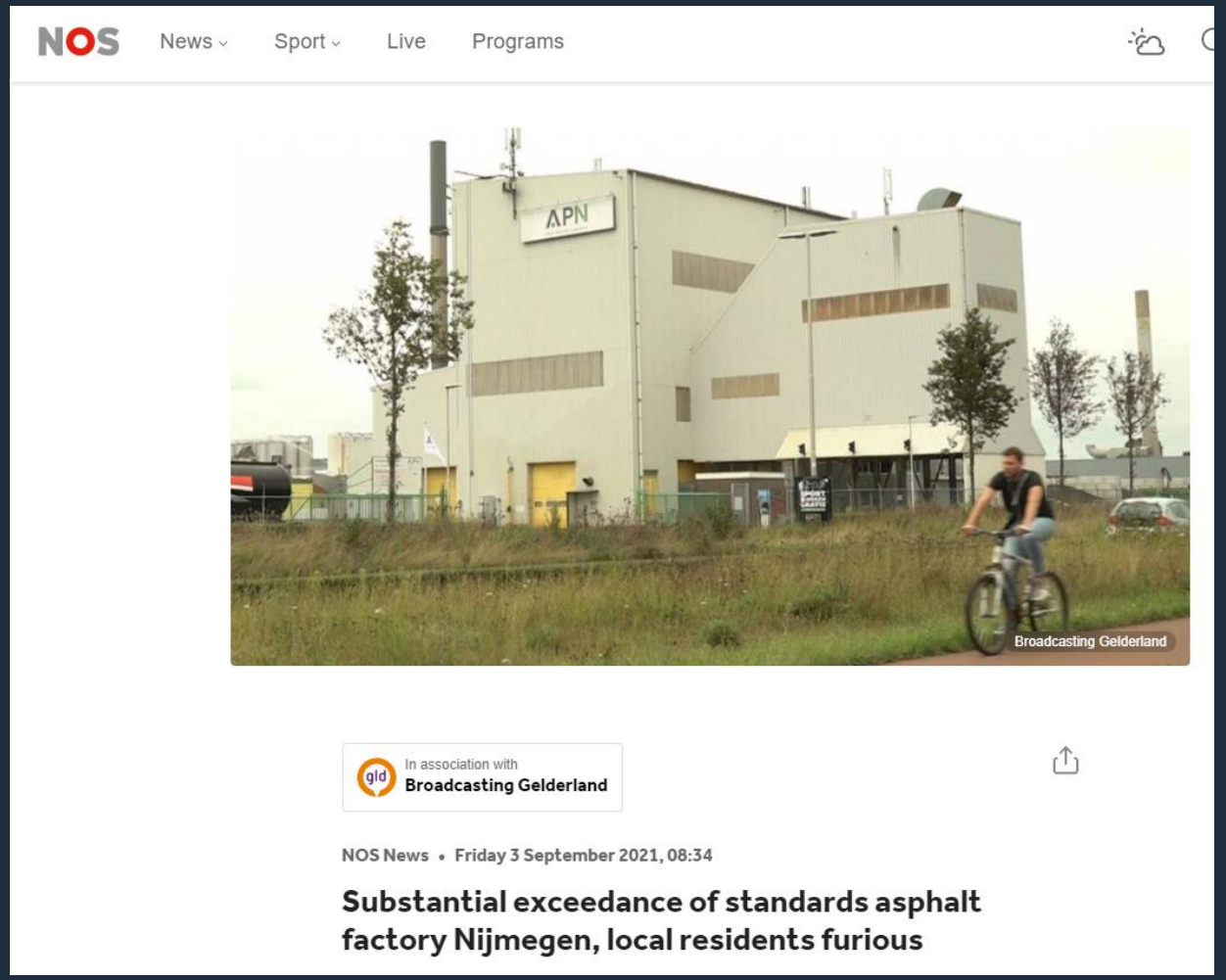
Motivation

- Mounting concerns have emerged regarding the potential effects of asphalt materials (e.g., RA) on air quality and human health during asphalt mixtures production
- The use of RA in asphalt mixtures has been associated with high levels of Benzene emissions at asphalt plants

Motivation



Source: https://www.destentor.nl/deventer/asfaltcentrales-massaal-in-de-fout-met-uitstoot-schadelijke-stoffen~ae6a6f9c/



Source: https://nos.nl/artikel/2396289-forse-normoverschrijding-asfaltfabriek-nijmegen-omwonenden-woest

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Motivation

- Mounting concerns have emerged regarding the potential effects of asphalt materials (e.g., RA) on air quality and human health during asphalt mixtures production
- The use of RA in asphalt mixtures has been associated with high levels of Benzene emissions at asphalt plants
- Increasingly lower Benzene emission limit values (from 5 to 2.5 to 1 milligram/m^3);

Research Gap and Objective

- **Gap**: Existing research on the relation between Benzene emissions and asphalt mixtures production is limited to *laboratory-scale methods and measurements*

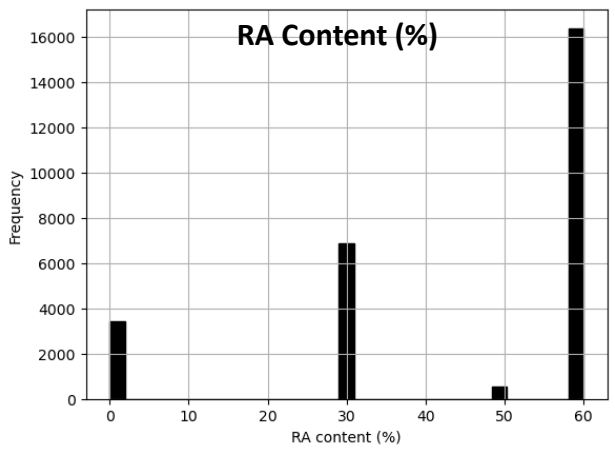
- **Limitations**: Not representative of real-world conditions of industrial facilities

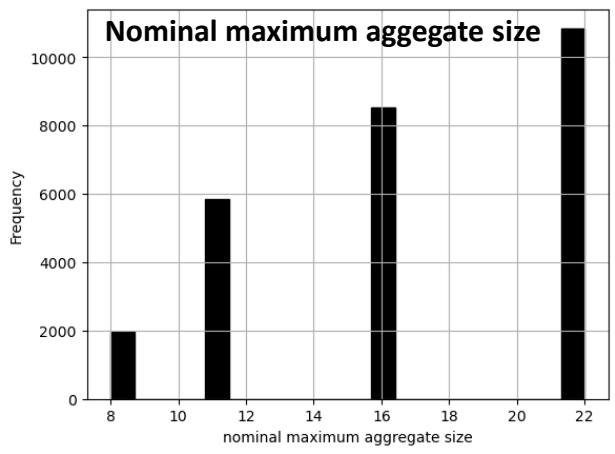
Research Objective: To understand how the RA content, asphalt mixtures production conditions and weather condition is related to benzene emissions based on measurements performed during the operation of a Dutch asphalt plant.

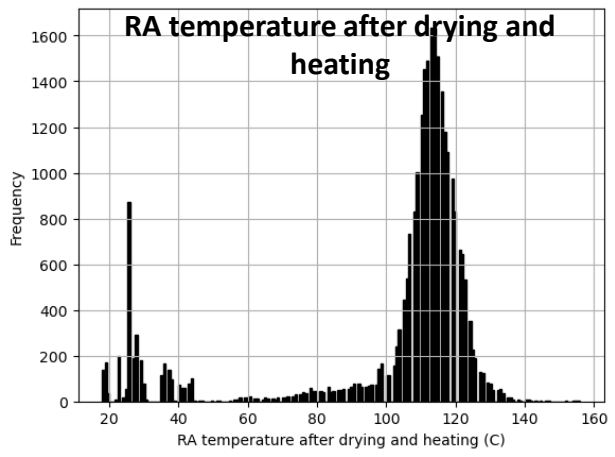
Case study description

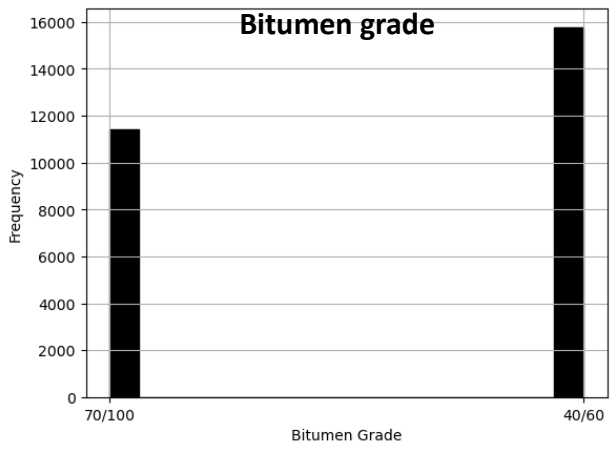
- Semi-continuous asphalt plant with parallel black (RA) and white (virgin minerals) drums
  - Energy source: natural gas
- Asphalt mixtures production period: May 2022 – December 2022
  - Data of 32 operation days
  - 19 asphalt mixtures:
    - 5 types: AC 22, AC 16, AC 11, SMA 11 and SMA 8;
    - 12 surface layers and 7 base/binder layers
- Emission data:
  - 15 seconds interval benzene measurements (total 27,206 data points)
  - Measurement device:
    - Ion Science Titan benzene measuring device installed at the plant chimney
    - Employs photoionization detection (PID) sensor technology using UV light

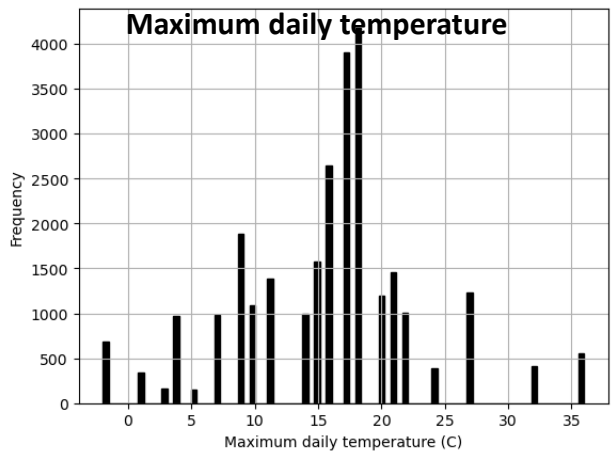
Case study description

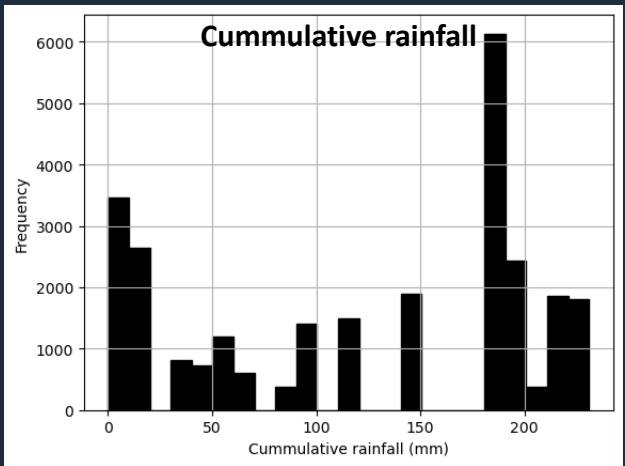












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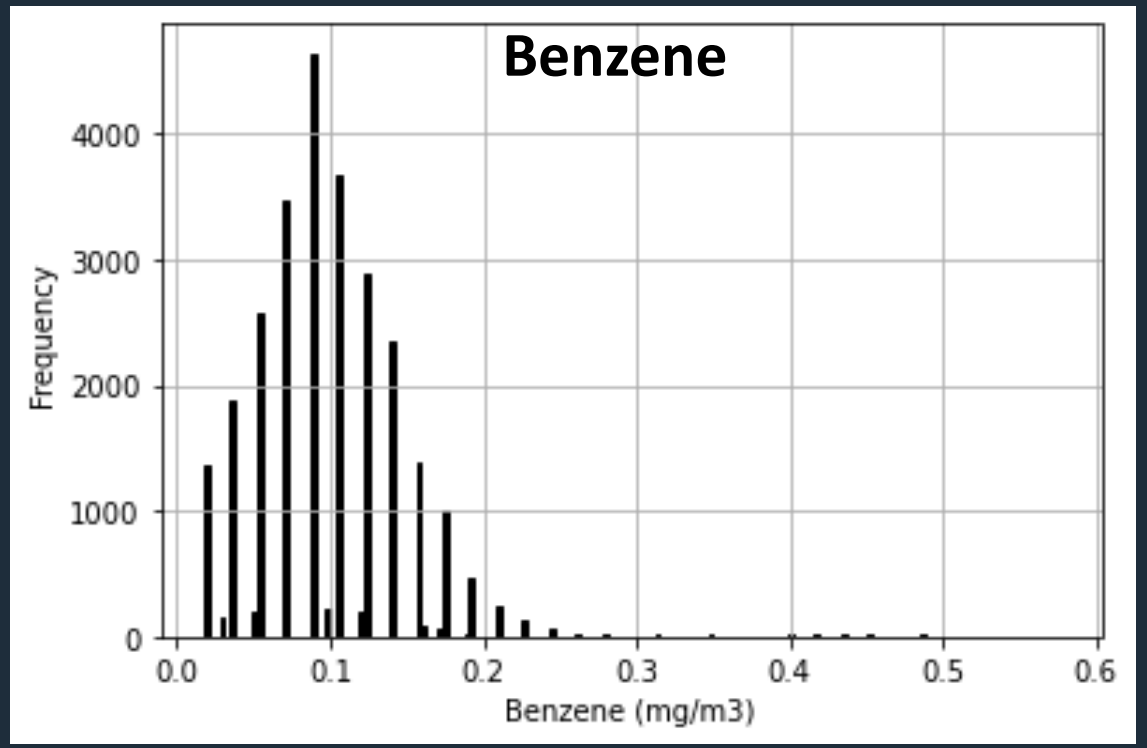

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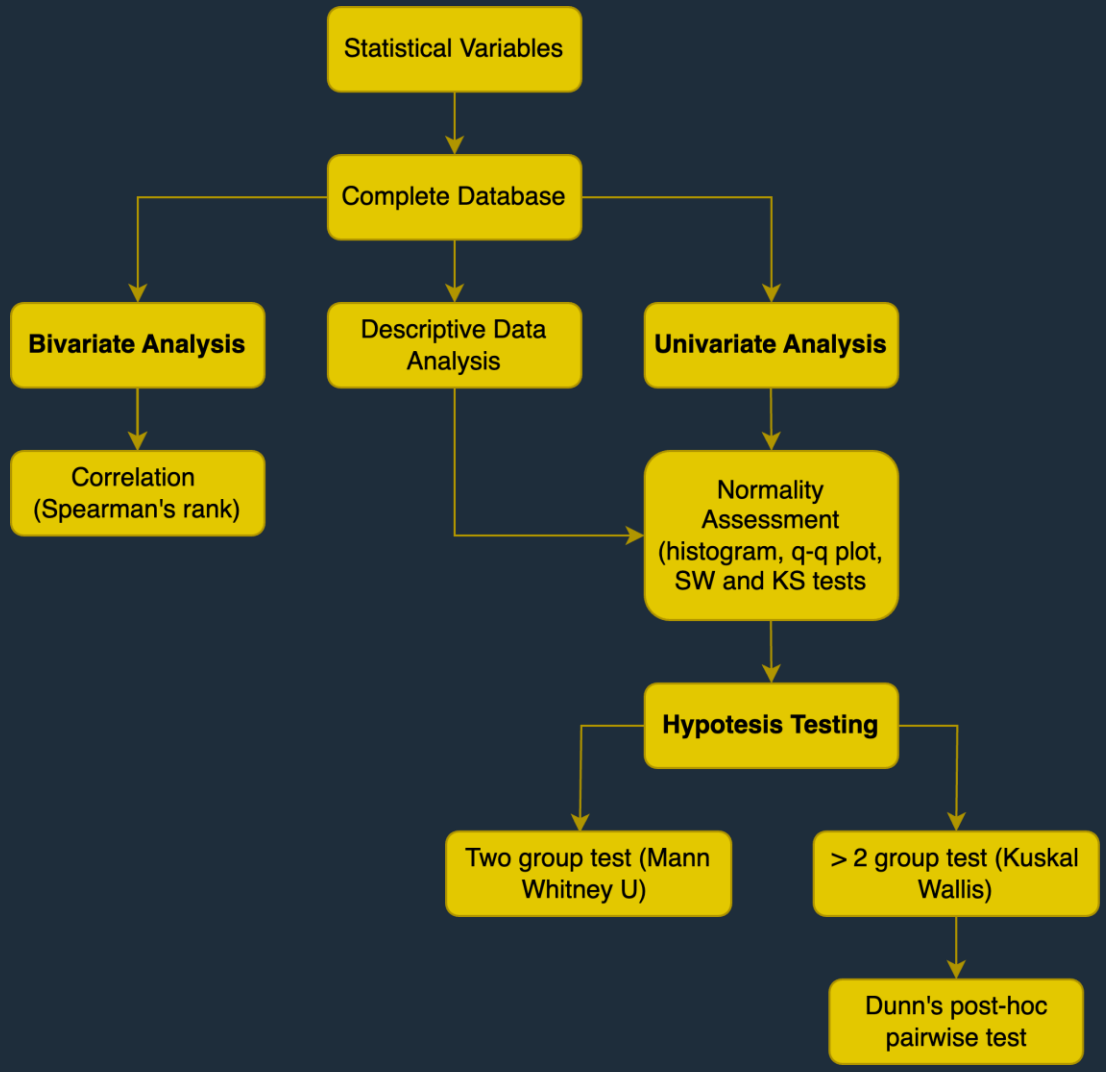
Statistical Analysis Methodology



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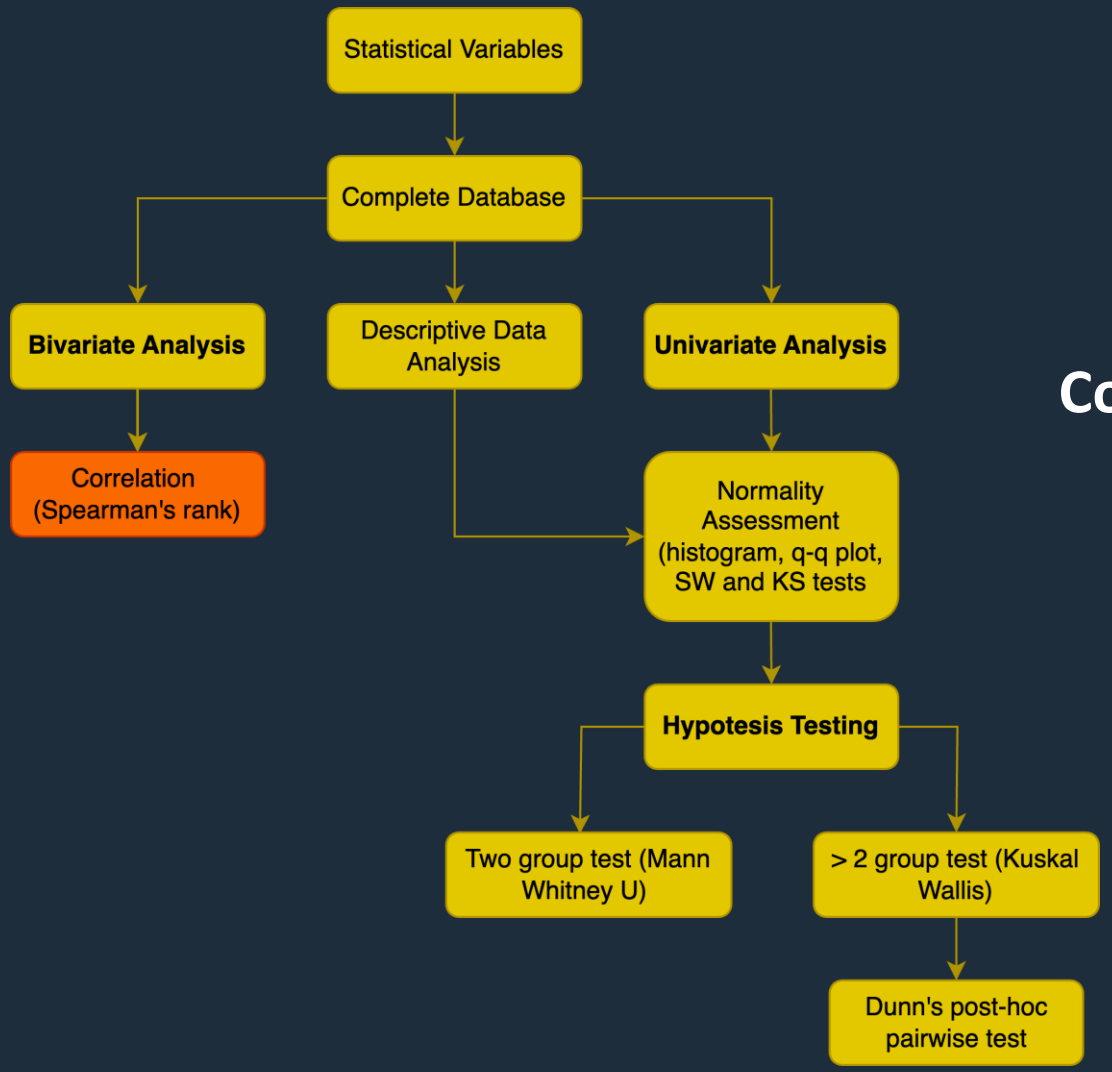

Correlation Analysis: Benzene vs.

- RAP temperature
- Maximum daily temperature
- Cummulative rainfall

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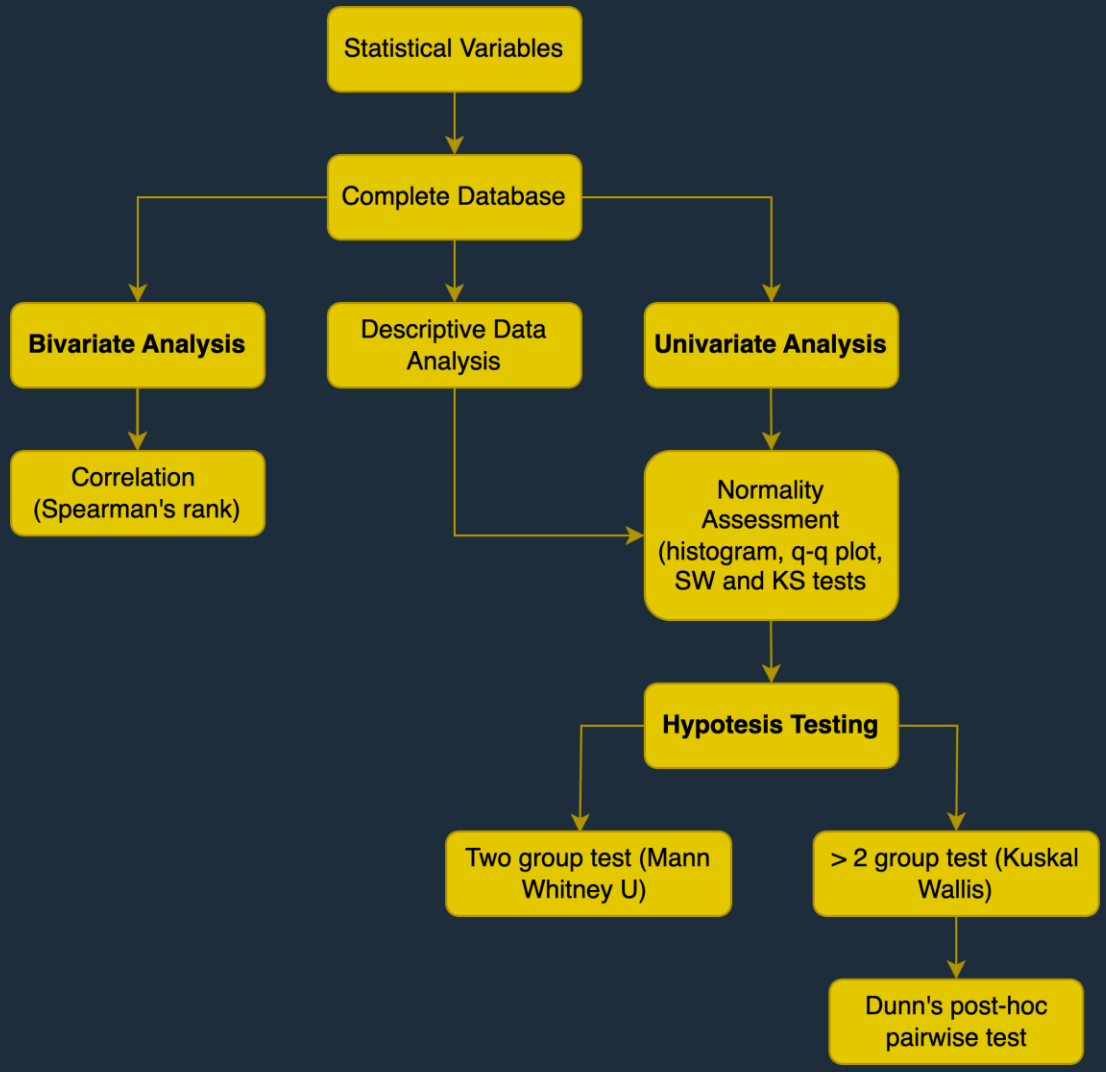

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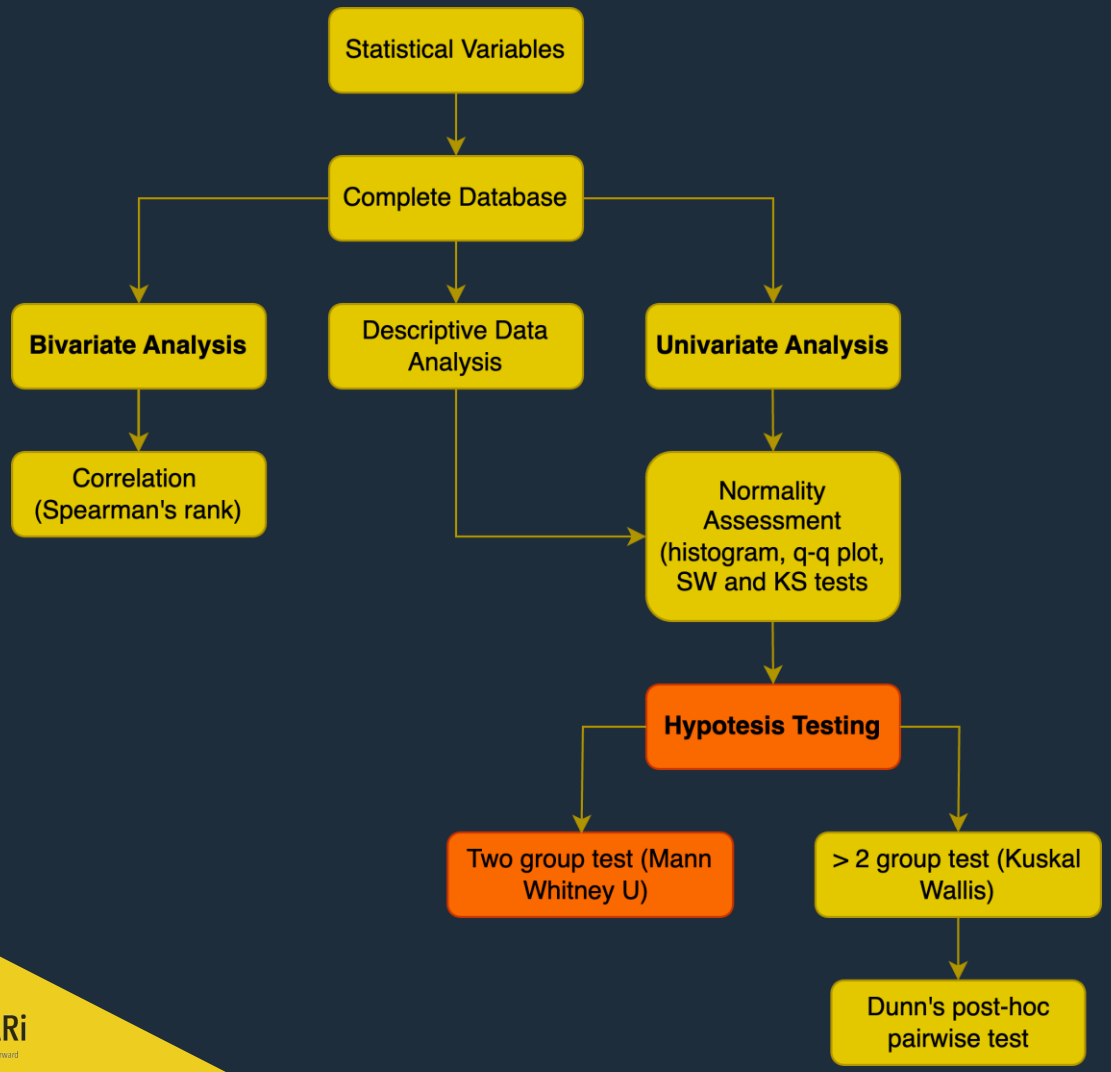

Mann-Whitney U test:

H_0: *The distribution of the benzene emissions for asphalt mixtures produced **with and without RA** is the same*

H_0: *The distribution of the benzene emissions for **HMA and WMA** is the same*

H_0: *The distribution of the benzene emissions for **AC and SMA mixtures** is the same*

H_0: *The distribution of the benzene emissions for mixtures containing **different types of bitumen** (i.e., 40/60 vs. 70/100) is the same*

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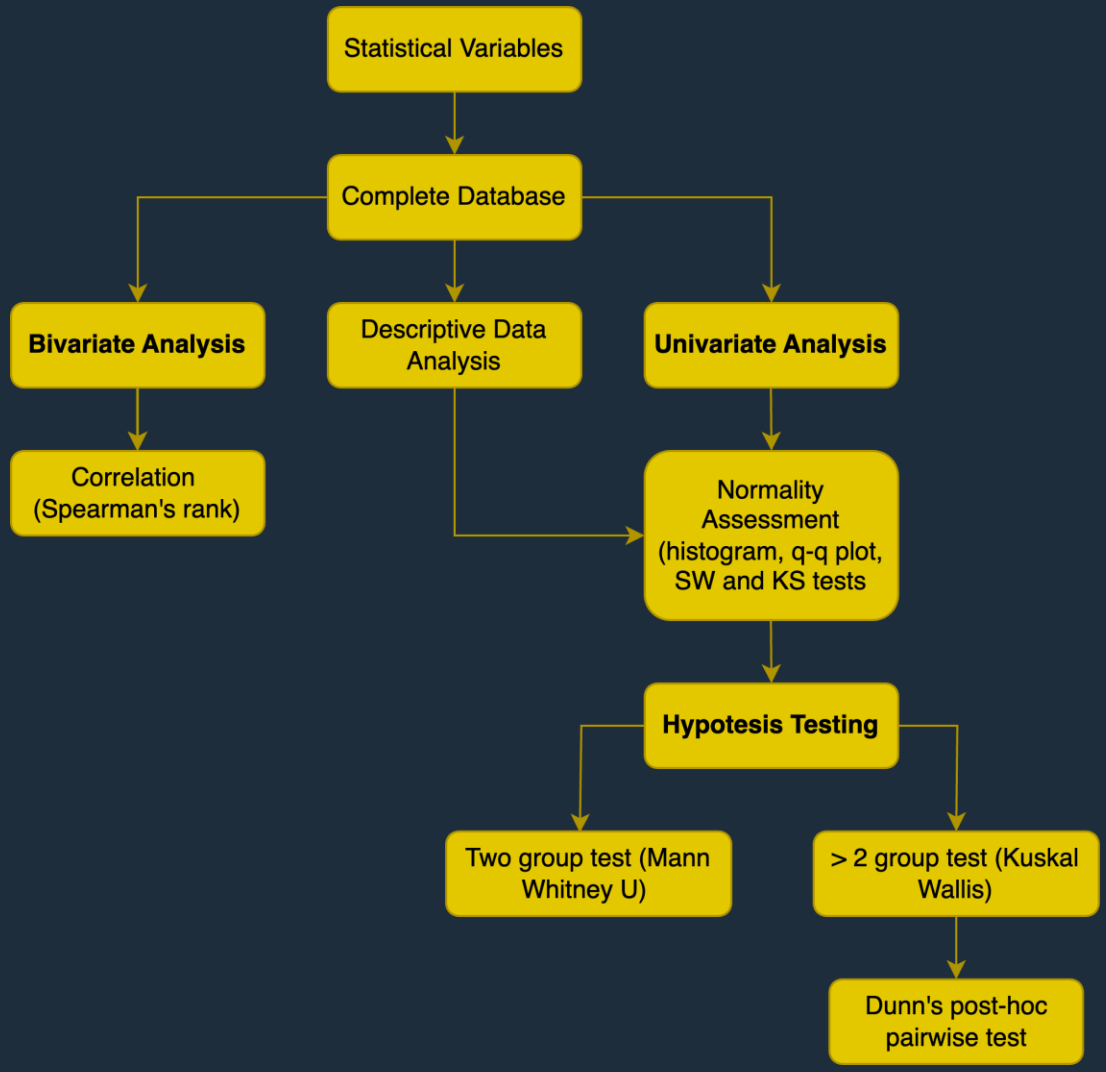

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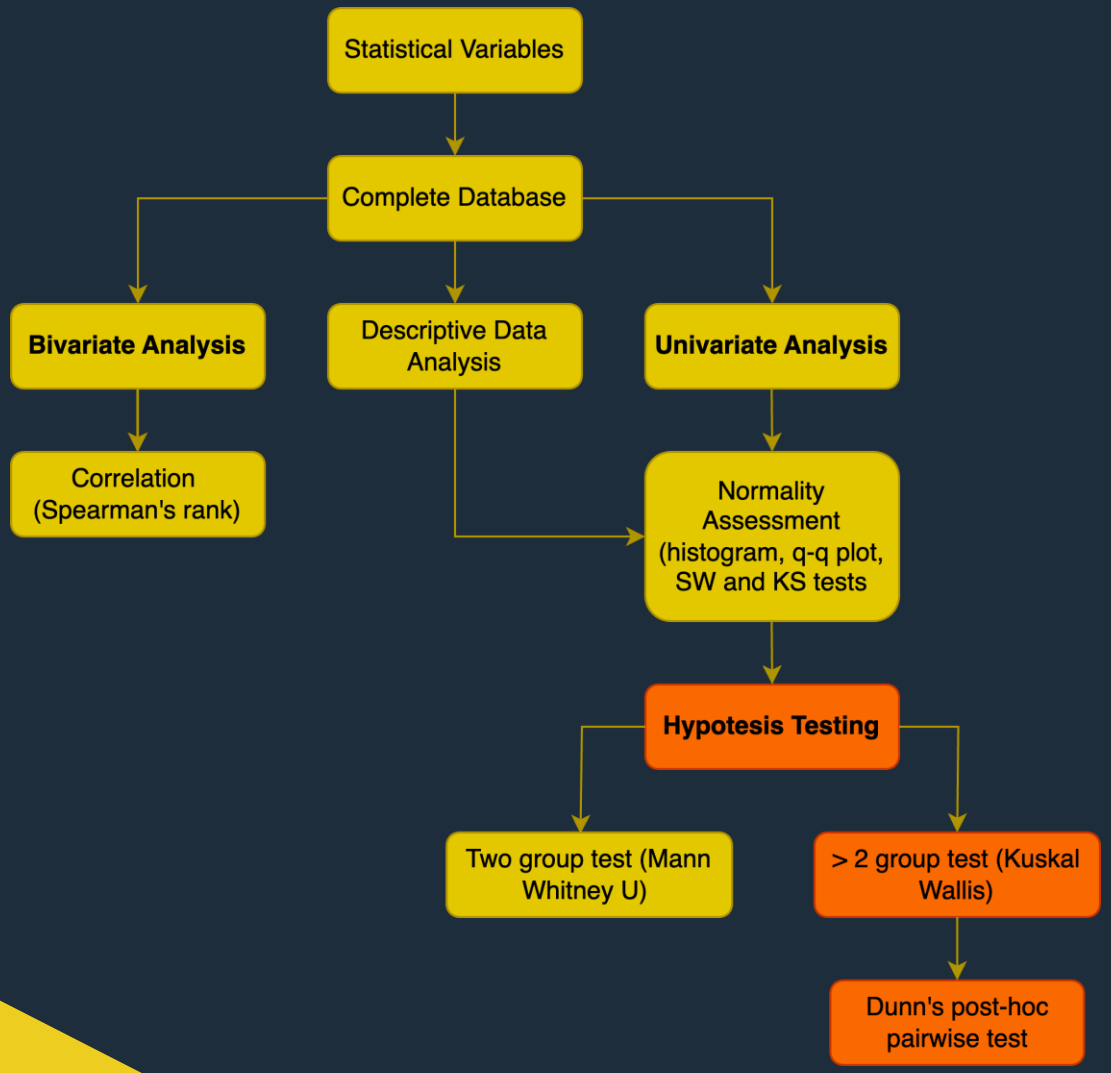

Kruskal–Wallis test + Dunn's post hoc test

H_0: *The distributions of the benzene emissions for mixtures produced with* ***0%, 30%, 50%, and 60% RA content*** *is the same*

Results: Correlation analysis

Dependent variable	Independent variable	ρ	*P*- value
BENZENE	RAP temperature	-0,007	0.22
	Maximum daily temperature	-0,040	<0.001
	Cumulative rainfall	0,0290	<0.001

No correlation between benzene emissions and any of the independent variables

Results: Hypothesis testing

Mann-Whitney U test:

H_0: *The distribution of the benzene emissions for asphalt mixtures produced with and without RAP is the same*

H_0: *The distribution of the benzene emissions for HMA and WMA is the same*

H_0: *The distributions of the benzene emissions for AC and SMA mixtures is the same*

H_0: *The distribution of the benzene emissions for mixtures containing different types of bitumen (i.e., 40/60 vs. 70/100) is the same*

p-value < 0.01 ⇒ Rejection **H_0**

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Results: Hypothesis testing

H_0: *The distributions of the benzene emissions for mixtures produced with 0%, 30%, 50%, and 60% RAP content is the same*

Kruskal–Wallis Test p-value	Dunn's Post Hoc Test Mixtures to compare	p-value
<0.01	0%RAP - 30%RAP	<0.001
	0%RAP - 50%RAP	0.1
	0%RAP - 60%RAP	0.1
	30%RAP - 50%RAP	1
	30%RAP - 60%RAP	<0.001
	50%RAP - 60%RAP	0.56

Results: Hypothesis testing

H_0: *The distributions of the benzene emissions for mixtures produced with 0%, 30%, 50%, and 60% RAP content is the same*

Kruskal–Wallis Test	Dunn's Post Hoc Test	
***p*-value**	**Mixtures to compare**	***p*-value**
<0.01	0%RAP - 30%RAP	<0.001
	0%RAP - 50%RAP	0.1
	0%RAP - 60%RAP	0.1
	30%RAP - 50%RAP	1
	30%RAP - 60%RAP	<0.001
	50%RAP - 60%RAP	0.56

Statistically significant

Rejection H_0

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Conclusions

- Benzene emissions are neither correlated with weather variables nor with the temperature of RA after drying and heating

- There is evidence of differences in the emissions of benzene when:
  - producing asphalt mixtures with varying RA content
  - producing different types of asphalt mixtures (i.e., HMA vs WMA)
  - producing asphalt mixtures with different bitumen penetration grades

Thank you!

Questions?

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