Construction of NOx Emission States Identification Method for Heavy-Duty Diesel Vehicles:

A Case Study of Nanjing

Session No.：SP-05

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Speaker's Name: Zixin Liu

Speaker’s Organization: Southeast University

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Contents

01 Background

- The exhaust pollution from road vehicles is becoming increasingly serious.
- The NOx emissions generate by heavy-duty diesel vehicles are enormous.
- There is **no clear and quantitative definition** of high emission state during vehicle driving.
- The consideration of **the continuity characteristics of emissions** is missing.

01 Introduction

An emission states identification method

1) **Based on PEMS high-precision emission data**

2) **Considered the time series characteristics of instantaneous mass of NOx and its change rate**

3) **Provided definition of different emission states.**

Part 1. Data acquisition and preprocessing

- Dataset creation → Outlier recognition → Time delay effect treatment

Part 2. Prediction model construction

- Predictive models of emission -related variables for NOx
  - → Predicted instantaneous mass
  - → Predicted change rate of mass

Part 3. Emission state labels acquisition

- Clustering of emission variables → Construction of the judgment matrix

02 Methodology

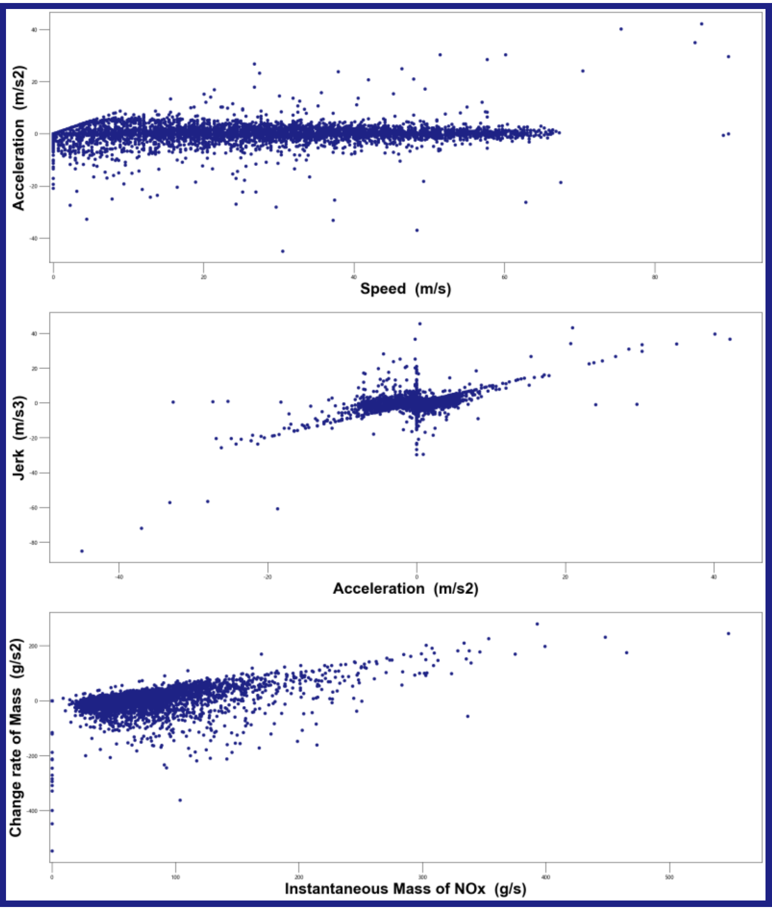
2.1 Data acquisition and preprocessing

2.2 Prediction model construction

2.3 Emission state labels acquisition

02 Methodology

Data acquisition and preprocessing



Driving-related data:

- Speed
- Acceleration
- Jerk

Emission-related data:

- Corrected Instantaneous Mass of NOx
- Change Rate of Mass

Missing value:

- Time-Gap

Outliers:

- Driving-related: Data distribution
- Emission-related: Isolation degree

Time-Lag: The time-delay effect processing method based on the micro-driving cycle characteristics

Step 1
(For basic time-lag)

$$r_k = \frac{S_k}{S^2} = \begin{cases} \dfrac{1}{n-k}\displaystyle\sum_{t=1}^{n-t}\left(\frac{X_t-\overline{X}}{S}\right)\left(\frac{Y_{t+k}-\overline{Y}}{S}\right), k \geq 0 \\ \dfrac{1}{n+k}\displaystyle\sum_{t=1}^{n-t}\left(\frac{X_t-\overline{X}}{S}\right)\left(\frac{Y_{t+k}-\overline{Y}}{S}\right), k \leq 0 \end{cases}$$

$$TimaLag_{basic} = \frac{\sum_{i=1}^{m}\tau_i}{m}$$

Step 2
(For correction factor)

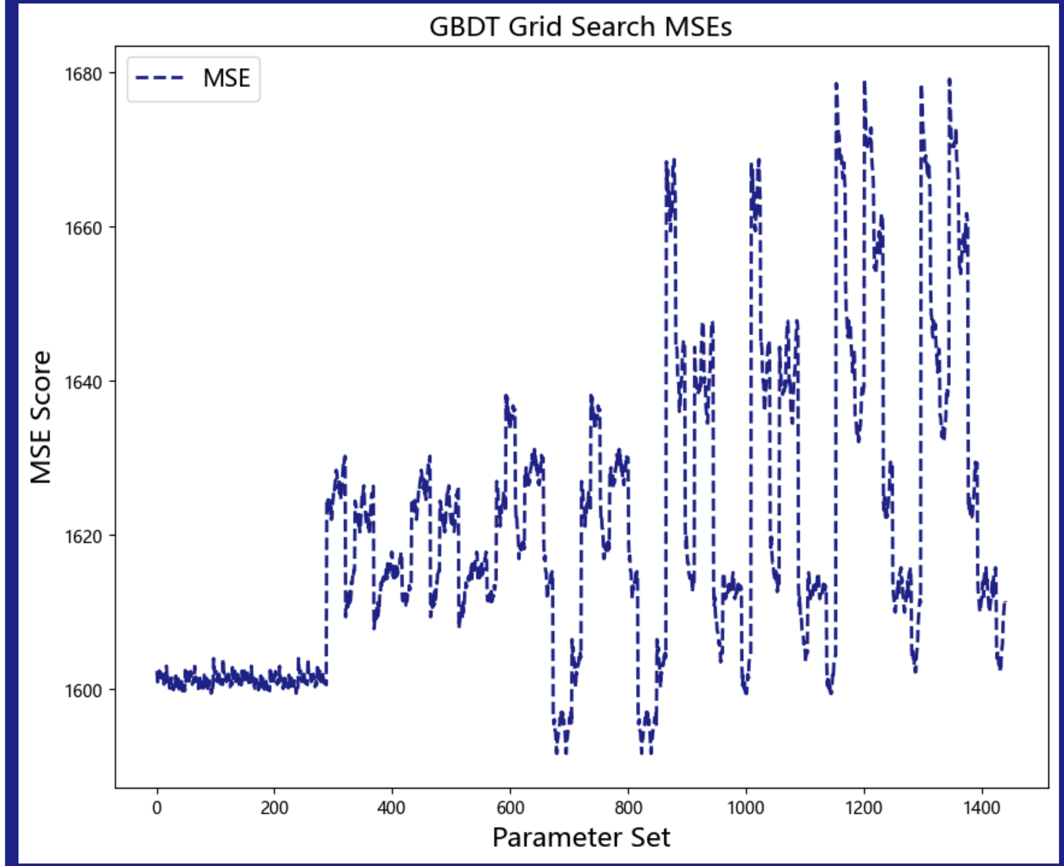
$$\alpha_i = \frac{\overline{Speed_i}}{\overline{\overline{Speed}}} \times \omega_{AS} + \frac{\sigma_{Speed_i}}{\sigma_{Speed}} \times \omega_{\sigma S} + \frac{\overline{Acc_{+i}}}{\overline{\overline{Acc_+}}} \times \omega_{AA+} + \frac{\overline{Acc_{-i}}}{\overline{\overline{Acc_-}}} \times \omega_{AA-} + \frac{\sigma_{Acc_i}}{\sigma_{Acc}} \times \omega_{\sigma A}$$

Step 3
(For final time-lag)

$$TimeLag_i = TimaLag_{basic} \times (1 + \alpha_i)$$

02 Methodology

Prediction model construction



Random Forest Model:

- $n_{estimators} = 130$
- $max_{depth} = 26$

GBDT model:

- $n_{estimators} = 32$
- $learning_{rate} = 0.093$

XGBoost model:

- $n_{estimators} = 16$
- $learning_{rate} = 0.079$

02 Methodology

Emission state labels acquisition

$$E_{DBI} = \frac{1}{k}\sum_{i=1}^{k} \max_{j \neq 1}\left[\frac{avg(C_i) + avg(C_j)}{d_{cen}(u_{i'} u_j)}\right]$$

Automatic boundary detection

Initial K-Center algorithm

Davies-Bouldin Index

Judgment Matrix for NOx Emission States Labels		Instantaneous Mass of NOx		
		Low-value	Normal-value	High-value
Change Rate of Mass	Low-value	Low	Lower	Normal
	Normal-value	Lower	Normal	Higher
	High-value	Normal	Higher	High

03 Case study

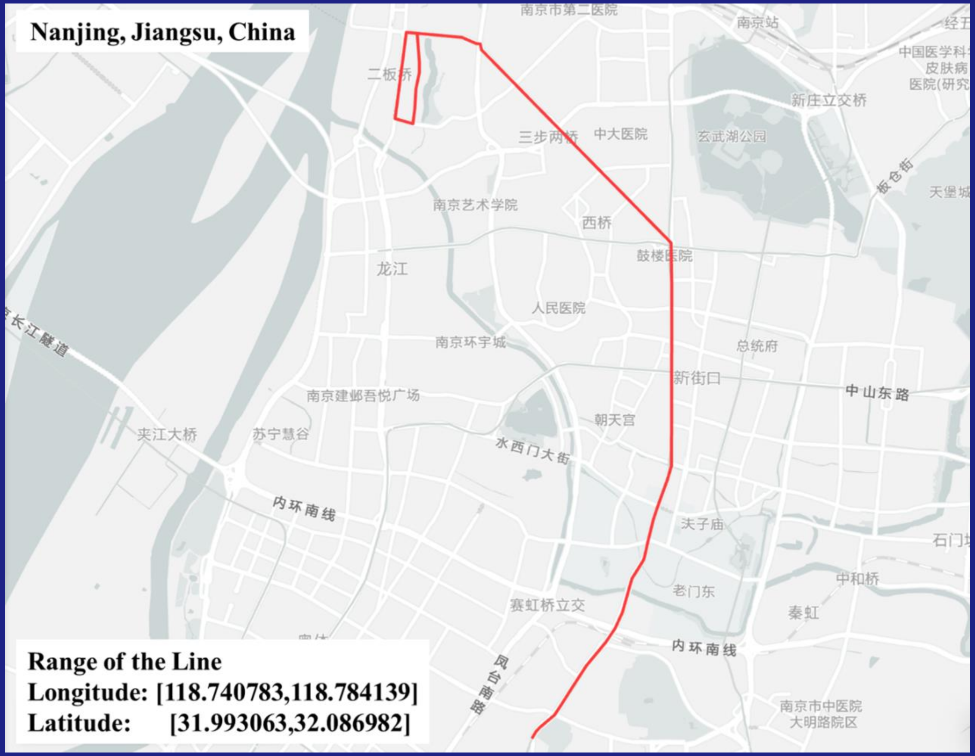
3.1 Analysis of prediction model performance

3.2 Comparison of clustering methods

3.3 Driving characteristics in emission states

03 Case Study

Emission prediction model for NOx



R-Square (R^2) of instantaneous mass

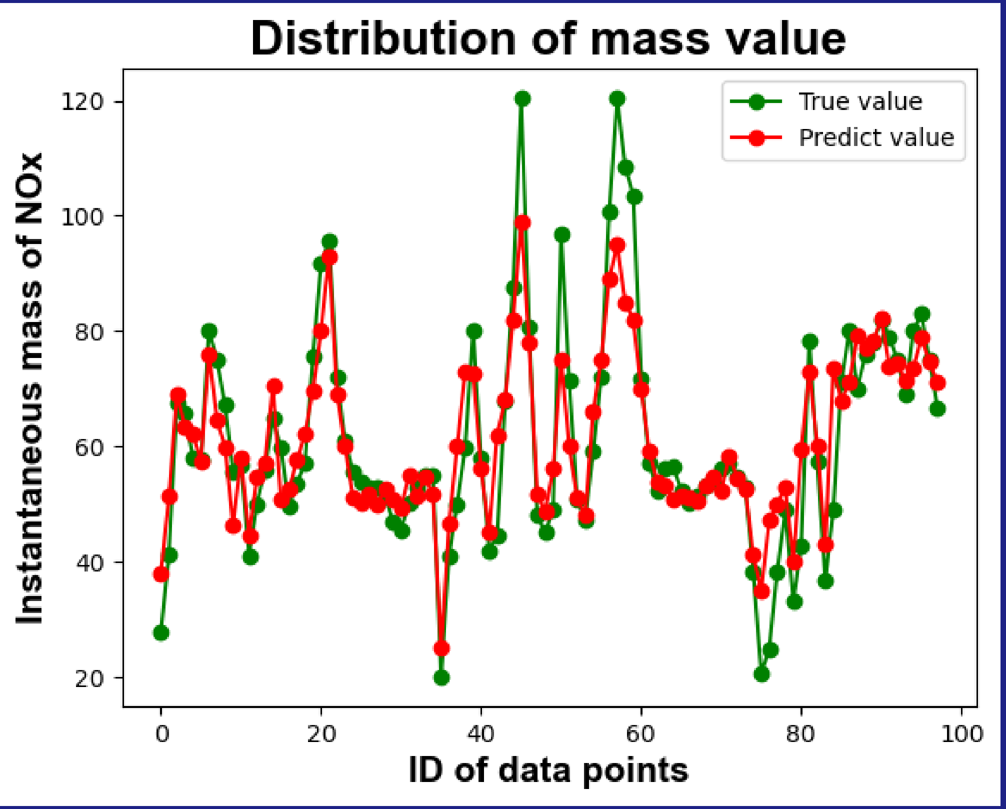
Random Forest	GBDT	XGBoost	Fusion
0.735→0.735	0.783→0.806	0.748→0.759	0.528

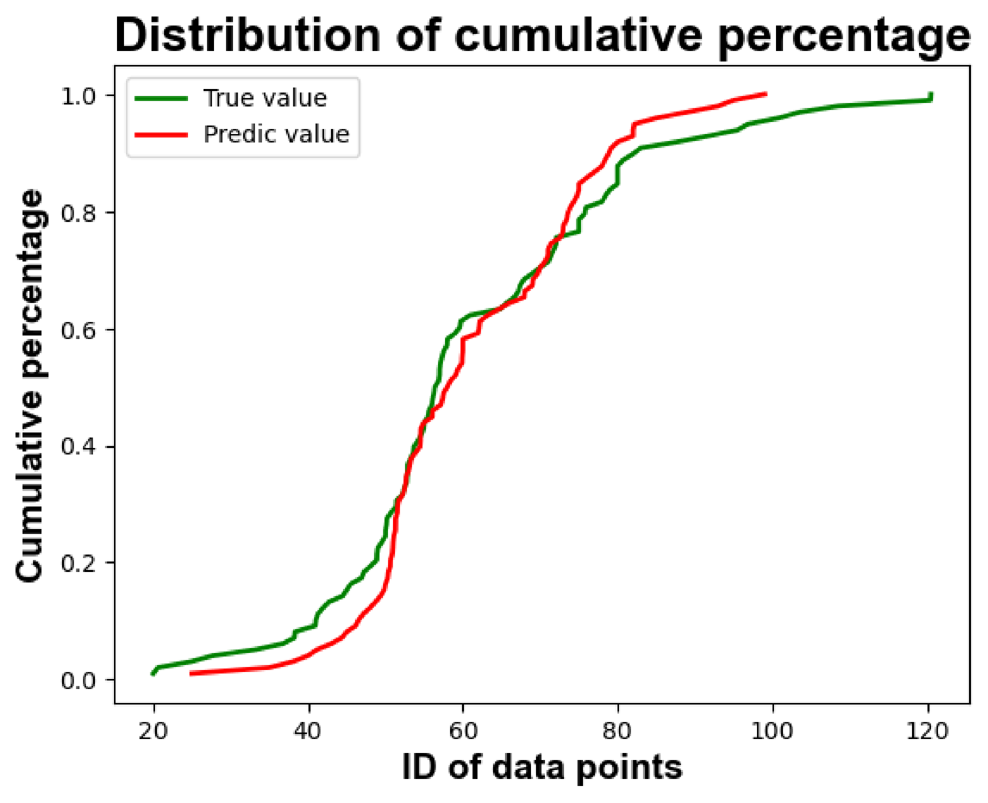
R-Square (R^2) of change rate of mass

Random Forest	GBDT	XGBoost	Fusion
0.668→0.668	0.790→0.792	0.603→0.653	0.498

03 Case Study

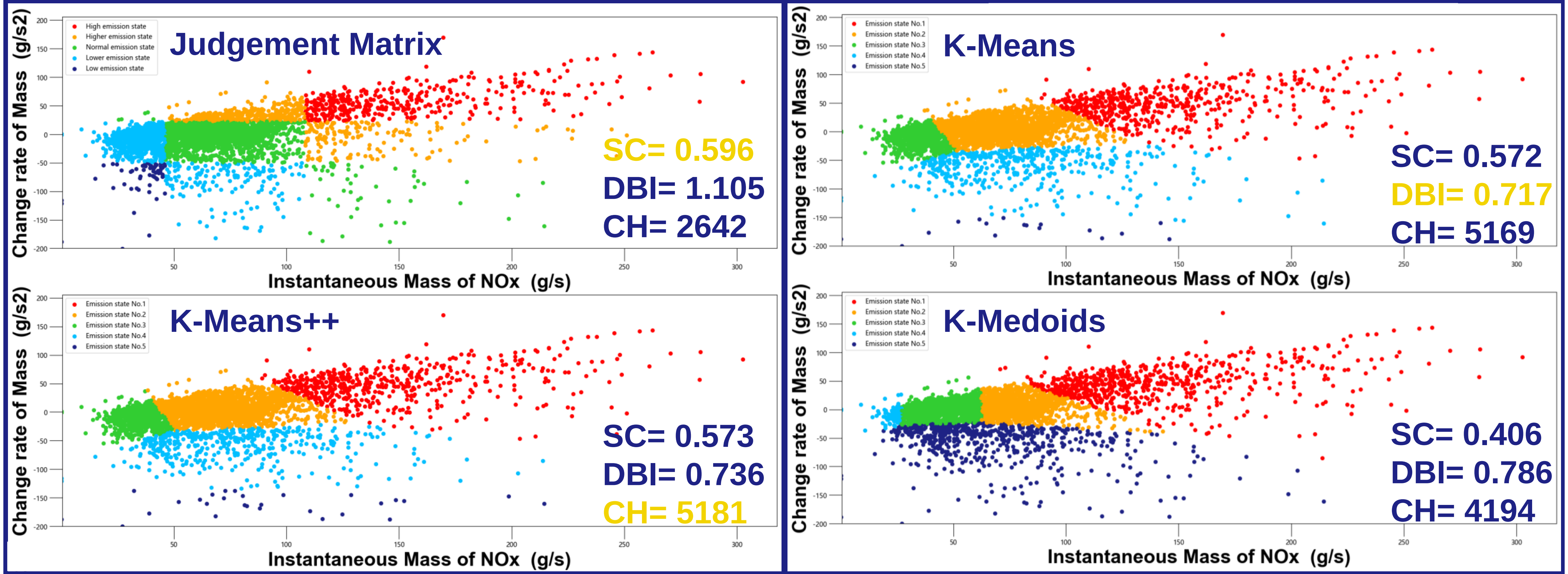
Prediction model selection and performance analysis





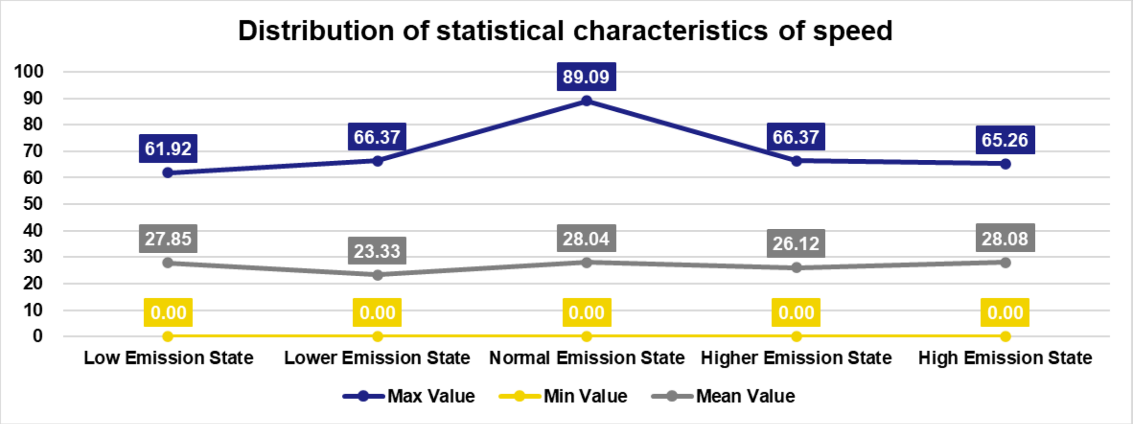
03 Case Study

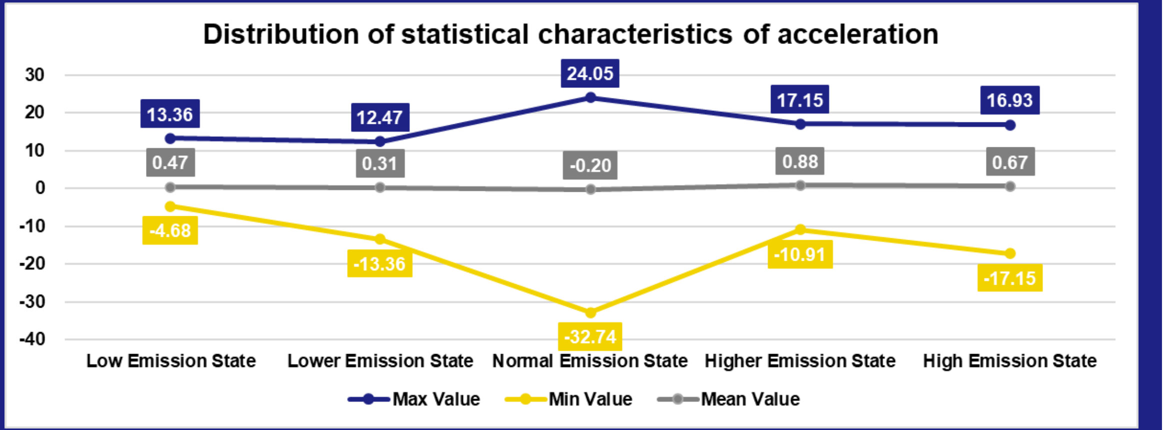
Comparison of different clustering methods

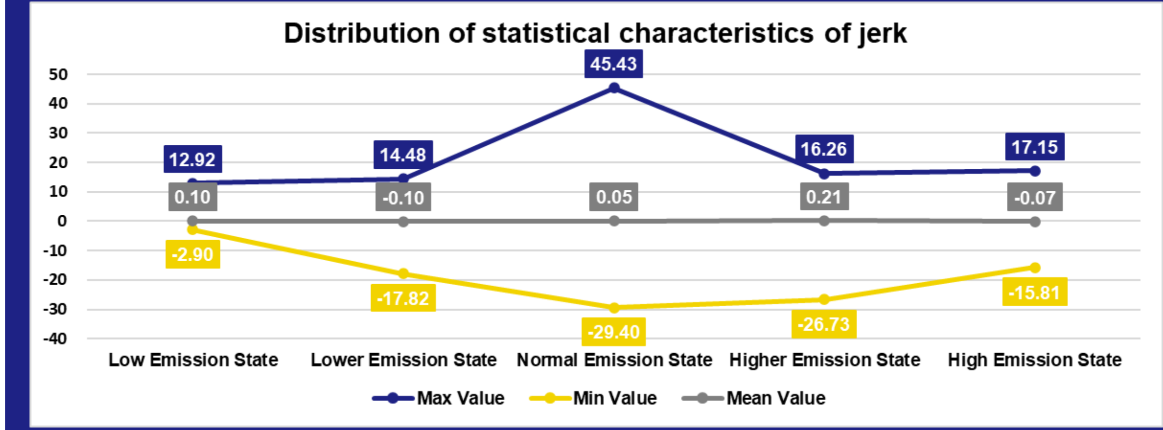


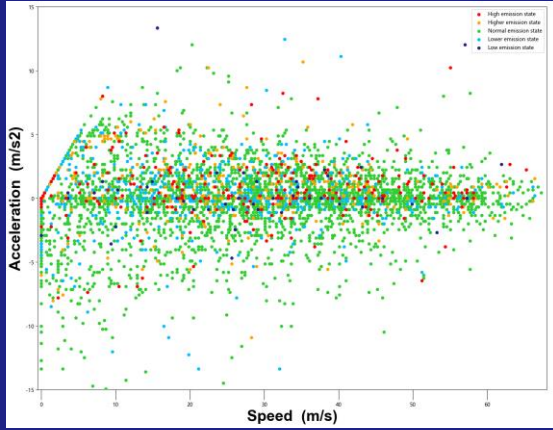
03 Case Study

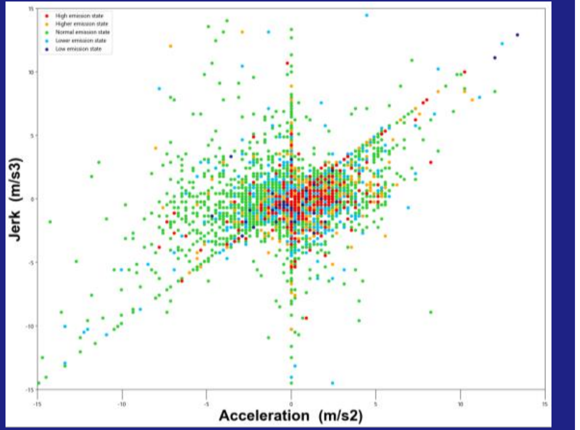
Driving characteristics in high / low emission state



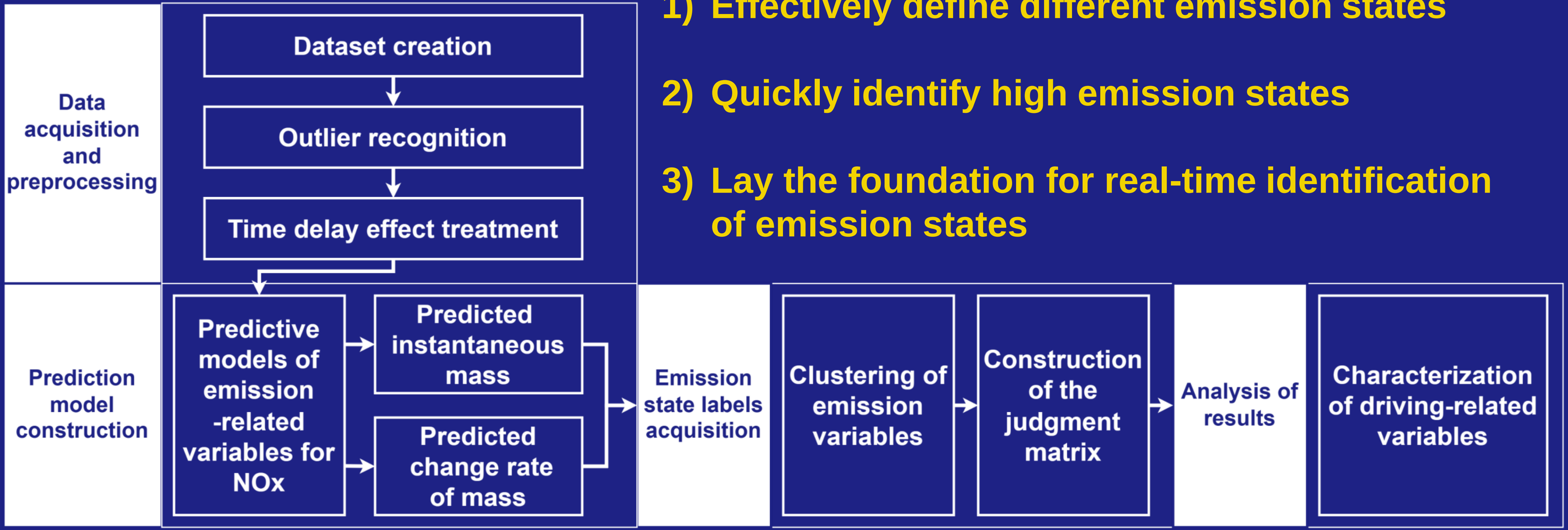








04 Conclusion



1) Effectively define different emission states

2) Quickly identify high emission states

3) Lay the foundation for real-time identification of emission states

ACKNOWLEDGEMENTS

modales
Adapting driver behaviour for lower emissions

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Thank you for your attention.

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