An Investigation of Discretionary Lane-changing Decisions
Insights From the Third Generation SIMulation (TGSIM) Dataset

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1.1 Background

Evidence of LC's adverse effects

- **Safety** (Pande and Abdel-Aty, 2006)
- **Traffic flow oscillation** (Zheng et. al, 2011)
- **Capacity drop** (Cassidy and Rudjanakanoknad, 2005)

More accessible data sources

- **Naturalistic Driving data**
  - SHRP 2
  - Combine interviews (Keyvan-Ekbatani et al., 2016)
- **Trajectory data**
  - NGSIM (FHWA, 2007)
  - HighD (Krajewski et al., 2018)
  - pNEUMA (Barmpounakis and Geroliminis, 2020)
  - I-24 MOTION (Gloudemans et al., 2023)

1.2 Motivation

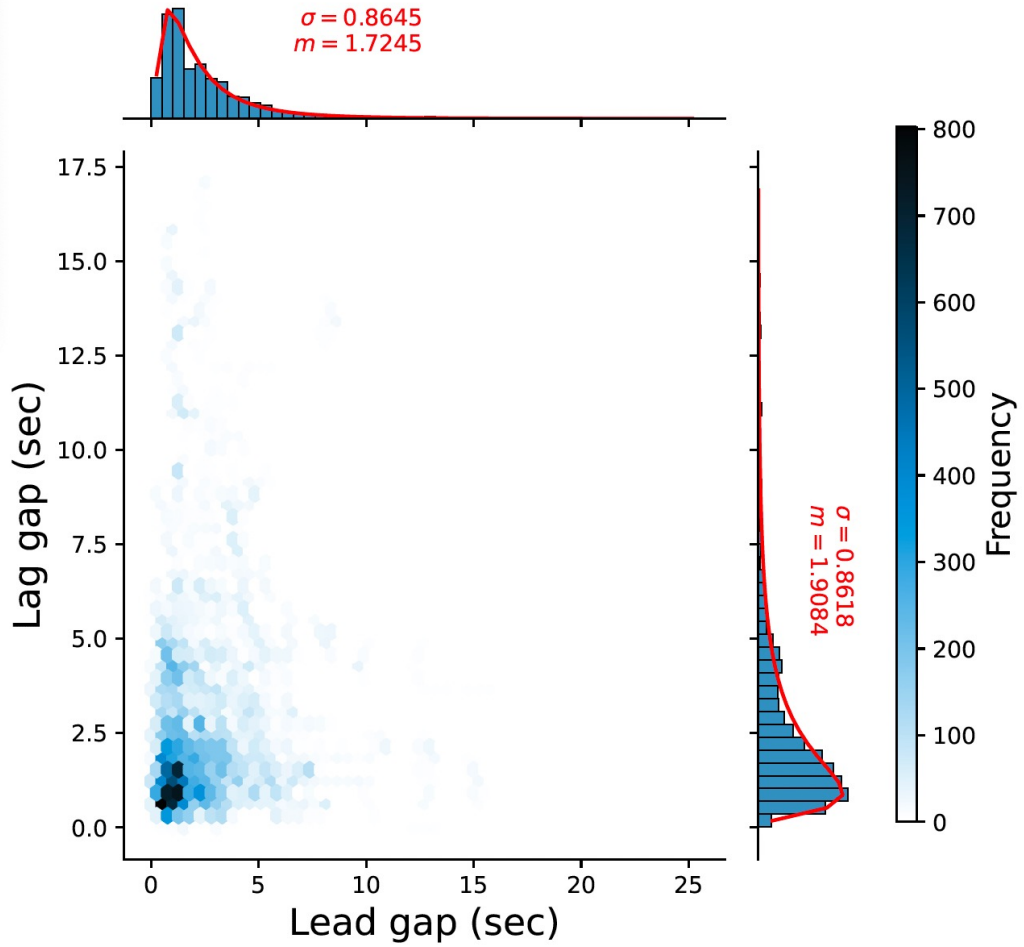
- **Existing datasets** based on fixed infrastructure or aerial videography may suffer from **imprecise lateral positions** or **limited coverage**
- **TGSIM** used a moving aerial videography with **abundant** and **accurate** real-world datasets,
- **Our goal** is to conduct an exploratory investigation on DLC and gain insights into different categories of DLC behaviors.

2.1 TGSIM dataset

- A **3-mile highway** segment on I-294
- Peak hour from **3 p.m. to 5 p.m.**
- A helicopter moving at **300 meters**
- Pixel size **0.3m*0.3m**
- **Lane assignment** is provided
- **3-sec data before and after LC** is extracted, forming **477 DLC cases**

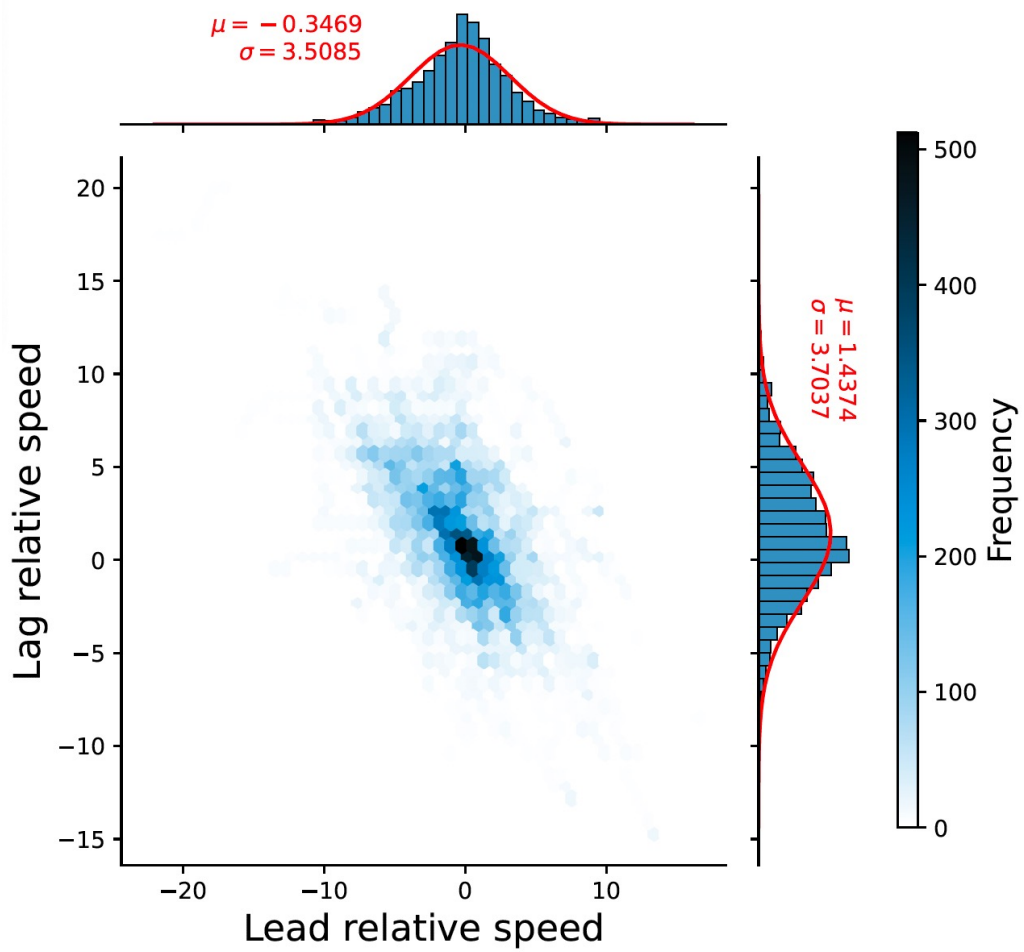
2.2 Discretionary lane-changing characteristics: Lead and lag gaps

- **The median**
  - Lead gap: 1.72 sec
  - Lag gap: 1.91 sec
- **Long-tail distribution**
  - Candidate dist.: **Power law** and **Log-normal**
  - **Likelihood ratio test** on lead and lag gaps
  - Results show the **gaps** are more likely to be **Log-normal distributed**
- **Is separating lead and lag necessary?**
  - Wilcoxon signed-rank test on paired samples

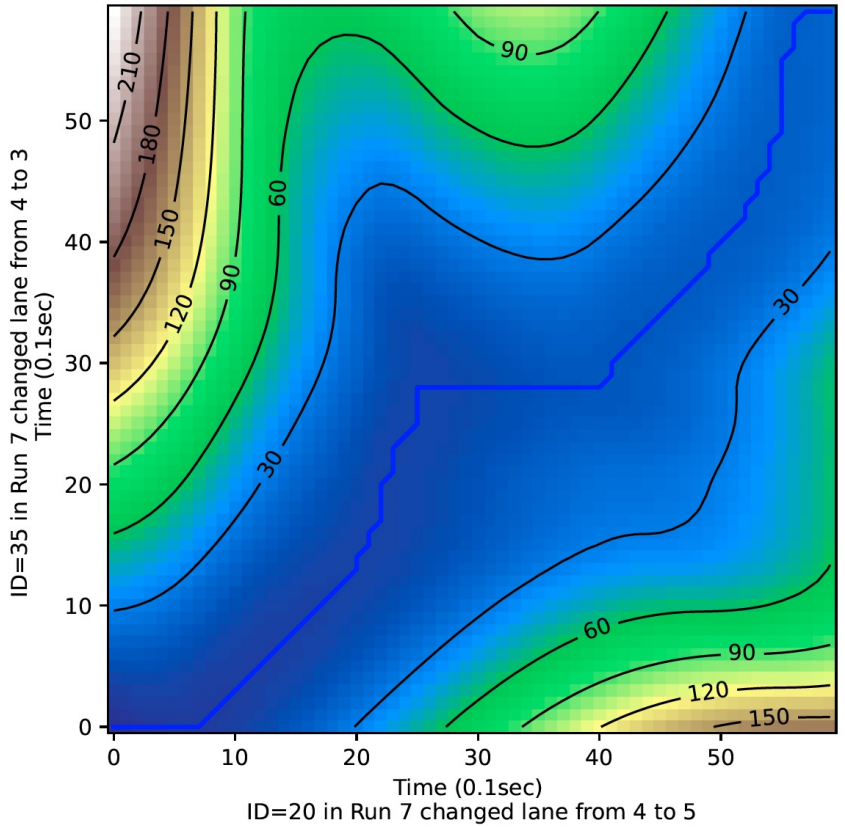


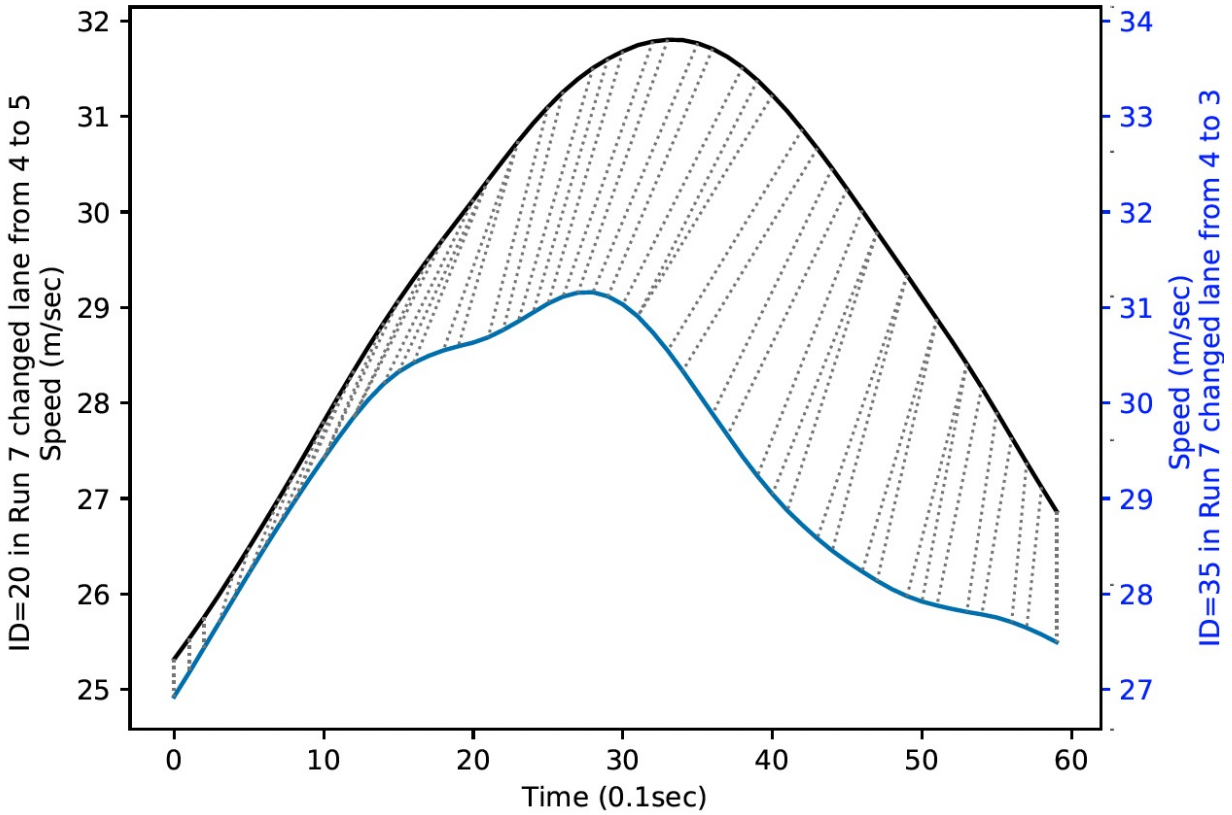
2.2 Discretionary lane-changing characteristics: relative speeds

- **The mean**
  - Lead relative speed: -0.35 m/sec
  - Lag relative speed: 1.43 m/sec
- **The median**
  - Lead relative speed: -0.18 m/sec
  - Lag relative speed: 1.15 m/sec
- **Is separating lead and lag necessary?**
  - Wilcoxon signed-rank test on paired samples



3.1 Dynamic time warping analysis (DTW) on driving behaviors





3.2 DTW-based affinity propagation clustering

Constructing the similarity matrix

- **Off-diagonal**

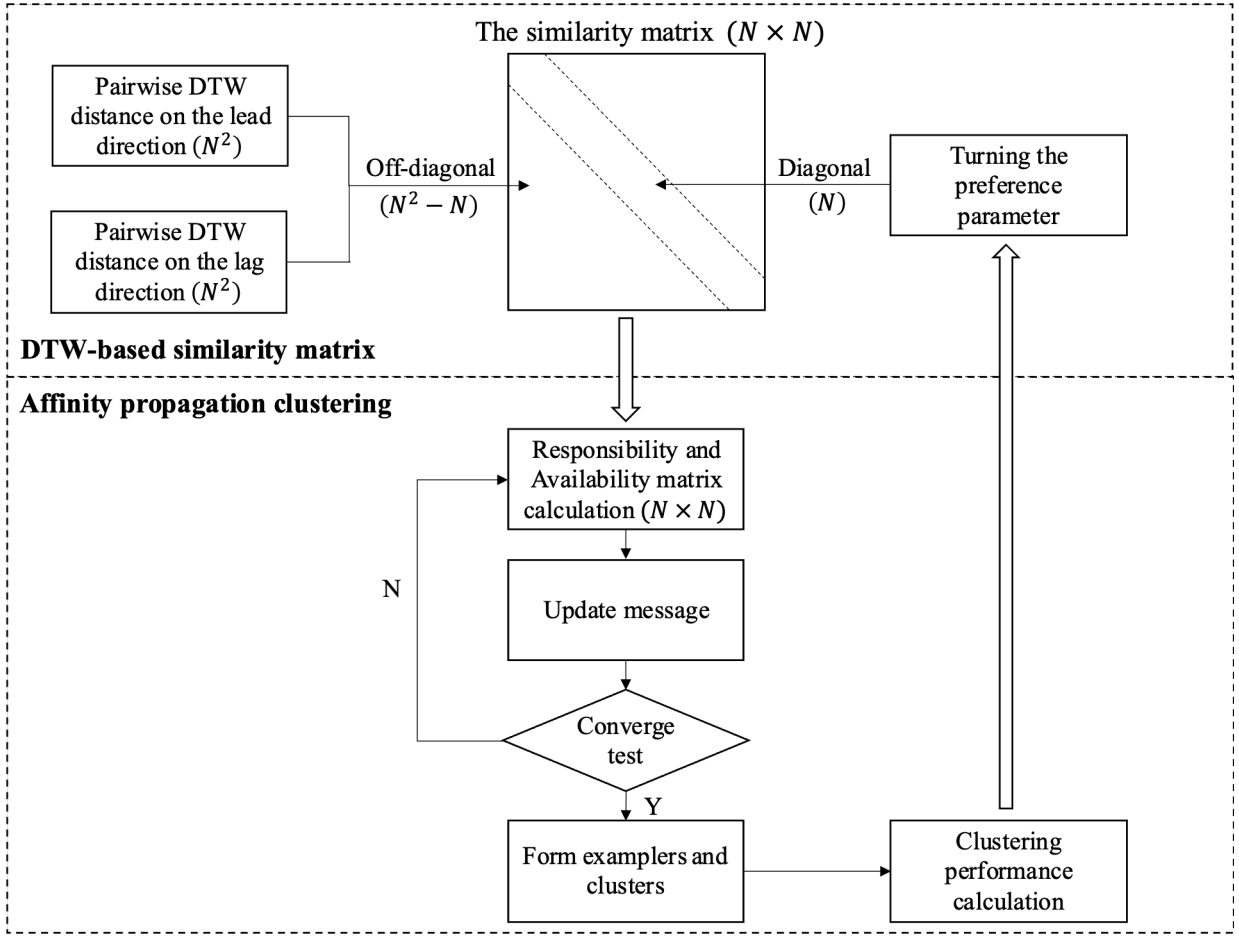
$$S(i,j) = -DTW^2\left(X_i^{lead}, X_j^{lead}\right) - DTW^2\left(X_i^{lag}, X_j^{lag}\right)$$

- **Diagonal (Preference)**

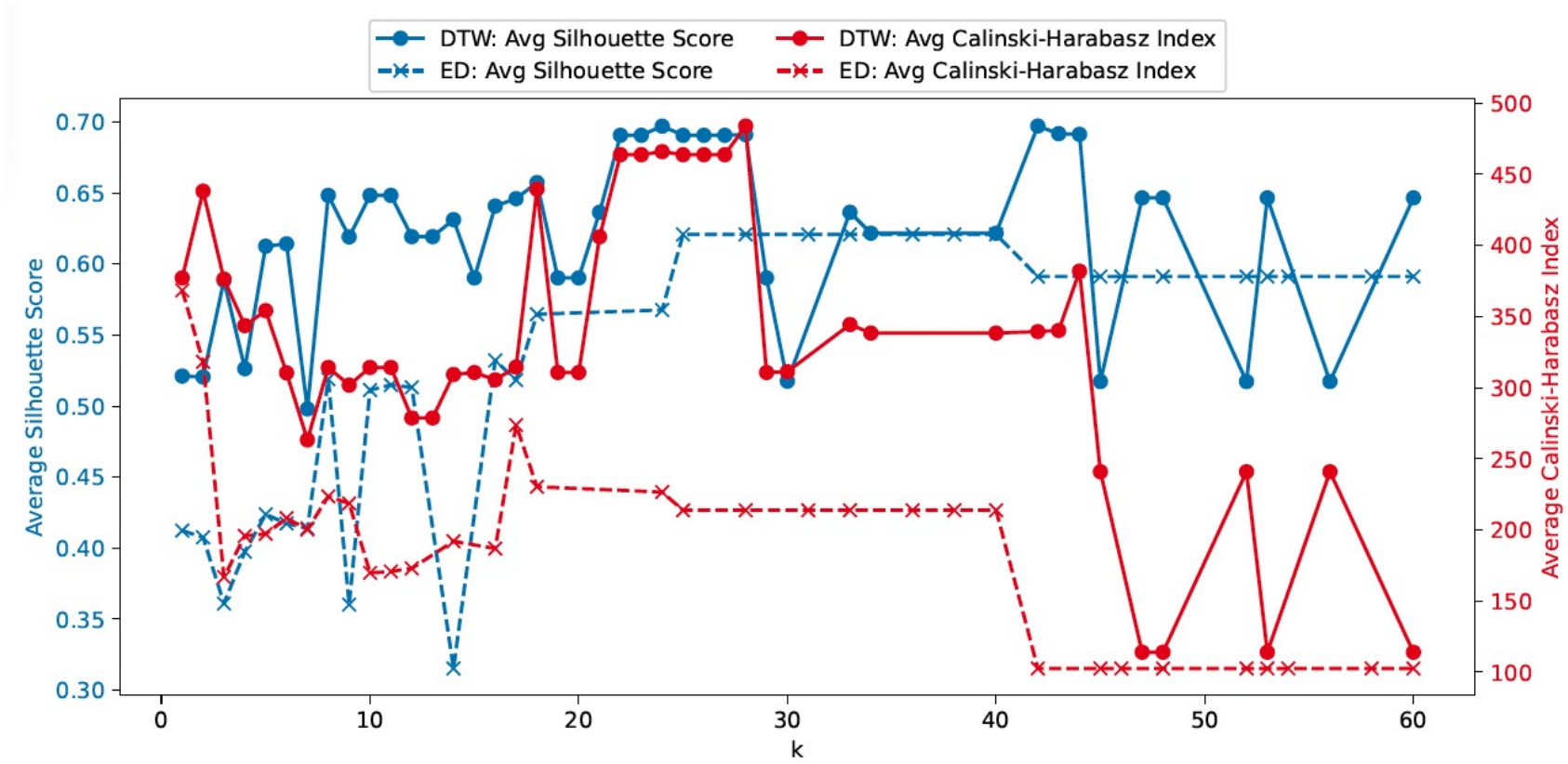
$$S(i,i) = k * median(Off\_diagonal)$$

k is a hyperparameter

- **Clustering performance**
  - Silhouette Coefficient
  - Average Calinski-Harabasz Index

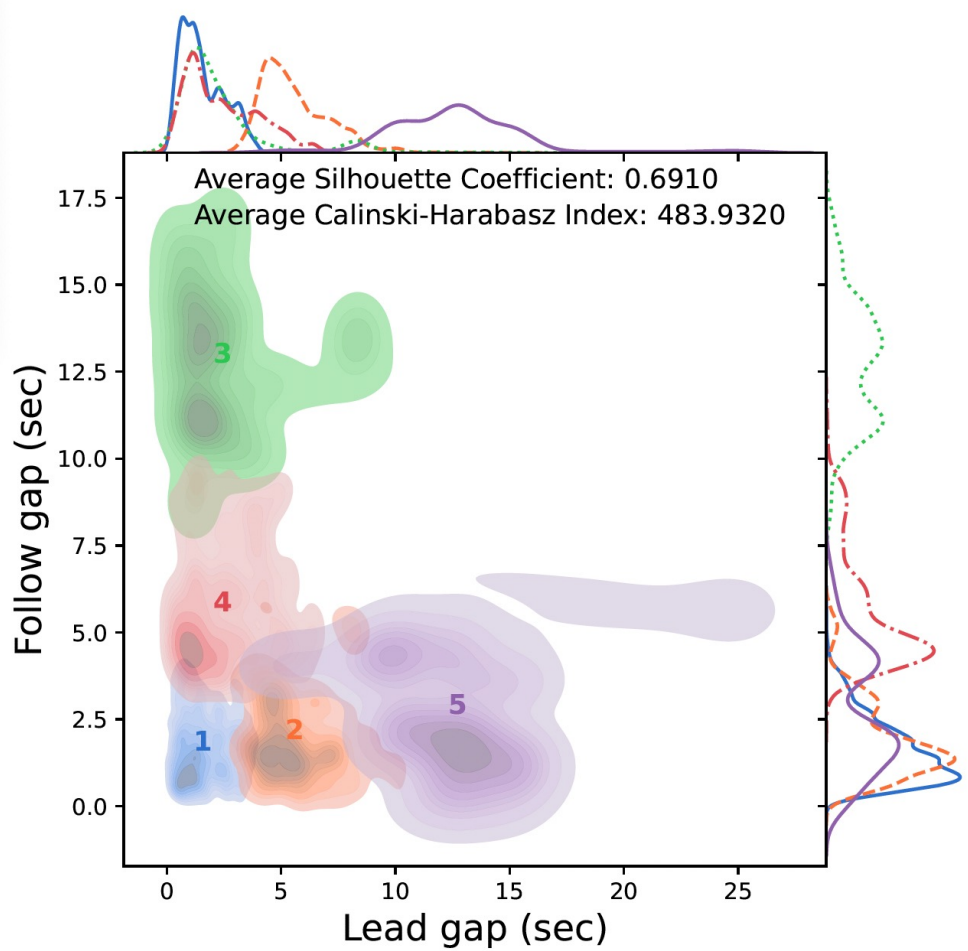


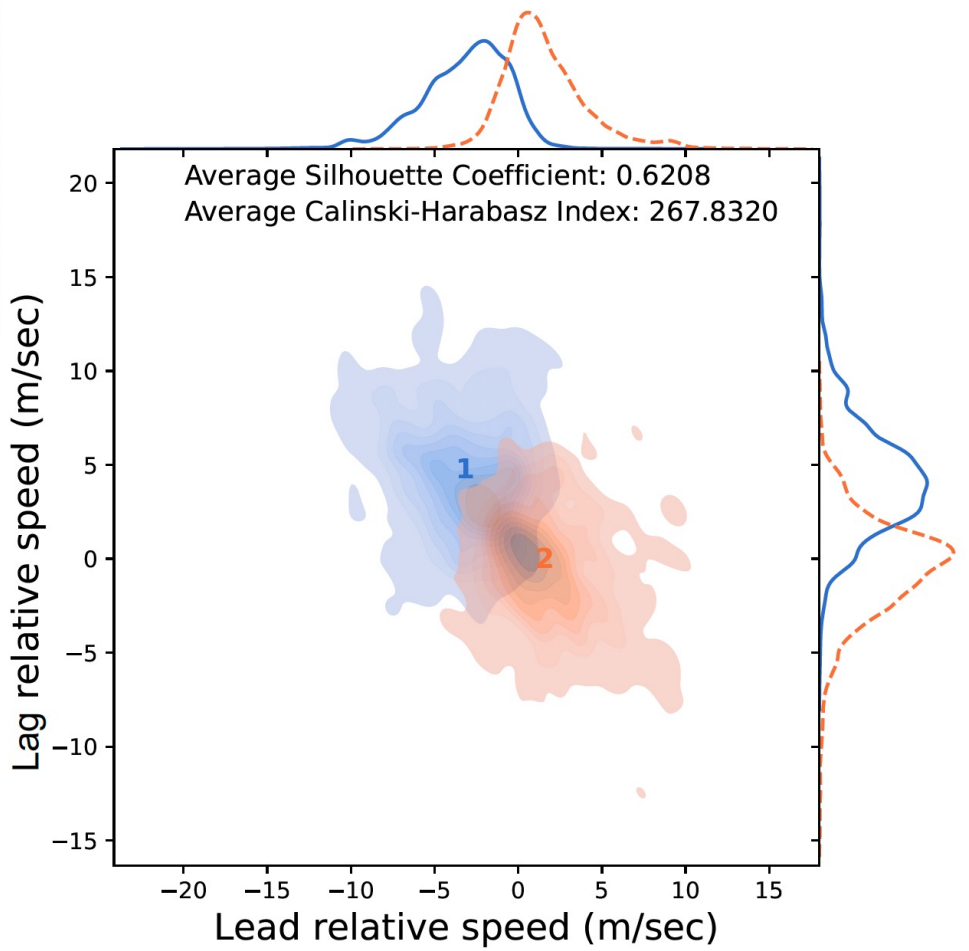
4.1 Comparison of DTW and ED



k=28 is the optimal value, and using DTW gains a higher score than ED

4.2 Clustering results





5. Summary

- ✓ **DLC gap acceptance characteristics**: DLC on highways exhibit **heavy tails** and is likely to be **lognormal distributed**
- ✓ **Directional analysis**: a separate examination of lead and lag directions is **necessary** for DLC behaviors
- ✓ **DTW vs. ED:** DTW outperforms ED in characterizing driving behavior differences by capturing the matching time patterns
- ✓ **DLC behavioral clustering:** DTW-based AP clustering categorizes DLC into aggressive, natural, and cautious on lead and lag directions.

Thank You!

Questions?

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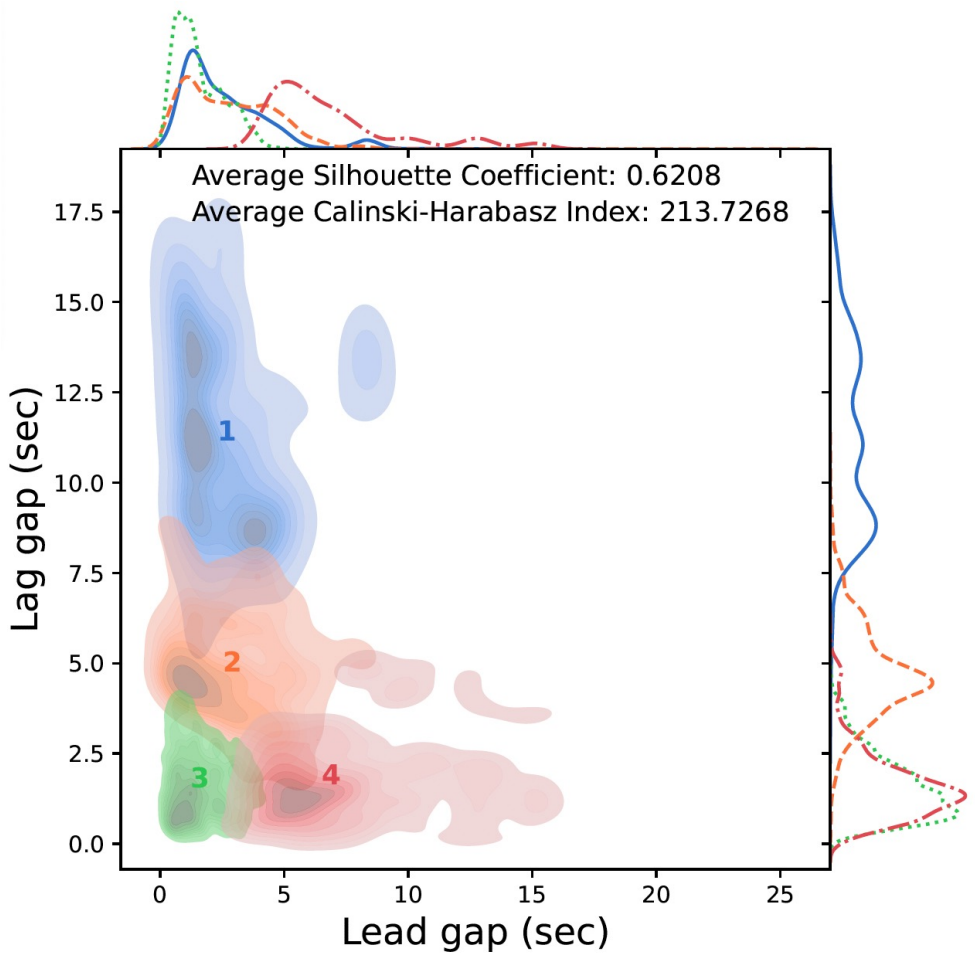
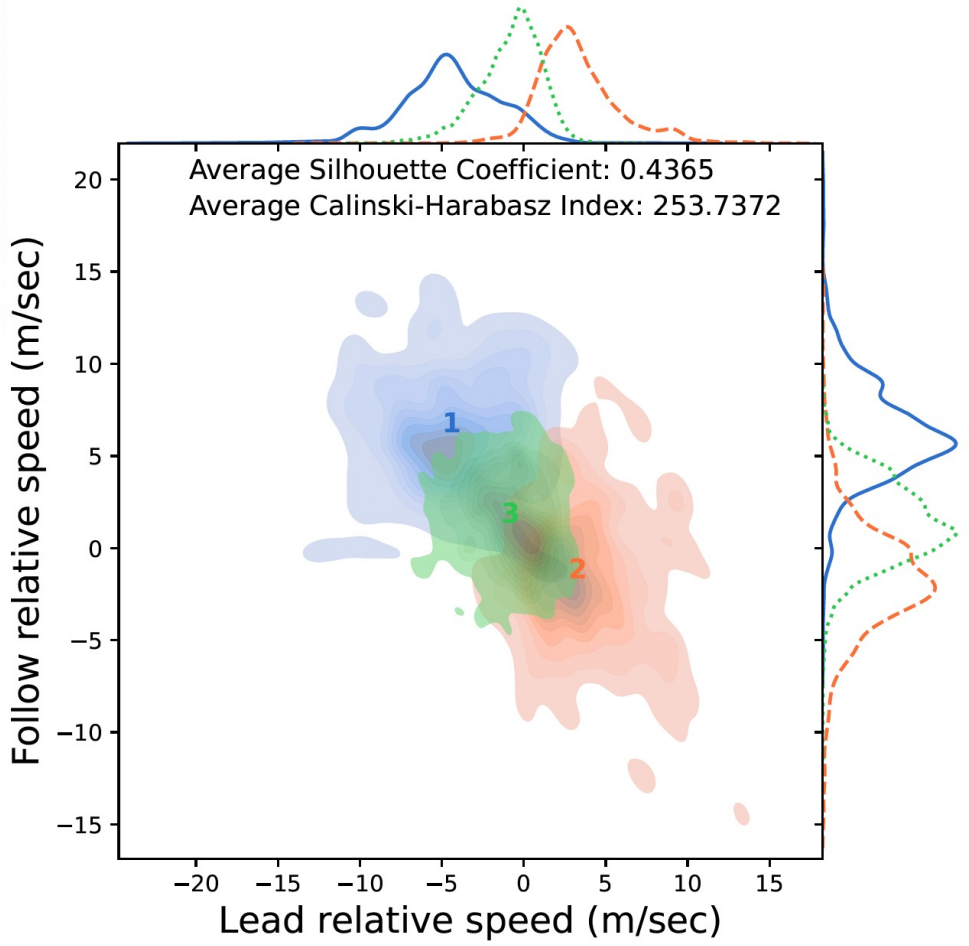
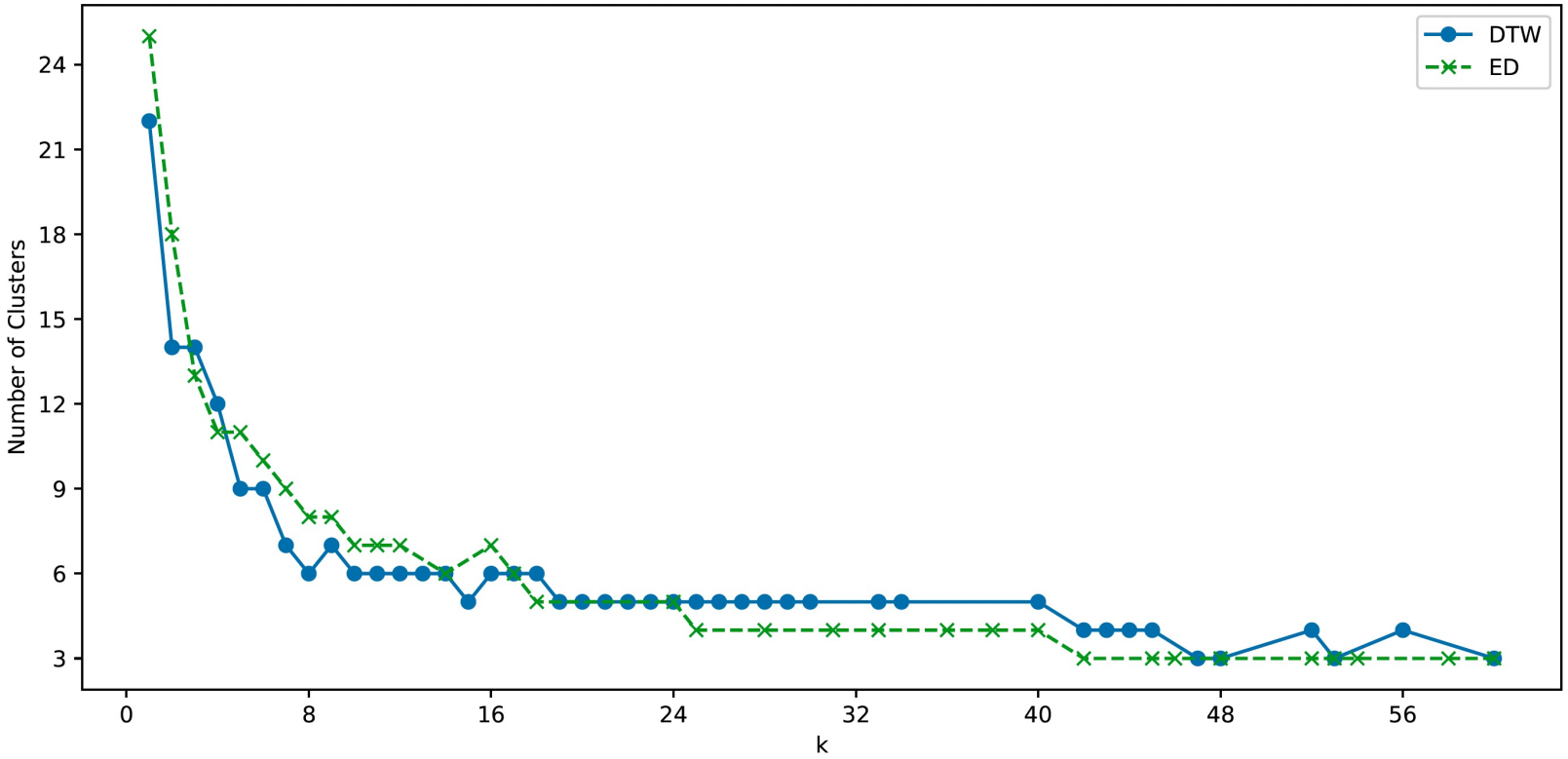
Clustering results with ED





Number of clusters for gaps



Number of clusters for relative speeds