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## Braking Behavior Profiling of Professional Car Drivers using Instrumented Vehicle Data

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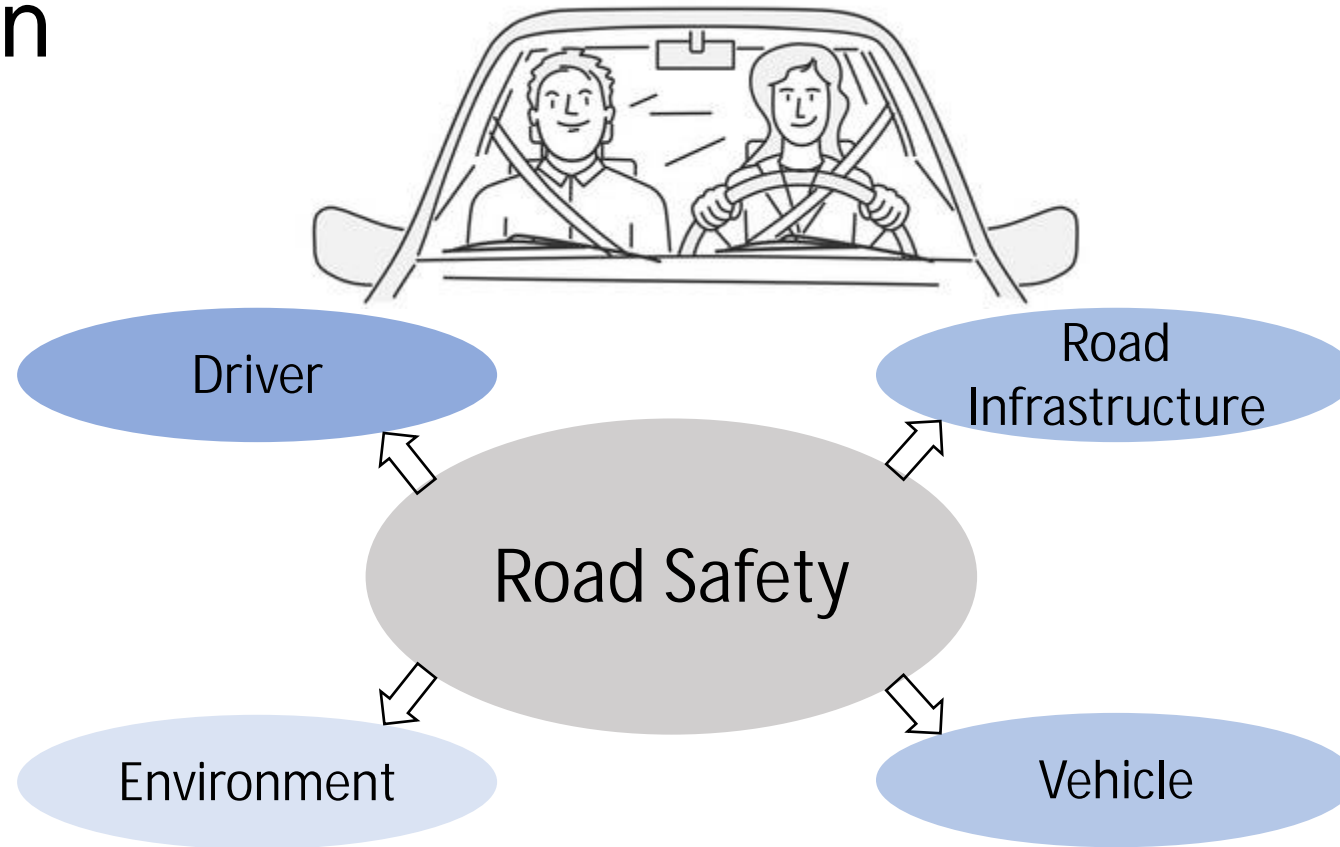


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# Introduction

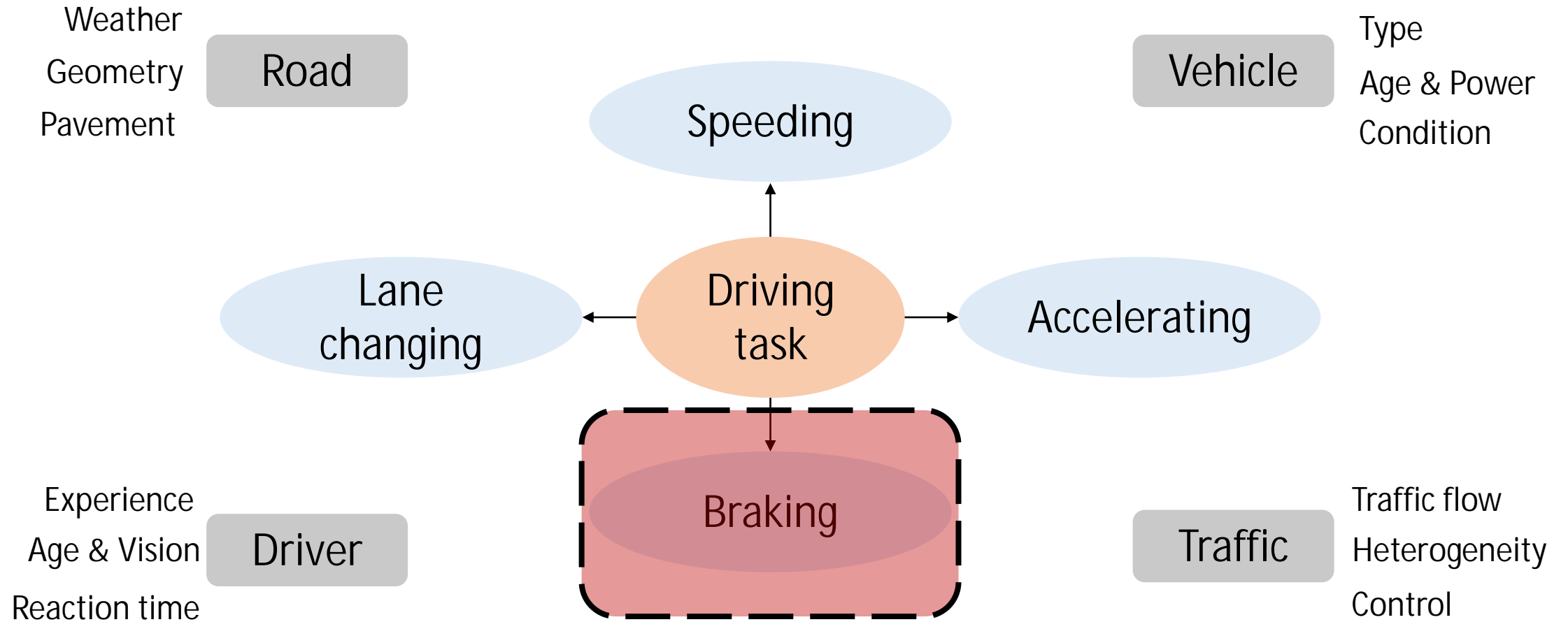


In India, 1.5 lakh deaths and 4.5 lakh injuries (MoRTH-2019)

82.5% of total accidents were due to the fault of the driver

Driver behavior is the major contributory factor (approx. 90%) of road crashes

# Introduction



Driving style – Habitual way of driving which characterizes driver

# Literature

- Driver behavior questionnaire (DBQ)  
(French et al., 1993; Taubman-Ben-Ari et al., 2004)
- Aggregated driving performance data  
(Constantinescu et al., 2010; Hong et al., 2014)
- Predefined thresholds of critical events  
(Johnson and Trivedi, 2011; Mantouka et al., 2019; Murphey et al., 2009)
- Continuous driving profiles  
(Chen and Chen, 2019; Higgs and Abbas, 2014; Yarlagadda et al., 2021)

# Research Gaps

Drivers are classified based on pre-defined thresholds aggregated over entire trip (aggregated statistical features of drive data)

The driving style/pattern is assumed to be uniform throughout the driving period

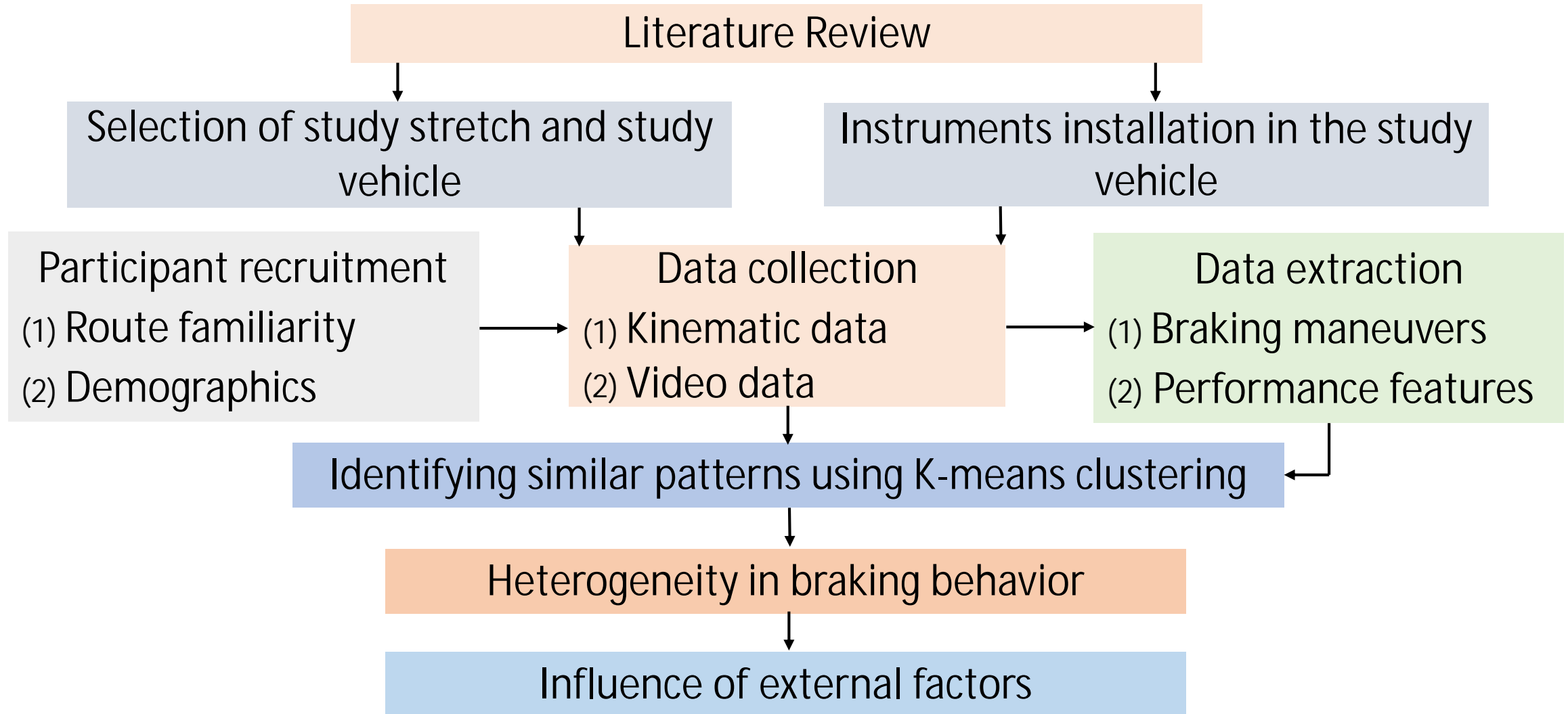
Characterization of driving styles was presented in a holistic manner combining the nature of different maneuvers

Definitive approach of understanding the behavior in a particular driving regime is less explored

# Objectives

- 1 To segment the driving profiles into events of braking maneuvers, and extract the respective performance feature data
- 2 To identify various braking patterns and present the behavioral heterogeneity
- 3 To explore the associations between identified braking patterns and the external influencing factors

# Methodology





# Data Collection

## Study area

- Four-lane divided (NH-65) (near Hyderabad city) – 23 km
- Rural (11 km), Suburban (12km)
- Intersections -12, Mid-block openings – 13

## Instruments

Video VBOX Pro – 10Hz  
Position – Latitude & Longitude  
Kinematic data – Speed, longitudinal & lateral acceleration, and heading  
Video data – Synchronized video data of four camera views

## Study Stretch

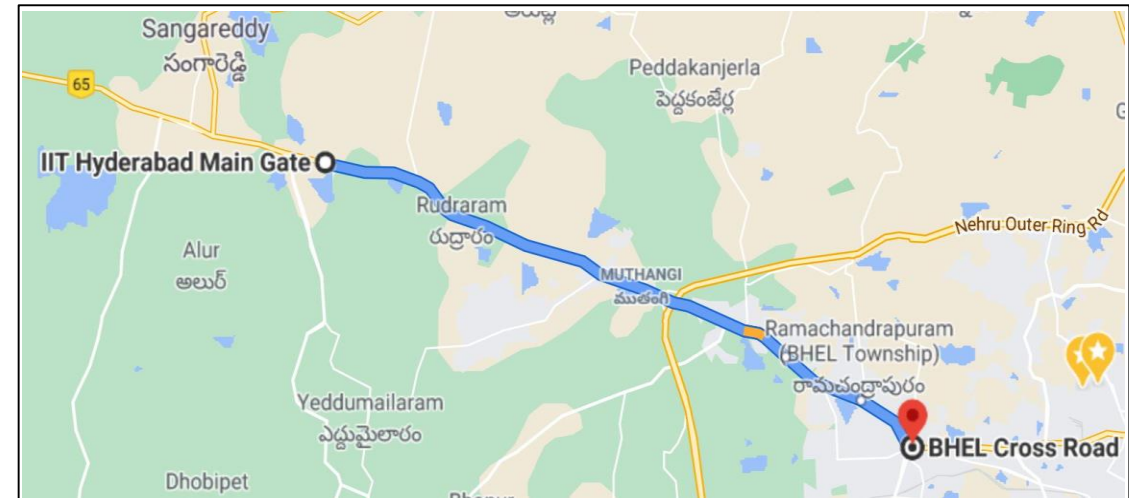


Figure 1. The study route, NH-65, India  
Source: Google Maps (2022)

- Average duration of each trip is 40 minutes
- Total 15 drivers – Two trips each

# Data Acquisition System

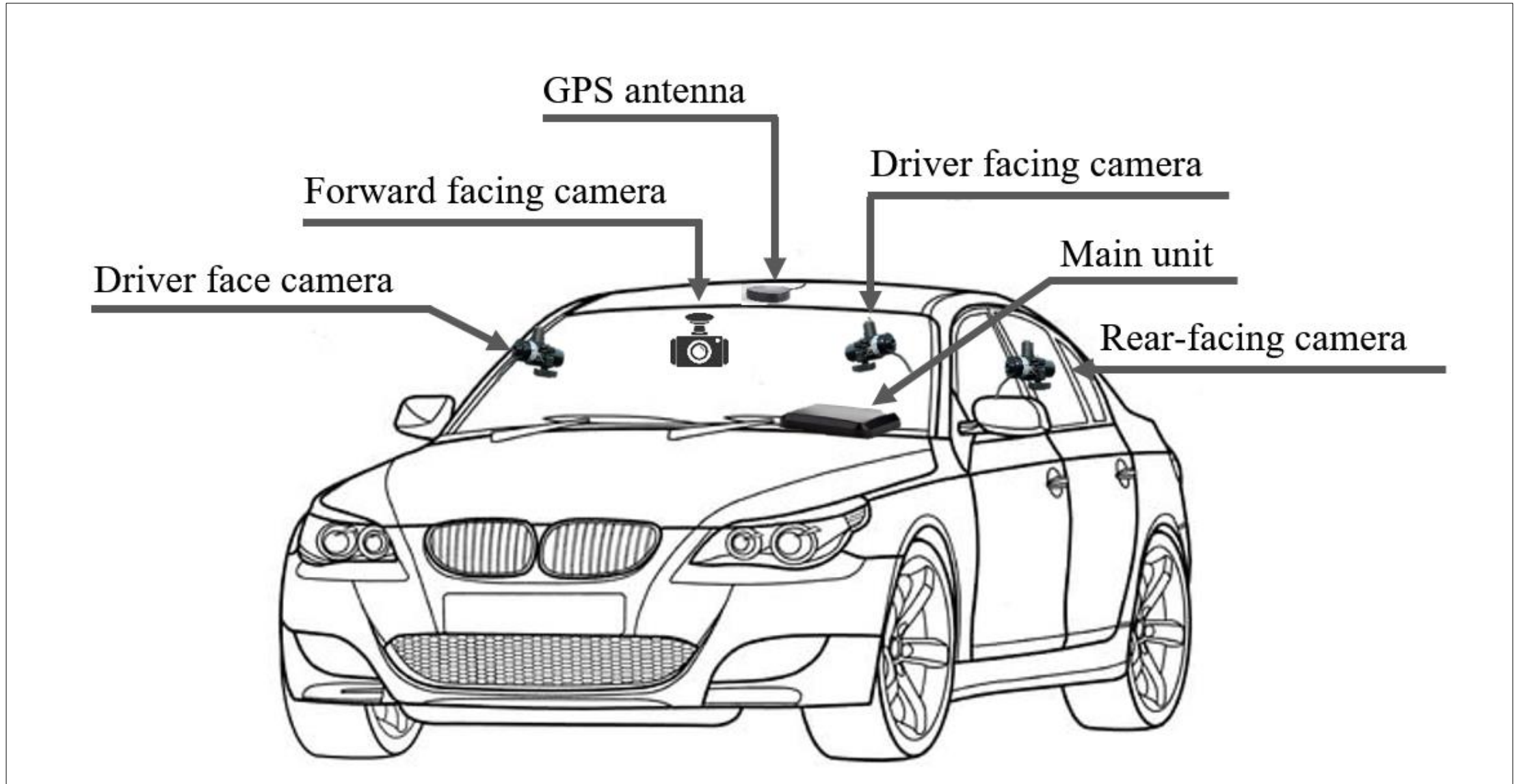


Figure 2. Instrumentation details

# Data Acquisition System



Figure 3. Study vehicle; Snapshots of collected video data; Recorded speed and acceleration profiles

# Data Extraction

## Stage-1

Insignificant maneuvers are eliminated

- Free-decelerations ( $<0.5$  g)
- Congested events ( $<15$  kpmh speed)
- Low-deceleration braking maneuvers ( $< 0.2$  g)

Total braking events - 995

## Stage-2

For each identified braking maneuver: The corresponding road Geometry, traffic condition, type of lead/crossing vehicle & state of driver distraction are extracted from video data

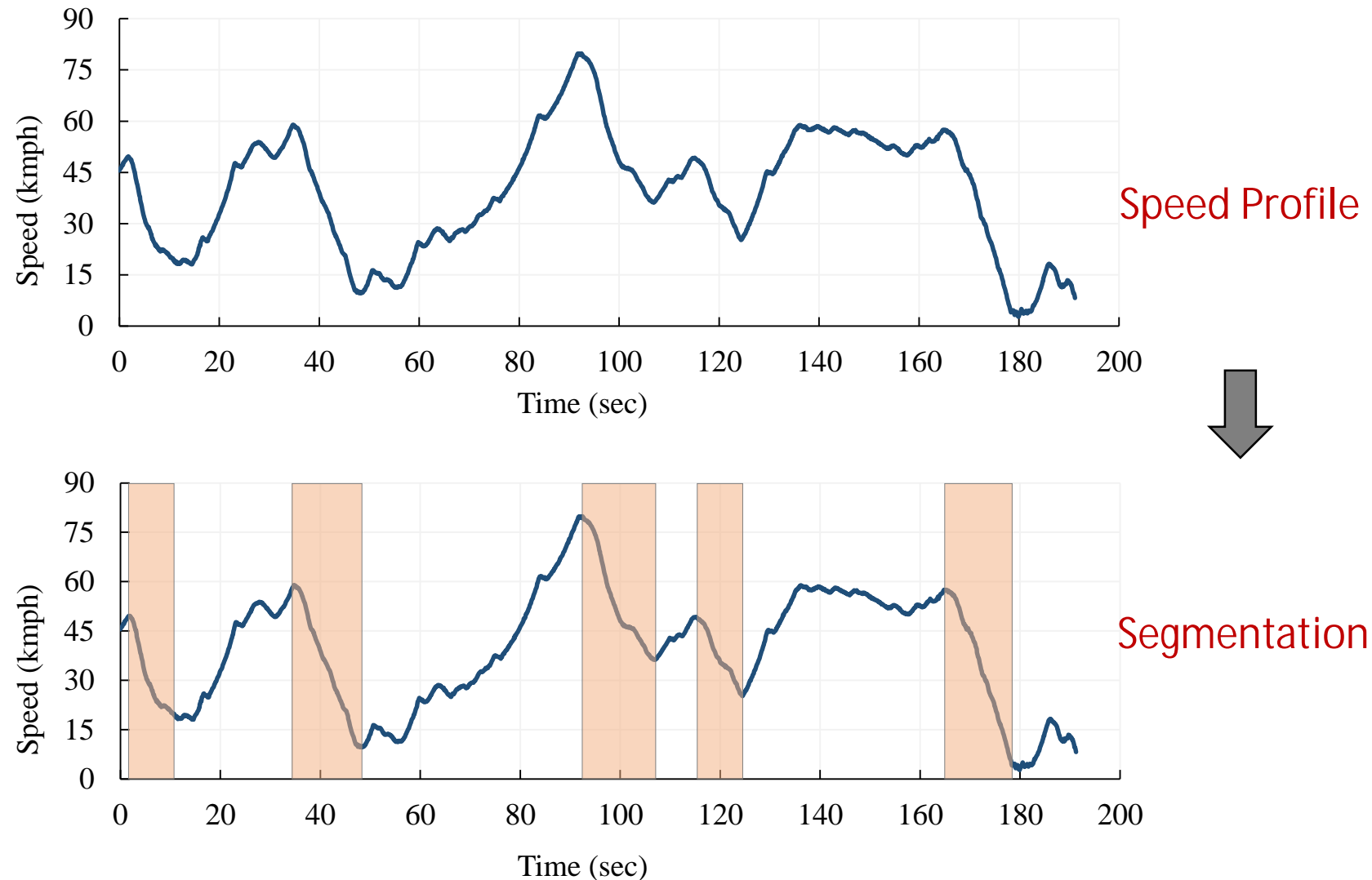


Figure 4. Illustration of event segmentation process

# Data Extraction

Table 1. Characteristic features of braking events

Feature Description	Variable	
Minimum speed (kmph)	$V_{min}$	Group-1 Speed choices
Maximum speed (kmph)	$V_{max}$	
Mean speed (kmph)	$V_{mean}$	
Standard deviation of speed	$V_{sd}$	
Maximum longitudinal deceleration (g)	$LA_{min}$	Group-2 Braking nature
Mean longitudinal deceleration (g)	$LA_{mean}$	
Standard deviation of longitudinal deceleration	$LA_{sd}$	

As the units of features are not uniform, the data is scaled prior analysis using Z-score standardization technique



# Silhouette analysis

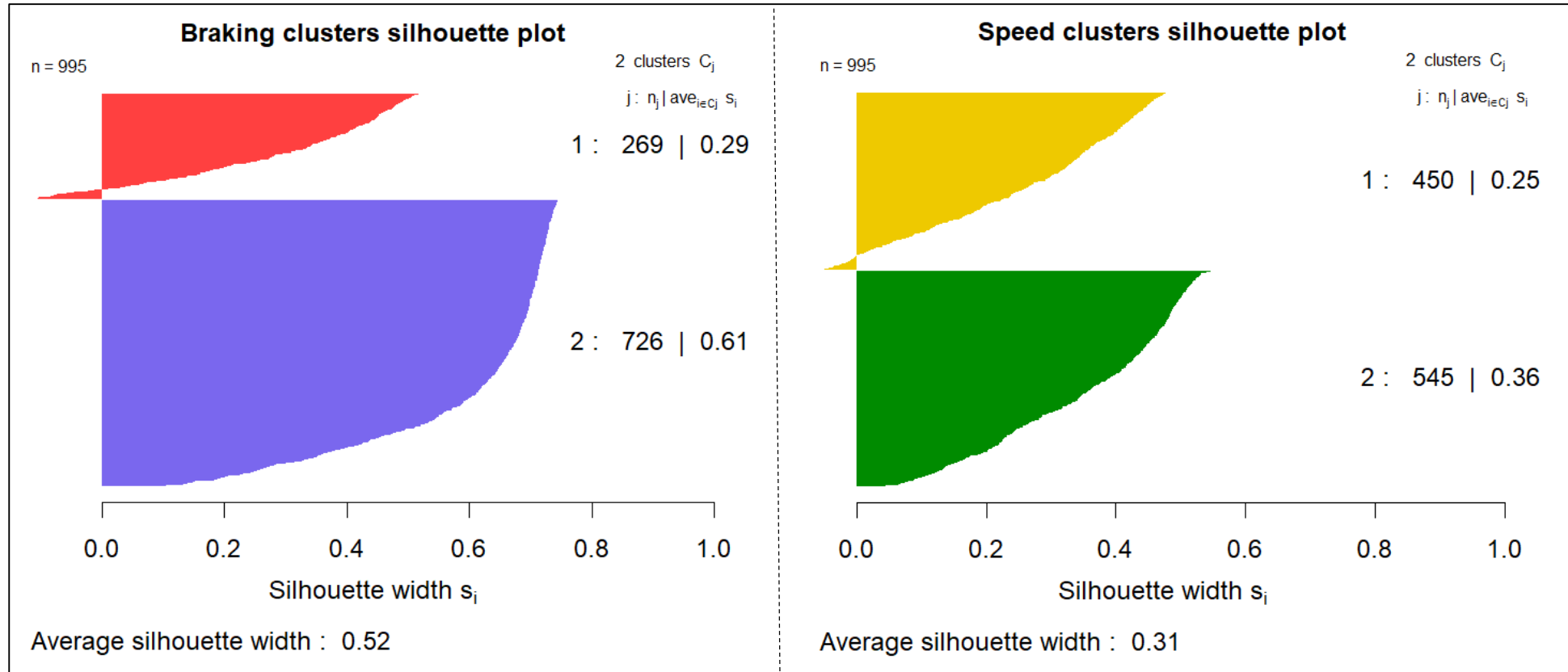


Figure 5. Silhouette plots of braking and speed clusters

- Silhouettes represent the compactness and separation of each cluster (how close each data point in one cluster is to the data points in neighboring clusters)
- Average silhouettes of all the clusters are positive showing well-separation from neighbor clusters

# K-means Clustering

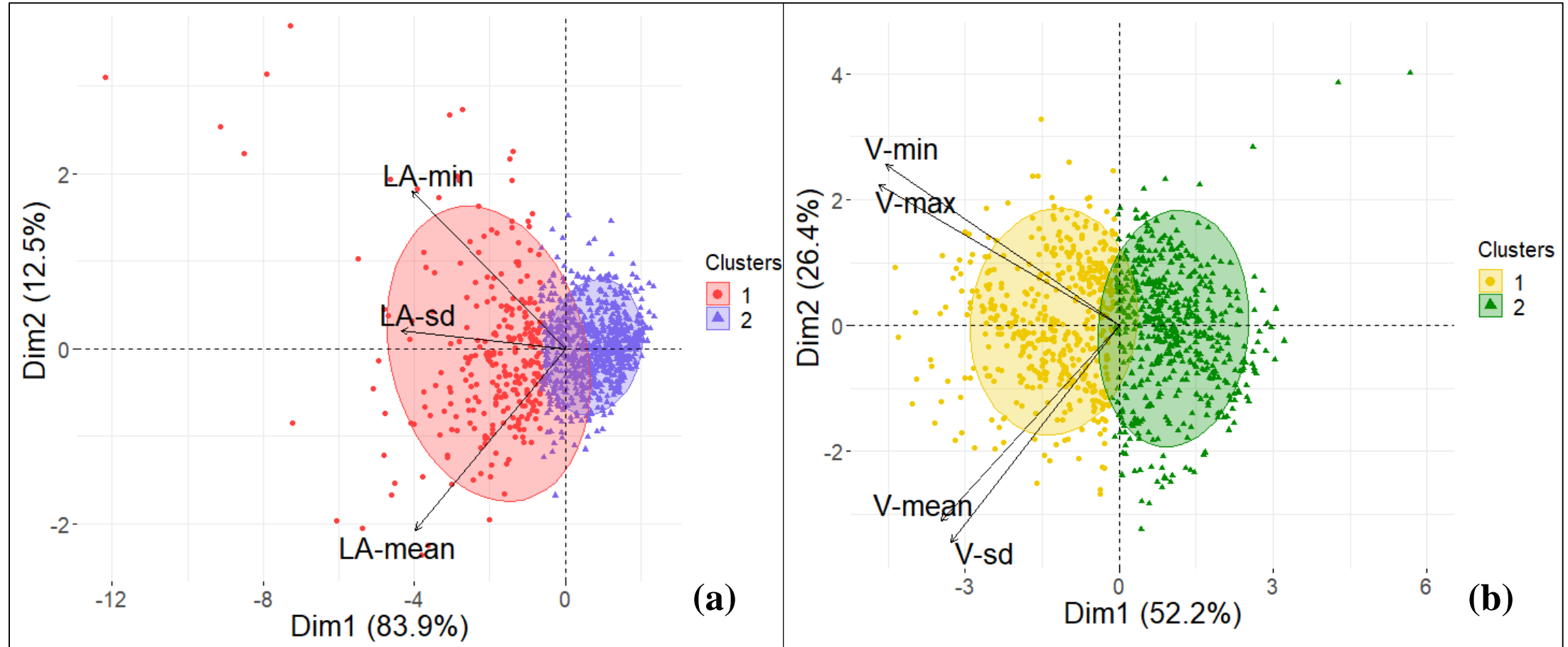


Figure 6. The bi-plots of (a) Braking clusters; (b) Speed clusters

# Clustering centroids

Table 2. Centroids of braking and speed clusters

Braking feature centroids					
Braking Clusters	$LA_{min}$	$LA_{mean}$	$LA_{sd}$	Classification	
1	0.38	0.14	0.09	Aggressive	
2	0.25	0.09	0.06	Non-aggressive	
Speed feature centroids					
Speed Clusters	$V_{max}$	$V_{min}$	$V_{mean}$	$V_{sd}$	Classification
1	65.78	44.59	54.24	14.28	High speed
2	40.83	18.88	31.34	16.29	Nominal

The identified clusters represent the distinctive braking patterns observed in the data without any prior ground truth



# Pattern Characterization

- Each event is associated with a specific braking cluster, and a speed cluster
- The combination of braking and speed clusters defines the nature of braking maneuver
- Total four driving patterns are identified considering all the possible combinations of the braking and speed clusters
- The driving patterns and the respective significance in road safety is shown below

Table 3. Braking pattern characterization

Patterns	Braking	Speed	Significance
P1	Aggressive	High	Fatal / high risky behavior
P2	Aggressive	Nominal	Rear-end collision tendencies
P3	Non-aggressive	High	Efficient driving skills
P4	Non-aggressive	Nominal	Base-line behavior

# Driver behavior heterogeneity

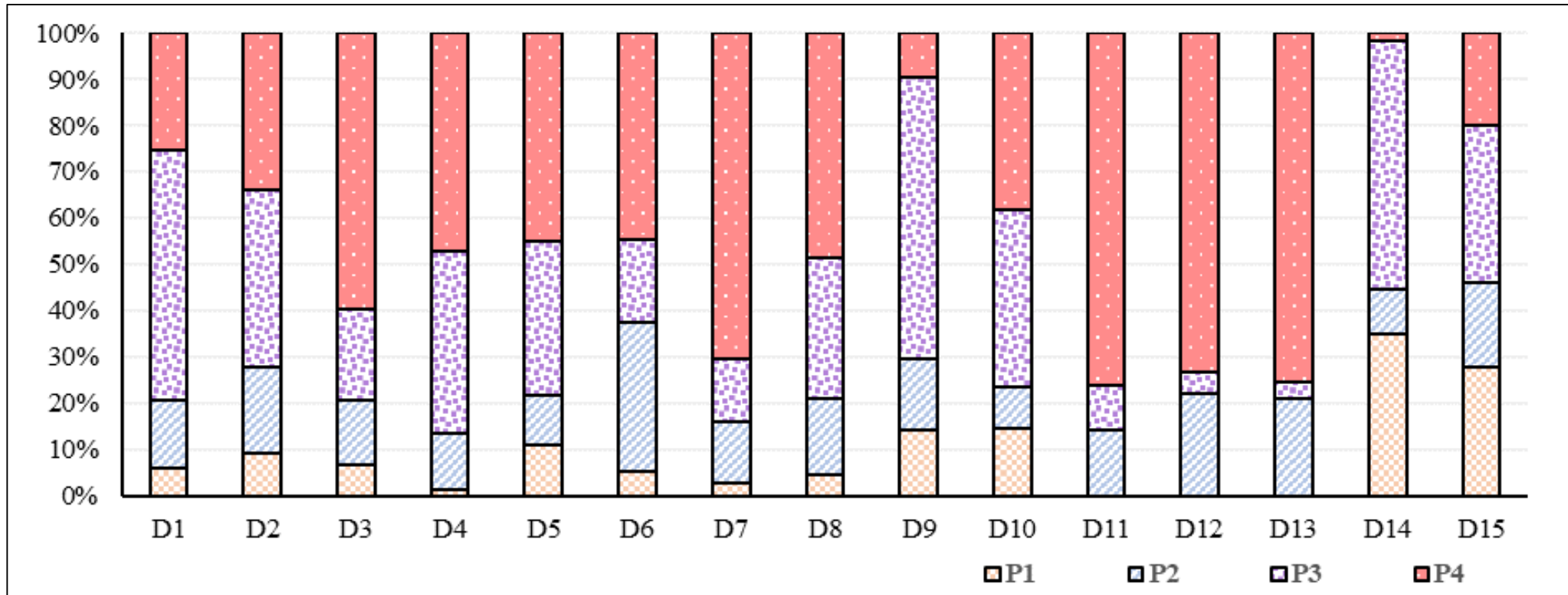


Figure 7. Proportions of driving patterns in individual driver

# Driver behavioral heterogeneity

- Individual drivers are exhibiting different driving patterns within the trip
- No driver was found to constantly exhibit a single driving pattern during the entire trip
- Each individual is showing a unique combination of driver aggression in braking and speed behavior
- Thus, the behavioral heterogeneity should be considered while assessing the driver, rather than characterizing the entire drive period as safe or unsafe

# Factors influencing driver behavior

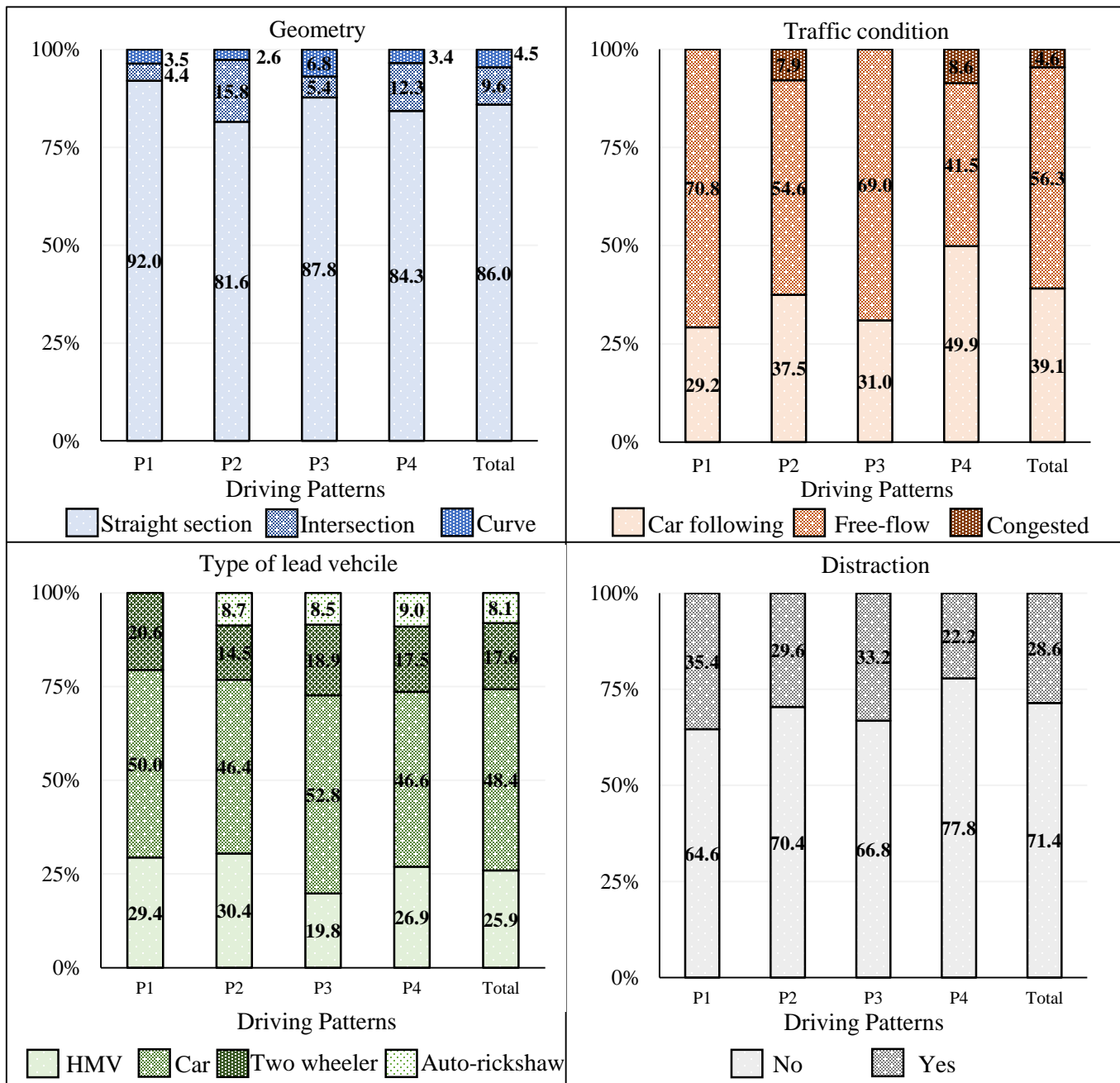
The correlations between different braking patterns and the external influencing factors are explored to identify the factors that influence driver behavior

Total four factors are considered in this study: the road geometry, traffic condition, type of lead/crossing vehicle, and presence of driver distraction

For each driving pattern, the proportion of events under various levels of external factor are computed

Also, the total proportions are computed, which indicates the dispersion of entire data against the levels of external factors

The overall composition (total) of each factor is considered as a benchmark to examine the break-down of proportion of events in each pattern



- The high risky behaviors appear to be happening more over straight sections, under free-flow conditions
- The drivers are observed to be exhibiting risky braking responses while following HMV and two-wheelers, compared to other vehicles
- Also, the distracted drivers are executing more-risky braking maneuvers

Figure 8. Proportions of events by levels of external factors

# Conclusions

The frequency of performing aggressive-high speed maneuvers or aggressive low-speed maneuvers or non-aggressive high-speed maneuvers, indicates different aspects of driver behavior

Aggressive-low speed maneuvers indicate more rear-end collision tendencies

Aggressive-high speed indicates fatal or high-risky nature

The non-aggressive high-speed maneuvers indicate efficient driving skills and driving stability.

The non-aggressive low-speed demonstrates the base-line behaviors

The identified at-risk behaviors may be further used to help drivers improve the way they drive

# Research Implications

- The identified aberrant behaviors in each driving period , helps in assisting drivers to improve the driving behavior
- Rather assigning a safe or unsafe labelling to the entire trip, this methodology shows the efficiency of NDS kinematic data in identifying the different driving patterns exhibited in longitudinal control

The correlation between the identified driving patterns and the road safety is the future scope of this study

Thank you