Leveraging Smartphone Telematics for Urban Traffic Safety: A Data-Driven Analysis of Unsafe Driving

Paraskevi Koliou
Dr., Transport Engineer

Together with:
George Yannis

Department of Transportation Planning and Engineering
National Technical University of Athens

12th European Conference on
Injury, Prevention and Safety Promotion
EU SAFETY 2025
1-2 October 2025 | Heraklion, Crete, Greece

EU | Safety 2025

Introduction

Research Significance

- **Road crashes** are a significant public health issue, with over **1.19** million annual fatalities worldwide.
- Current road safety measures show **slow progress**, necessitating **new** approaches for crash prediction and prevention.
- **Unsafe traffic events**, such as harsh accelerations and braking, occur more frequently and are easily obtainable using smartphone app data.
- **Leveraging real-time data** from smartphone sensors offers a proactive approach to traffic safety analysis and intervention.

Objectives

1. Explore the link between unsafe driving events (harsh braking/acceleration) and crashes

2. Identify high-risk junctions and driver behaviour

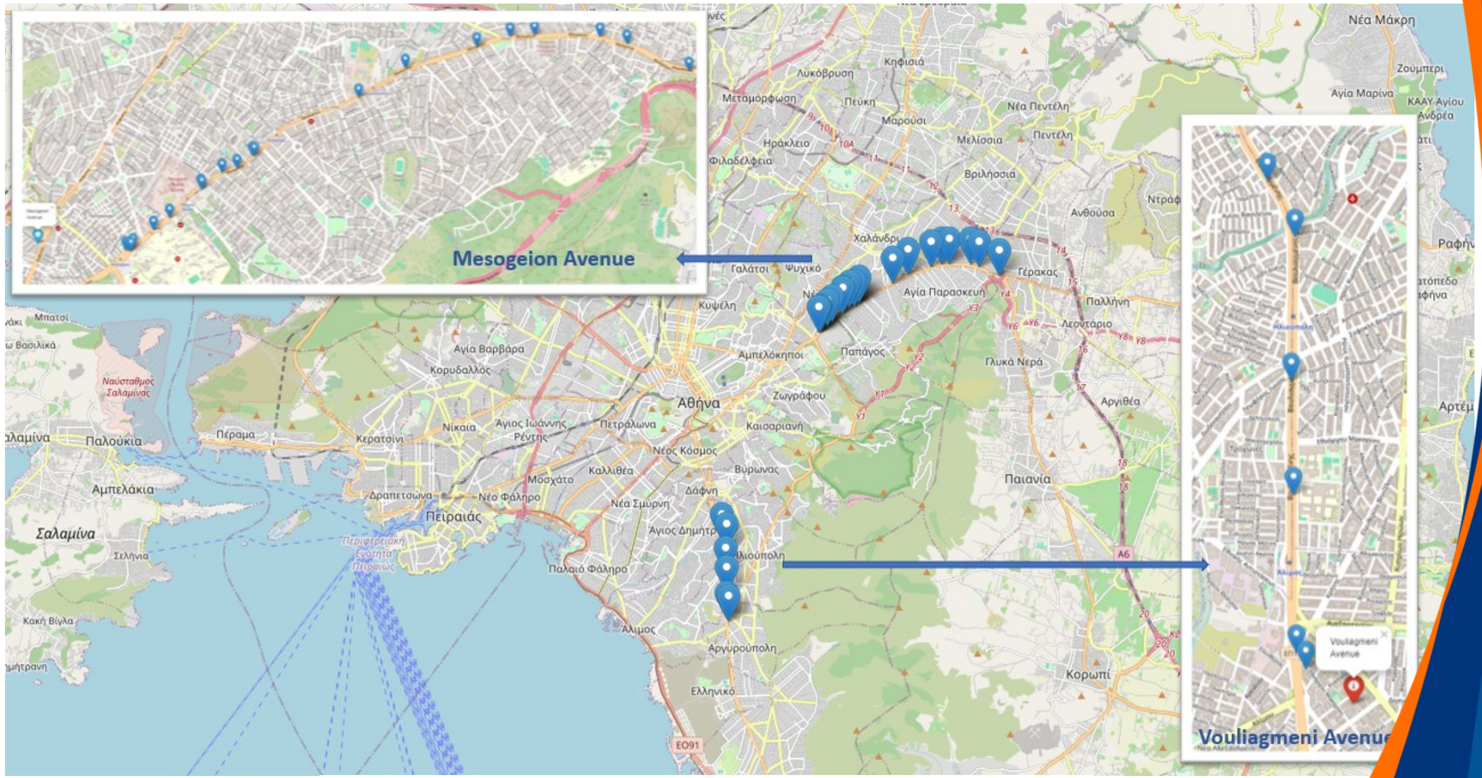
3. Develop predictive models to support targeted interventions

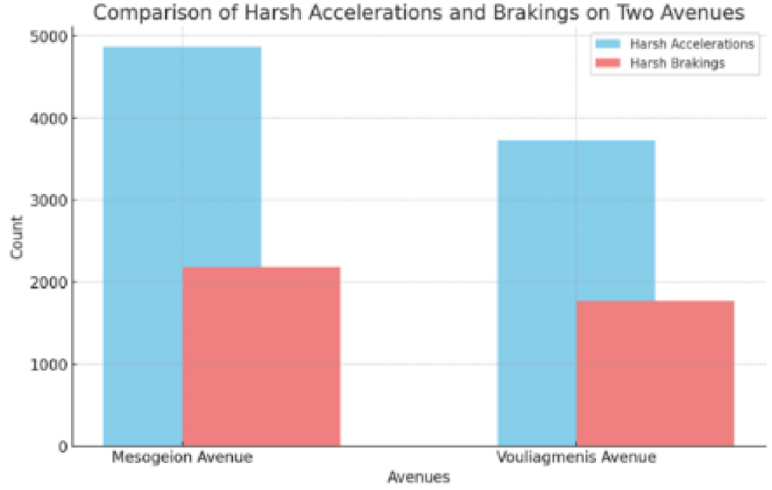
Data Sources

1. Driving Behavior Data: Collected from **~300 drivers in Athens** using the OSeven smartphone app (https://oseven.io), recording instances of harsh acceleration and braking, **12,500+ events.**

2. Traffic Metrics: Obtained from the Attica Traffic Management Center, **including traffic volume, average speeds, and occupancy rates.**

3. Road Characteristics: Extracted from Google Maps, detailing **lane configurations** and **intersection characteristics.**





Methodology

1. **Exploring** the relationship between **Unsafe Driving Events and Crash Occurrences:** Investigate how unsafe traffic events relate to crash rates.
2. **Leveraging Smartphone Data for Traffic Safety Analysis:** Utilise smartphone app data to gather detailed insights on driving behaviour, including GPS, speed, acceleration, and braking patterns.
3. **Identifying High-Risk Areas and Patterns:** Use clustering and spatial analysis methods to detect hotspots and patterns of unsafe driving behaviour.
4. **Developing Predictive Models for Crashes:** Employ advanced machine learning techniques, such as Gradient Boosting, to identify key predictors of crashes and create robust predictive models.
5. **Improving Road Safety Through Targeted Interventions:** Provide actionable insights for designing better road safety policies, improving infrastructure, and educating drivers on safer practices.
6. **Enhancing Analytical Frameworks:** Integrate advanced clustering, spatial, & feature importance analyses for a comprehensive, data-driven understanding of traffic safety challenges.

Summary of Key Techniques

Method	Techniques	Equations Used
Clustering	K-Means	$\text{WCSS} = \sum_{i=1}^{k} \sum_{x \in C_i} \|x - \mu_i\|^2$, where C_i is the i-th cluster, x is a data point, and μ_i is the cluster centroid.
	DBSCAN	$N(p) \geq \text{min\_samples}$, where $N(p)$ is the number of points in the ε-neighborhood of p.
	Hierarchical Clustering	Distance: $d_A(x_i, x_j) = \sqrt{\sum_{k=1}^{p}(x_{ik} - x_{jk})^2}$, Linkage: $d_A(x_i, x_j) = \min\{d(x_i, x_j) : x_i \in A, x_j \in B\}$.
Spatial Analysis	Local Moran's I	$I_i = \frac{z_i}{m^2} \sum_{j=1}^{n} w_{ij} z_j$, where z_i and z_j are deviations from the mean, and w_{ij} is the spatial weight.
	Local Geary's C	$C_i = \frac{1}{2m^2} \sum_{j=1}^{n} w_{ij}(x_i - x_j)^2$, where x_i and x_j are feature values, and w_{ij} is the spatial weight.
Machine Learning	Random Forest	Feature Importance: $\text{Importance}(X_j) = \frac{1}{T} \sum_{t=1}^{T} I_t(X_j)$, where T is the number of trees, and $I_t(X_j)$ is the importance of feature X_j in tree t.
	Gradient Boosting	Boosting minimizes: $L(y, f(x)) = \sum_{i=1}^{n} l(y_i, f(x_i))$, where l is the loss function and $f(x)$ is the prediction function.
Dimensionality Reduction	PCA	Projection: $X_{\text{normalized}} = \frac{X - \mu_x}{\sigma_x}$, Eigenvector Decomposition: Data projected on components with largest eigenvalues.

Research Results

- **Clustering:** 3 junction profiles; Cluster 1 = high braking + high crash incidence.
- **Predictors:** **Speed variability + braking metrics** (Prob_Brk, Mod_Freq_Brk) = **strongest crash predictors** (>80% importance).
- **Hotspots:** Specific junctions (JM1, JM14, JM17, JV9) identified.
- **Insights:** **Driver behaviour** outweighs road design/traffic volume in crash risk.

Figure 1: DBSCAN and K-Means Clustering Results

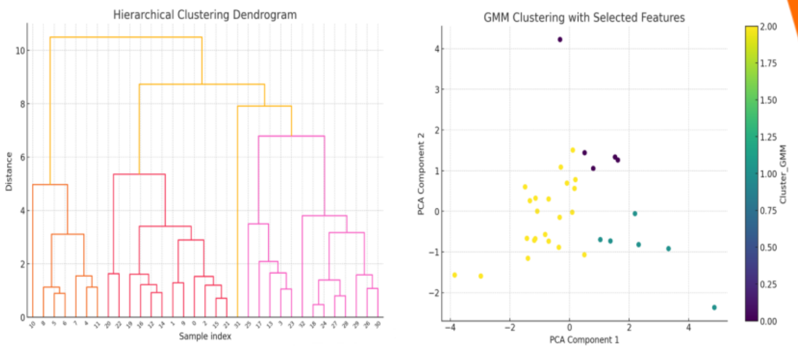


Figure 2: Hierarchical Clustering and Gaussian Mixture Models (GMM)

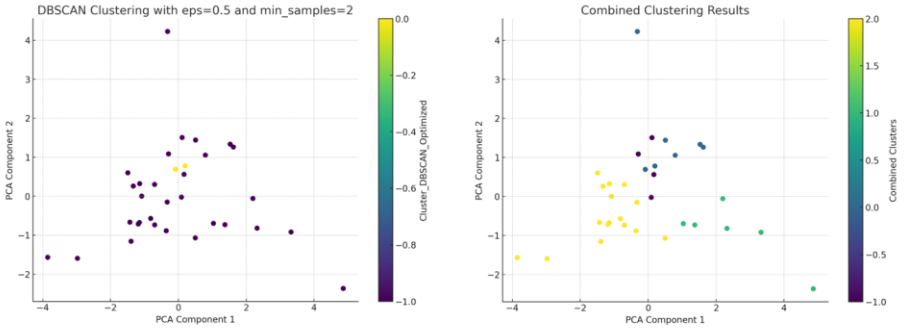
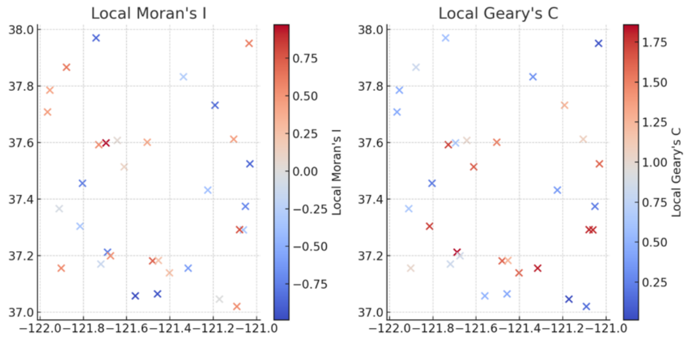


Figure 3: DBSCAN with expanded parameter range and Combined clustering analysis results



Junctions	Latitude	Longitude	UnsafeEvents	Local_Moran_I	Local_Geary_C
JM1	37.374540	-121.051114	7.618182	-0.718152	0.215783
JM14	37.212339	-121.688289	4.584000	-0.768262	1.859395
JM17	37.304242	-121.815146	3.770667	-0.338204	1.742921
JM21	37.611853	-121.105173	3.719540	0.459212	1.078684
JV9	37.065052	-121.457304	5.548628	-0.949162	0.444216

Figure 4: Significant Clusters and Outliers based on Local Moran's I and Local Geary's C values.

Conclusions

1. **Driving Behaviour:** Speed variability and aggressive braking behaviour (e.g., harsh braking) are strong predictors of crashes.

2. **Braking Metrics**: Probability of braking and frequency of harsh braking are among the most critical factors influencing unsafe driving events.

3. **High-Risk Areas:** Using spatial analysis tools specific junctions were identified as high-risk areas.

4. **Cluster Analysis:** Advanced clustering methods revealed distinct patterns of unsafe driving events, highlighting hotspots and spatial outliers.

Leveraging Smartphone Telematics for Urban Traffic Safety: A Data-Driven Analysis of Unsafe Driving

Paraskevi Koliou

Dr., Transport Engineer

Together with:

George Yannis

Department of Transportation Planning and Engineering
National Technical University of Athens

Contact Information:
Dr. Paraskevi Koliou, Research Associate, NTUA
Department of Transportation Planning and Engineering
Email: evi_koliou@mail.ntua.gr
Website: https://www.nrso.ntua.gr/p/evikoliou/

EU | Safety 2025