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Enhancing Urban Road Safety Resilience: A Data-Driven Approach Using Telematics, Machine Learning, and Geospatial Analysis

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Introduction

Road safety remains a critical global issue, with over **1.19 million deaths** annually. In Europe, progress is uneven, despite initiatives like the EU Vision Zero aiming to halve road deaths by 2030.

Traditional crash-based analyses are retrospective and limited by **underreporting** and low **data granularity**, requiring crashes to occur before action is taken.

Smartphone-based telematics enable a proactive shift by capturing frequent unsafe driving events, like harsh braking, rapid acceleration, and speeding, as surrogate safety indicators.

This study explores how these unsafe events relate to crash occurrences at **478 intersections** in central Athens, leveraging:

- Telematics data from smartphone apps
- Police-reported crash records
- Machine learning models (e.g., XGBoost, Random Forests)

The goal is to classify intersections by crash risk and identify urban **hotspots** for **proactive safety interventions and data-driven policymaking.**

Objectives

1. **Classify and predict safe vs. unsafe** road segments using telematics and crash data.
2. **Identify behavioral risk factors** (speeding, harsh braking, harsh acceleration).
3. **Generate geospatial risk maps** for targeted safety interventions.
4. **Propose data-driven strategies** to enhance resilience in urban road networks.

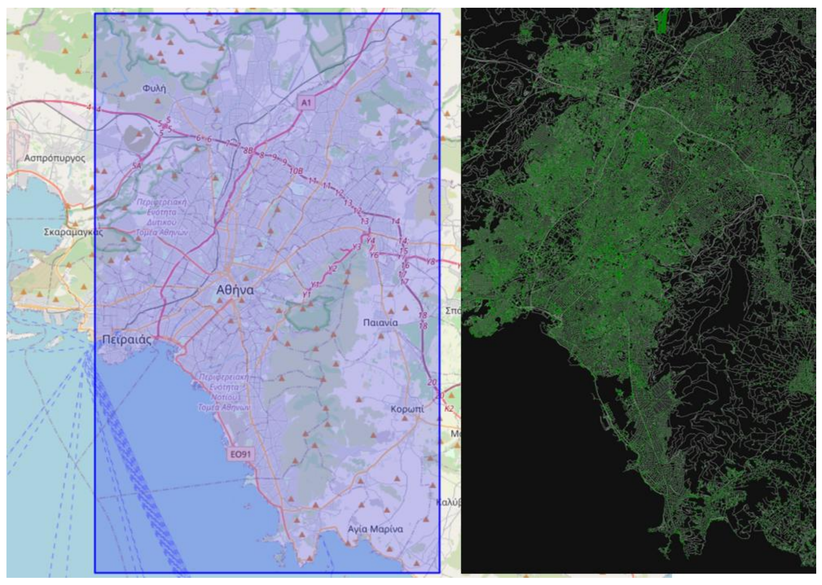


Figure 1: *Study network of Athens, used for OSM data.*

Methodology

1. Study Area

- Location: Central Athens, Greece
- Scope: 478 urban intersections

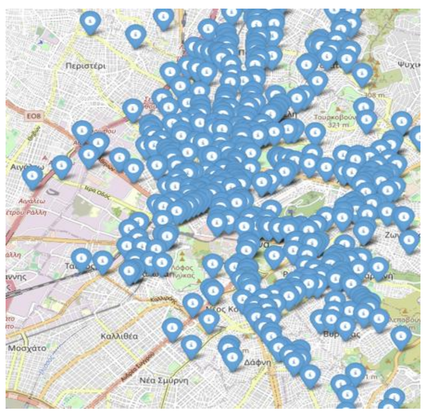


Figure 2: *Plot of Crashes that occurred in segments on a Folium Map.*

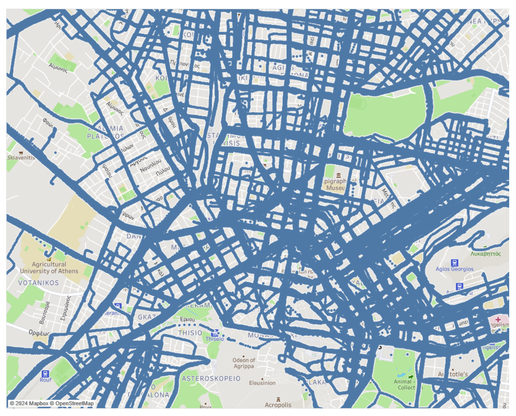


Figure 3: *Telematics data collected in Athens urban roads.*

2. Data Sources

- Telematics Data:
  - Collected via smartphone apps
  - 2,614 trips from 257 drivers (harsh braking, acceleration, speeding)
- Crash Data:
  - Greek Traffic Police records, Geocoded historical crashes
  - Linked by segment and street name
- Geospatial data: Road networks from OpenStreetMap (processed via OSMnx).

3. Data Processing

- Mapped crash incidents to road segments.
- Derived behavioral risk metrics
- Normalised data for fair comparisons across different road segments

4. Feature Engineering

- Computed Metrics:
- Harsh Braking Ratio, Harsh Acceleration Ratio, Speeding Ratio, Number of Lanes

5. Predictive Modelling Approach

- XGBoost classifier for crash risk prediction.
- SMOTE to handle imbalanced datasets (safe >> unsafe).

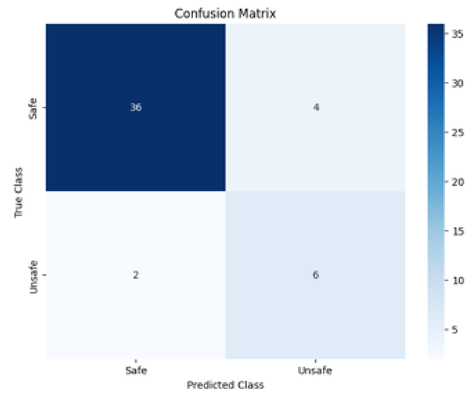
6. Model Evaluation

- Metrics Used: Accuracy, Precision, Recall, F1-Score
- Confusion Matrix analysis to assess performance

Results

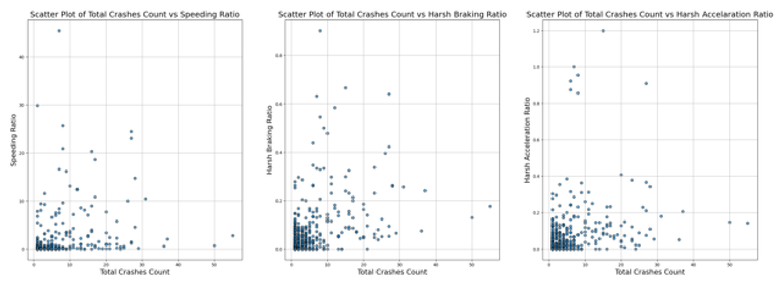
1. Model Performance:

- Accuracy: 88%.
- Precision: Safe = 95%, Unsafe = 60%.
- Recall: Safe = 90%, Unsafe = 75%.
- F1-score: Safe = 92%, Unsafe = 67%.



2. Key Behavioral Insights:

- Harsh braking → high on Kifisias & Piraeus Streets.
- Speeding → frequent on Thiseos & Lavriou Streets.
- Aggressive acceleration → concentrated on Petrou Ralli & Athinon Streets.



3. Visualization Evidence:

- Confusion matrix shows classification reliability (safe vs unsafe).
- Scatter plots confirm correlations between crashes and risk factors (speeding, braking, acceleration).
- Geospatial Risk Mapping: High-risk intersections and corridors highlighted via heatmaps.

Conclusions

1. Telematics, Machine Learning and GIS provides a **proactive approach** to road safety.
2. Unsafe driving behaviors (speeding, braking, acceleration) **strongly predict crash risk**.
3. Predictive models assist policymakers in **targeted interventions** (adaptive speed limits, enforcement, calming measures).
4. This framework **strengthens urban road safety resilience.**
5. **Future work:** Expand with environmental data (weather, pedestrian density), validate across diverse cities, and integrate real-time monitoring.

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