Predicting Pedestrian Violations in Urban Intersections: A Comparison of Random Forest and XGBoost Models

Stella Roussou
PhD Candidate, Research Associate

Together with:
Apostolos Ziakopoulos and George Yannis

Department of Transportation Planning and Engineering
National Technical University of Athens

Road Safety on Five Continents
20th international RS5C conference
Leeds, UK from 3–5 September 2025

Background

- Human behavior, road characteristics (design and condition of roads), vehicle safety standards, environmental factors, and socioeconomic differences are some of the complex factors that contribute to road incidents.
- A dynamic but often hazardous urban environment is created due to the co-existence of vehicles, pedestrians, and vulnerable road users (cyclists, scooters, children, etc.).
- In Athens, Greece, there is high pedestrian activity combined with limited traffic monitoring infrastructure.
- Illegal crossings at signalized intersections increase the risk of crashes.
- To confront this issue, computer vision and video recognition technologies are providing tools and methods to monitor and analyze traffic, and in this way, becoming fundamental techniques for road safety.
- The present research was carried out within the research project “PHOEBE - Predictive Approaches for Safer Urban Environment”.

Objectives

- Real-Time Detection & Tracking with YOLOv8 + ResNet-50:
  - Accurate, real-time detection of pedestrians and vehicles.
  - Enables traffic monitoring even in cities lacking integrated surveillance infrastructure, like the city of Athens.
- Analyze pedestrian behavior at two congested intersections.
- Predicting Pedestrian Violations using Machine Learning Models.
- Evaluate and compare Random Forest and XGBoost performance for pedestrian violation prediction.
- Enhance urban traffic safety by integrating AI with object detection and predictive analytics.

Data Collection

- Video footage captured manually at 2 locations:
  - The end of Panepistimiou Street, Athens - a critical urban corridor connecting Syntagma and Omonoia Squares, and
  - Panepistimiou & Vasilissis Sofias – an important street of a high pedestrian used junction.
- Smartphone cameras with tripods are used to overcome the lack of fixed infrastructure.

Projected Object Behavior Analysis

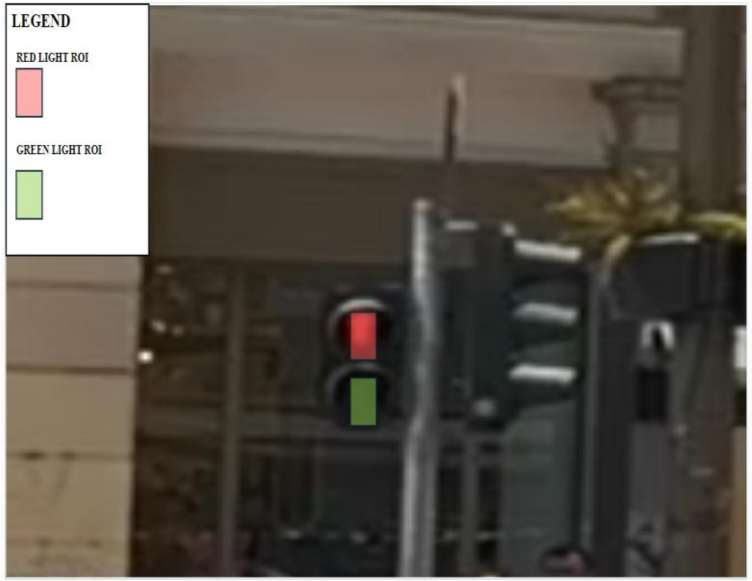
- The algorithm checks their positions relative to Regions of Interest (ROI), which define critical areas such as crosswalks or traffic light positions.
- If a pedestrian is found inside the crosswalk during a pedestrian red traffic light, their behavior is flagged as illegal.
- Similarly, vehicles entering the crossing area during a pedestrian green traffic light are flagged as illegal.

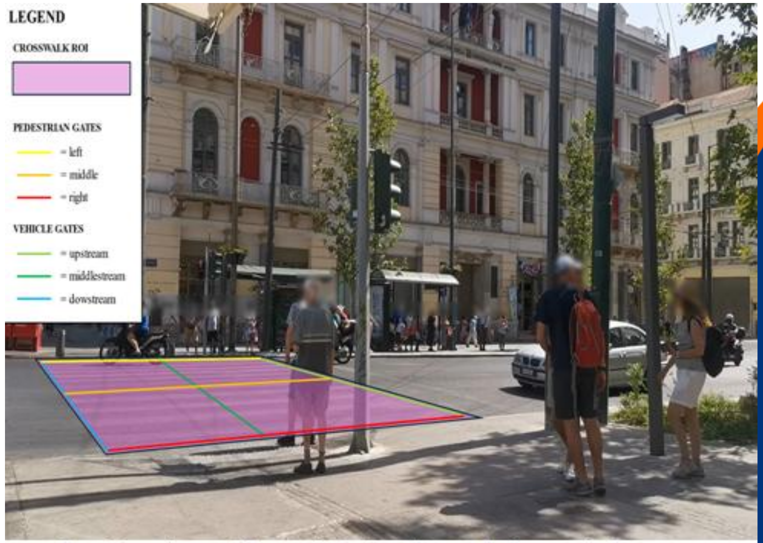
Tracking Area of Panepistimiou & Vasilissis Sofia's Street

Video Detection Framework

The system uses a multi-step tracking logic including:

- **Object detection YOLOv8** detector, which is a neural network-based object detection framework, detecting objects including pedestrians and vehicles.
- **ResNet-50 and Re-Identification** network in order to maintain consistent tracking of objects across multiple frames.
- The **Hungarian Algorithm** for matching the detected objects to the tracked ones, which is crucial for maintaining consistent identities.
- **Kalman filter-based prediction**, which tracks continuous movement, as objects can become occluded or temporarily disappear from the scene (e.g., a pedestrian walks behind a vehicle).
- The **traffic light detection** component isolates the regions corresponding to the traffic lights using Regions of Interest (ROIs) and applies **color segmentation** to determine whether the light is red or green.





Tracking Area of Panepistimiou Street & Omonoia Square

Modeling Approach

- Two ensemble classifiers—Random Forest (RF) and XGBoost—were trained on pedestrian behavior data to detect illegal crossings.
- Features: pedestrian/vehicle coordinates and speeds, traffic light status, and TTC.
- Undersampling to address class imbalance.
- Train/test split: 80/20 + Grid Search for tuning.
- Metrics: accuracy, precision, F1-score, and both models were evaluated separately for the 2 intersections locations.

Results – Omonoia Square

- Simpler environment.
- Random Forest achieved ~83% accuracy.
- By contrast, XGBoost significantly outperformed RF, reaching an accuracy of 93%.
- XGBoost needed 30% longer training time.

- XGBoost optimal settings: 100 estimators, depth at 10, learning rate at 0.1, and subsample = 0.8.
- RF was optimized with: 200 trees, depth at 15, and minimum samples per split = 10.

Table 1: *Classification Report for XG Boost Model*

Metric	Class 0 (No Violations)	Class 1 (Violations)	Macro Average	Weighted Average
Precision	0.96	0.93	0.95	0.95
Recall	0.93	0.96	0.95	0.95
F1-Score	0.95	0.95	0.95	0.95

Table 2: *Classification Report for Random Forest Model*

Metric	Class 0 (No Violations)	Class 1 (Violations)	Macro Average	Weighted Average
Precision	0.87	0.80	0.84	0.84
Recall	0.78	0.88	0.83	0.83
F1-Score	0.82	0.84	0.83	0.83

Results – Panepistimiou Street

- Congested and dynamic environment.
- The Random Forest model achieved an overall accuracy of 88%.
- While it demonstrated strong precision for the majority class (96%), its performance in detecting violations (minority class) was lower, with 55% precision, 68% recall, and an F1-score of 61%.

Table 1: *Classification Report for Random Forest Model*

Metric	Class 0 (No Violations)	Class 1 (Violations)	Macro Average	Weighted Average
Precision	0.96	0.55	0.76	0.92
Recall	0.91	0.68	0.79	0.88
F1-Score	0.93	0.61	0.77	0.89

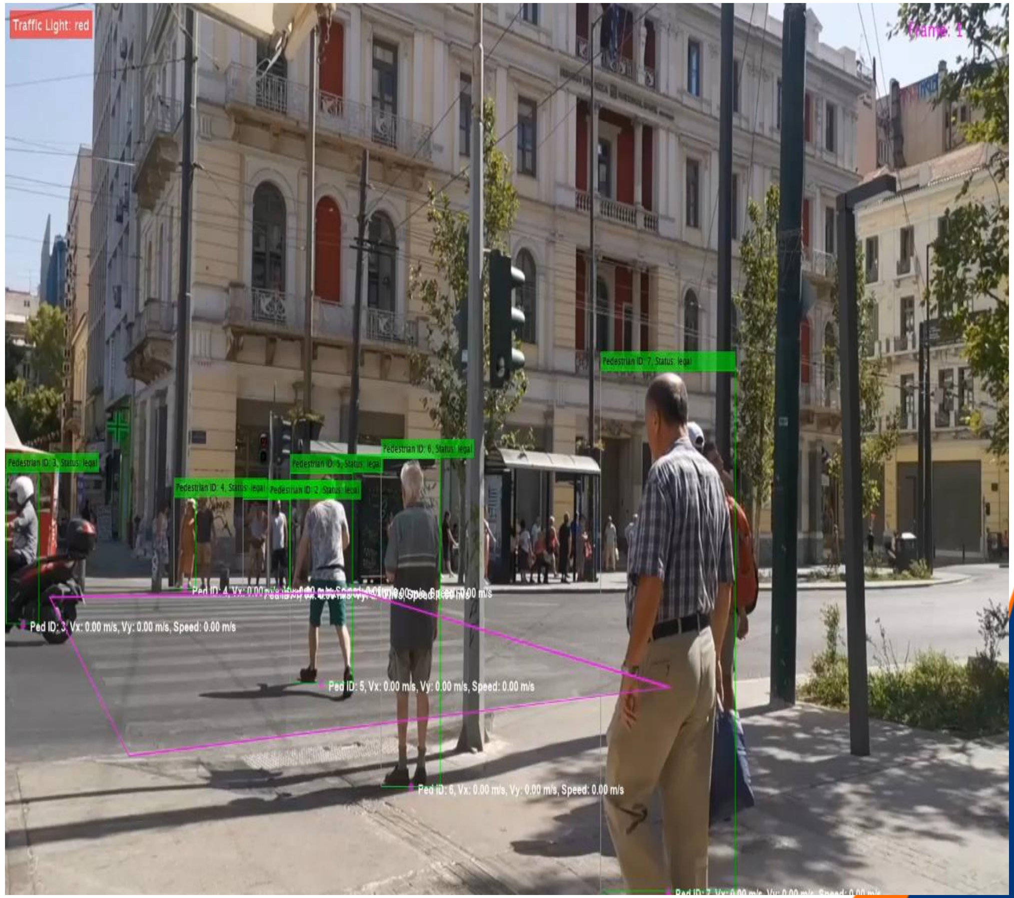
- By contrast, XGBoost significantly outperformed RF, reaching an accuracy of 93%. For the minority class, it achieved 72% precision, 88% recall, and an F1-score of 79%.

Table 2: *Classification Report for XG Boost Model*

Metric	Class 0 (No Violations)	Class 1 (Violations)	Macro Average	Weighted Average
Precision	0.96	0.72	0.84	0.93
Recall	0.95	0.88	0.91	0.93
F1-Score	0.96	0.79	0.87	0.93

Discussion

- The simpler environment of Omonia Square allowed both models to perform well, but XGBoost clearly outperformed Random Forest (93% vs. 83% accuracy).
- In contrast, Panepistimiou Street (congested and dynamic) challenged both models more, highlighting the importance of environmental complexity in predictive performance.
- XGBoost required longer training time compared to Random Forest, but the improvement in predictive accuracy and class balance may justify the computational cost.
- For real-world applications (e.g., real-time monitoring), this trade-off must be carefully considered.
- The stronger detection of violations by XGBoost suggests it can be more reliable in early-warning systems and policy evaluations where accurately identifying risky pedestrian behavior is crucial.



Conclusions & Future Work

- **Both models effective** for predicting pedestrian violations.
- Useful for integration into urban safety systems.
- Future: **expand features (e.g. PET),** test scalability across cities.
- Findings support the use of machine learning for:
  - Monitoring pedestrian violations.
  - **Enhancing traffic light compliance**.
- Future research directions:
  - **Incorporate contextual data** (weather, road layout and pedestrian demographics).
  - Validate models with larger and more diverse datasets in field conditions.

Predicting Pedestrian Violations in Urban Intersections: A Comparison of Random Forest and XGBoost Models

Stella Roussou

PhD Candidate, Research Associate

Together with:

Apostolos Ziakopoulos and George Yannis

Department of Transportation Planning and Engineering

National Technical University of Athens

Road Safety on Five Continents

20th international RS5C conference

Leeds, UK from 3–5 September 2025