AI-Powered Tracking and Analysis of Pedestrian and Vehicle Behaviours with Time-to-Collision Estimation

Roberto Ventura[a]*, Stella Roussou[b], Apostolos Ziakopoulos[b], Benedetto Barabino[a], and George Yannis[b]

[a] *Department of Civil, Environmental, Architectural Engineering and Mathematics (DICATAM) - University of Brescia - Via Branze, 43 – 25123 Brescia (Italy).*

[b]*Department of Transportation Planning and Engineering - National Technical University of Athens (NTUA) - 5, Iroon Polytechniou - GR-15773 Athens (Greece).*

Abstract

The integration of Computer Vision techniques has greatly advanced road safety analysis, particularly in assessing traffic conflicts and near-miss events, typically measured through Surrogate Safety Measures (SSM). Nonetheless, there are still gaps in the literature regarding integrating multiple advanced models, real-world coordinate mapping, and comprehensive behavioural analysis within a unified framework. This study addresses these challenges by introducing an advanced detection and tracking algorithm to monitor pedestrian and vehicle behaviours in complex urban environments, with a particular focus on interactions with traffic signals Time-to-Collision (TTC) estimation, and Post Encroachment Time (PET). The system achieves high precision and robustness by combining YOLO-v10, ResNet-50, and Re-ID object detection and identification models with Kalman filtering, homography transformations, and re-identification techniques.

Using street-level video footage from a specific day at a location in Athens, Greece, the discrepancy between automated and manual counts is compared with those derived from a previous detection algorithm integrating YOLOv8. The evaluation focuses on the relative performance of both methods in capturing illegal pedestrian and vehicle behaviours. Additionally, analysis of TTC and PET trends reveals a clear inverse relationship between these variables and vehicle speed indicating the possibility of collisions. Furthermore, illegal crossings are associated with consistently lower TTC and PET values, underscoring a heightened chance of near-collision incidents.

These findings underscore the effectiveness of the proposed approach, as demonstrated through a comparative analysis of error and accuracy metrics with alternative detection methods. This analysis highlights the superiority of our approach in accurately capturing high-risk behaviours, particularly illegal crossings, which are critical yet often neglected in traffic safety research. By focusing on illegal crossing behaviours, this study contributes a novel perspective to urban safety analysis, addressing a significant gap in the existing literature and providing valuable insights for data-driven interventions in traffic management and policy development.

***Keywords*:** Road Safety; Artificial Intelligence; Object tracking; Behaviour analysis.