Proactive infrastructure safety management

1 Introduction to Work Package 6

Work Package 6, termed 'Proactive infrastructure safety management', focuses on advancing the application of Artificial Intelligence (AI) to improve road safety. Within the framework of the Marie Skłodowska-Curie Industrial Doctoral Network, six doctoral candidates (DCs) are conducting complementary research comprising AI-supported infrastructure safety assessment, proactive safety analytic methodologies, as well as video image processing, spatial scaling and generative advisory model methodologies for road safety analysis. The DC projects collectively and interconnectedly contribute towards developing new scalable and equitable AI technologies for proactive infrastructure safety management.

The DCs' work will develop new data fusion methods exploiting an array of hybrid road attributes datasets (e.g., video, sensor, geospatial, manual) and translate them into road scanning and evaluation models of proactive risk mapping. This will be complemented by new scalable models for a seamless infrastructure safety management from micro to macro levels. It will improve AI methods for traffic conflicts detection and incorporate subjective safety into safe routing advice tools for children, as well as BIM tools for the safe navigation of connected and Automated Vehicles (CAVs) in the complex urban setting; it will also create an AI Large Language model to provide advice to road authorities for enhancing safety of VRU groups.

2 Methodological advances beyond state-of-the-art

The six WP6 approaches have clearly discernible methodological elements towards advancing proactive, data-driven road safety assessment and optimisation, combining AI, computer vision, spatial analysis, simulation, and human-centred evaluation. Collectively, the studies progress from extracting and integrating heterogeneous road and driving data (e.g., telematics, video, imagery, and infrastructure attributes) to developing predictive models that identify risk-prone areas and safety hotspots, leveraging both statistical and machine learning approaches. A related research task incorporates subjective perceptions and personalized preferences to generate safety-aware routing systems, bridging the gap between objective indicators and user experience through reinforcement learning and supervised/probabilistic modelling.

The methodology also advances towards with the deployment of multi-camera AI frameworks for precise 3D trajectory reconstruction, enabling surrogate safety metric computation (TTC, PET) and conflict matrix synthesis for systemic risk assessment. Large-scale AI-based infrastructure assessment pipelines are also developed using hybrid Vision Transformer & CNN models, temporal feature aggregation, and camera & LiDAR fusion to enhance attribute recognition, geometric precision, and minority-class detection across extensive road networks. These approaches demonstrate a consistent emphasis on multi-source data integration, rigorous preprocessing, spatiotemporal awareness, and performance evaluation under complex, real-world conditions. Finally, the methodology is extended into a design and

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human-centred optimization phase by integrating BIM, microsimulation, and generative AI via Graph Attention Networks. Reinforcement learning guided by Surrogate Safety Measures iteratively improves road network layouts, which are then evaluated in First-Person Perspective simulations to incorporate human feedback, particularly from vulnerable users.

Across all Doctoral Research projects of the WP6 of IVORY, the combined methodological synthesis highlights a multi-layered, iterative workflow: (i) systematic data acquisition and preprocessing, (ii) AI-driven modelling for safety assessment or optimization, (iii) multi-modal integration for enhanced precision, and (iv) human- and policy-centred evaluation to ensure actionable, user-informed insights for proactive road safety management.

3 Scientific Outputs and Publications

During the first reporting period, the DCs have actively contributed to the dissemination of their research through conference presentations and journal submissions. Key outputs include papers under review or accepted in leading international channels (journals and/or conferences), demonstrating strong engagement with both academic and industrial communities, as shown on Table 1.

Table 1: WP6 Scientific Outputs

Doctoral Candidate	Scientific output
DC 8 – Júlia Alves Porto	Conference Papers: • Porto, J. A., Ziakopoulos, A. & Yannis G. (2025). "Road segmentation made simple: a practical comparison of segmentation models and post-processing techniques". 12th International Congress on Transportation Research (ICTR) 2025, Thessaloniki, Greece, 16-18 October 2025. • Porto, J. A., Ziakopoulos, A. & Yannis, G. (2025). "Training a YOLO-based model for speed limit sign recognition", Navigating the Future of Traffic Management, International Symposium, IRF & ICCS, Athens, Greece, 29 June – 03 July 2025. • Porto, J. A., Ziakopoulos, A., Lopez, D. F., Yannis, G. (2026) "Lane segmentation from Street-Level Imagery via noisy Label Generation and Contrastive Self-Supervision". Abstract accepted for Transport Research Arena (TRA) 2026, Budapest, Hungary, 18-21 May 2026. Conference Papers Under Review: • Porto, J. A., Ziakopoulos, A., Yannis, G. (2026) "Weak supervision and fine-tuning with contrastive learning for multiclass lane segmentation". Full paper submitted to World Conference of Transport Research (WCTR), Toulouse, France, 6-10 July 2026. • Porto, J. A., Roussou, S., Andrade, M., Ziakopoulos, A., Yannis, G. (2026) "Conflict detection and analysis in urban arterial roads of Brasília, Federal District of Brazil, using HD-CCTV monitoring cameras and the YOLO model". Abstract submitted to Road Safety and Simulation (RSS), Naples, Italy, 23-26 June 2026. • Porto, J. A., Ziakopoulos, A., Avgeros, J., Lopez, D. F., Yannis, G. (2026) "Are telematics-based hazard levels associated with street-level visual features? A case study of motorway intersections in Gorizia Province, Italy". Abstract submitted to Road Safety and Simulation (RSS), Naples, Italy, 23-26 June 2026.
DC9 – Simone Paradiso	Conference Papers: • Paradiso, S., Ziakopoulos, A. & Yannis, G. (2025). "The use of Graph Neural Networks for Clustering in Road Safety Analysis". 13th Symposium of the European Association for Research in Transportation – hEART2025, 10-12 June 2025, Munich, Germany. • Paradiso S., Nikolaou D., Ziakopoulos A., Aivaliotis A. & Yannis G. "Combining diverse data sources for intersection crash analyses based on incomplete records", Navigating the Future of Traffic Management, International Symposium, IRF & ICCS, Athens, Greece, 29 June – 03 July 2025.

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	• Paradiso, S., Ziakopoulos, A. & Yannis, G. (2025). "Hierarchical Clustering on Graph Embeddings: A Scalable Approach to Risky Intersections". Road Safety on Five Continents (RS5C), 3–5 September 2025, Leeds, UK. • Paradiso, S., Ziakopoulos, A. & Yannis G. (2025). "Aggregating Telematics for Road Safety Analysis". 12th International Congress on Transportation Research (ICTR) 2025, Thessaloniki, Greece, 16-18 October 2025.
DC10 – Akanksha Agarwal	Conference Papers Under Review: • Agarwal, A. et al. "Decoding the roads: An infrastructural-driven machine learning approach to predict safety". Abstract submitted to 8th IRTAD International Conference: Better Road Safety Data for Better Safety Performance, Athens, Greece, on 15-17 April 2026.
DC11 – Nimra Jabeen	Conference Papers Under Review: • Jabeen, N., et al. Abstract submitted to 8th IRTAD International Conference: Better Road Safety Data for Better Safety Performance, Athens, Greece, on 15-17 April 2026.
DC12 – Muhammad Shahid	Journal Paper: • Shahid, M., Gregurić, M., Hassani, A., & Ševrović, M. (2025). Optimizing Car Collision Detection Using Large Dashcam-Based Datasets: A Comparative Study of Pre-Trained Models and Hyperparameter Configurations. Applied Sciences, 15(13), 7001. Conference Papers Under Review: • Shahid, M., et al., "Impact of Camera–LiDAR Data Fusion on Road Attribute Identification Using Deep Learning: An Empirical Investigation" (Under Review). Abstract submitted to 8th IRTAD International Conference: Better Road Safety Data for Better Safety Performance, Athens, Greece, on 15-17 April 2026.
DC13 – Göker Malik Altuntaş	Conference Papers Under Review: • Altuntaş, G., Ools, S., Pirdavani, A. 'Bridging Design and Safety Assessment: A BIM-Based Framework for Road Network Evaluation'. Submitted to 10th International Conference on Road Safety and Simulation (RSS), Naples, Italy, 23-26 June 2026.

4 Next Steps and Ongoing Research

In the next project phase, the DCs will focus on scaling their methods and validating them across diverse datasets, platforms, and real-world environments. Key objectives include:

- Using AI-extracted features from street-level and aerial imagery as inputs to logistic regression models to analyse associations with harsh driving events, integrating iRAP-coded data, identifying influential risk features, and iteratively optimizing AI models for efficient risk assessment.
- Integrating Transformer-based Graph Neural Networks for global attention, transitioning toward supervised learning using crash data, expanding telematics features, and developing hierarchical GNNs for macro-level spatial analysis.
- Addressing missing OSM data using denoising autoencoders, developing validation frameworks, applying probabilistic classification to generate weighted safety scores for routing integration, and incorporating user feedback ethically into a dynamic, user-tailored safety model.
- Scaling the framework from intersection-level to city-wide deployments through federated learning, enhancing multimodal data fusion with video, telematics and/or radars, embedding explainable AI for transparent conflict detection, and establishing adaptive, continuous learning systems aligned with Vision Zero goals.
- Improving geometric precision through multi-sensor fusion of video and LiDAR, designing robust AI models for proactive road risk detection under diverse

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conditions, and creating a scalable, real-time framework for multimodal road safety auditing.

- Building an intermediate layer between Civil3D and SUMO-driven GAT-based GANs to optimize real-world intersection geometries, generating BIM-based design alternatives, validating through simulation, and expanding the pipeline to include broader use cases and road attributes.

Through these efforts, IVORY Work Package 6 will facilitate the creation of proactive infrastructure safety management and assessment systems, which would contribute towards crash avoidance and mitigation, as well as improving road safety outcomes. The interdisciplinary collaboration among academic and industrial partners, enhanced by timely secondments, will continue to strengthen the integration of AI-driven innovation and ease its transition into practical mobility solutions.

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