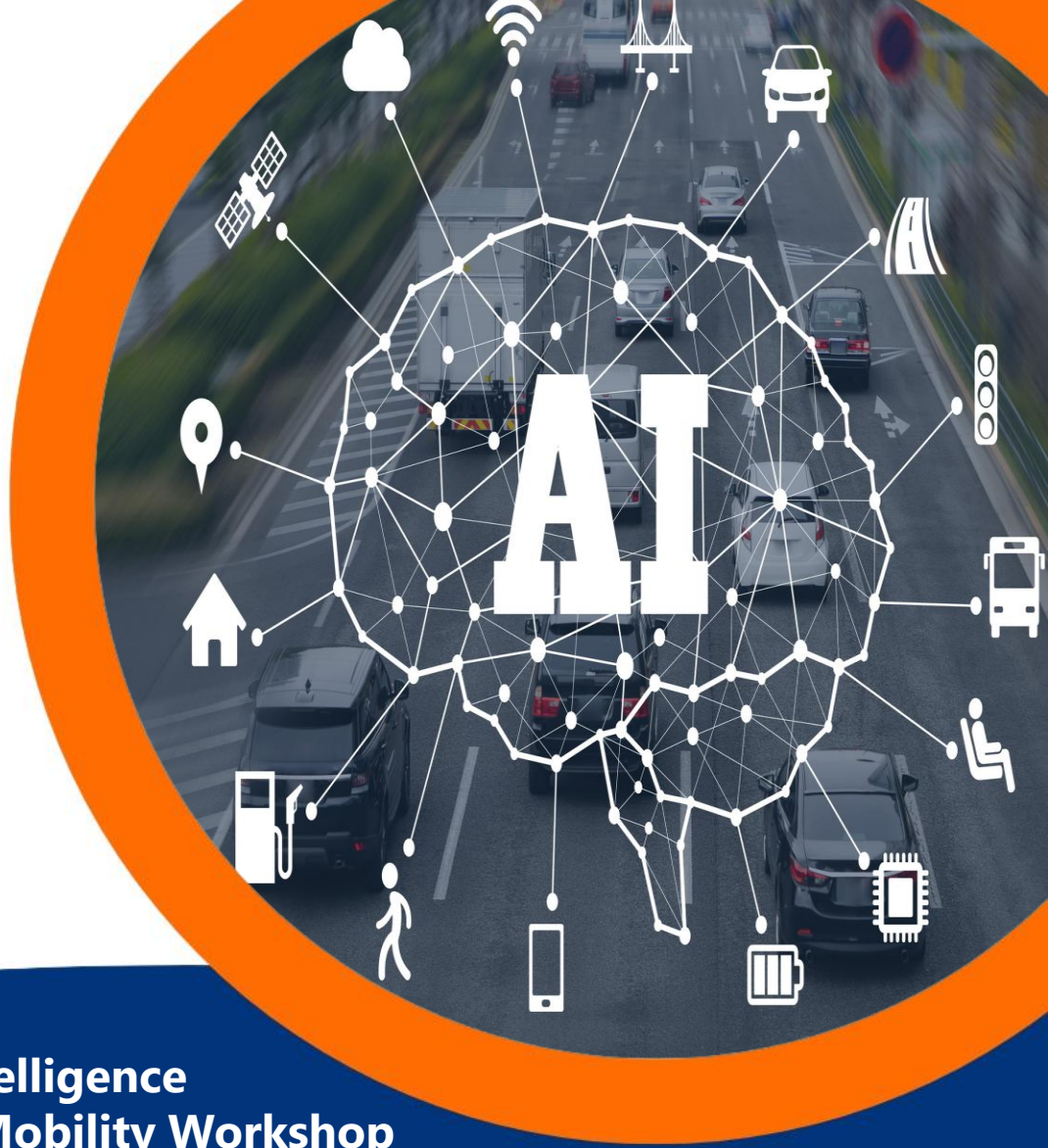
AI for road safety monitoring and crash prediction from micro-to-macro levels - IVORY



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Artificial Intelligence for Road Safety and Mobility Workshop

8th UN Global Road Safety Week

Athens, 15 May 2025

DECADE OF ACTION FOR ROAD SAFETY 2021 - 2030

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The IVORY project

- **IVORY**:

  "AI for Vision Zero in Road Safety"
  ivory-network.eu

- **Partners:**

  4 Universities
  8 Non-academic partners
  13 Associated Partners
  10 Countries

- **Duration of the project**:

  48 months (November 2023 – October 2027)

- **Framework Program**:

  This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101119590

Co-funded by the European Union

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PhD Goals

- To investigate the effect of spatial scale on road safety monitoring and crash prediction.
- To develop a new AI framework to observe and analyze road safety KPIs and predict crashes by achieving transition from smaller scales to larger ones, considering the time dimension.
- To assess the effectiveness and scalability of microscopic road safety models for macroscopic crash prediction and vice versa.

Data Collection

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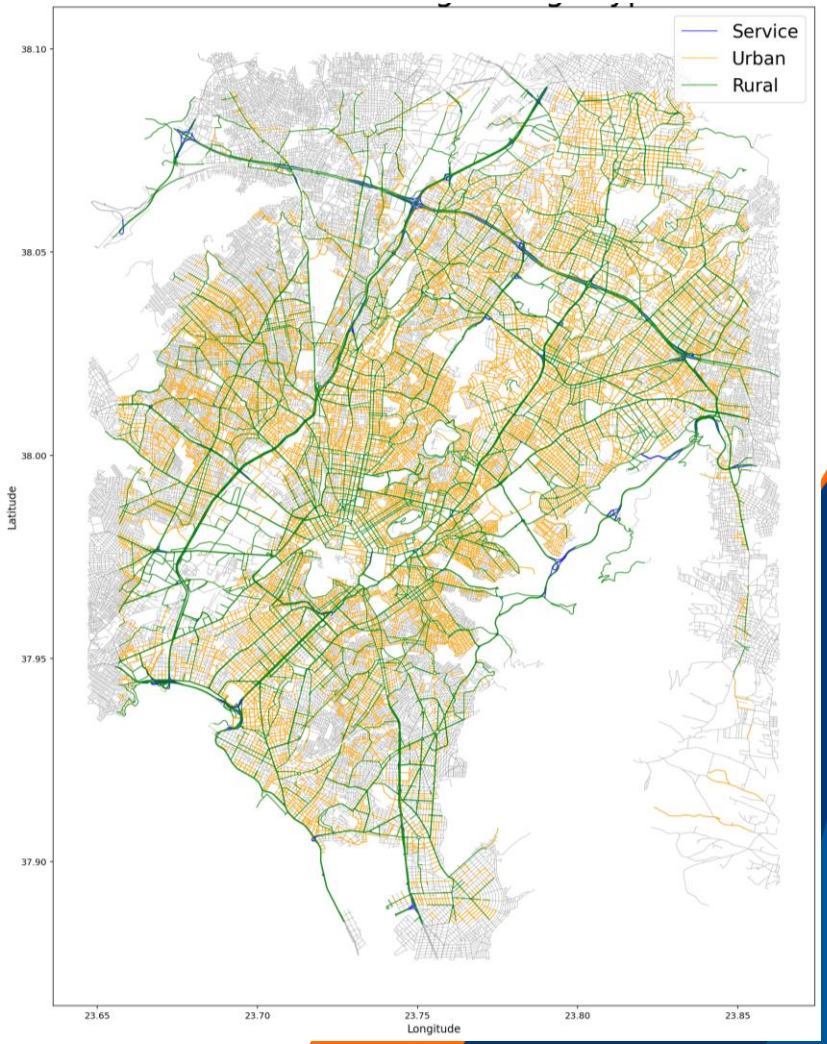
- **Data Sources**
  - Exploration of OpenStreetMap (OSM) database for spatial context.
  - Integration and aggregation of Telematics data provided by OSeven Telematics onto spatial entities.

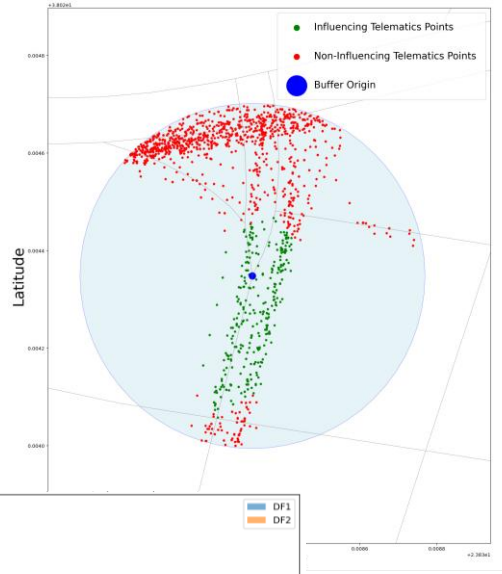
- A graph was extracted from OSM, with node and edge datasets cleaned and preprocessed. Telematics data underwent further cleaning and refinement.

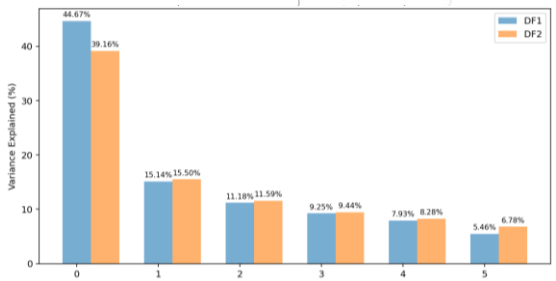
- The study area was selected around the main central area of Athens.

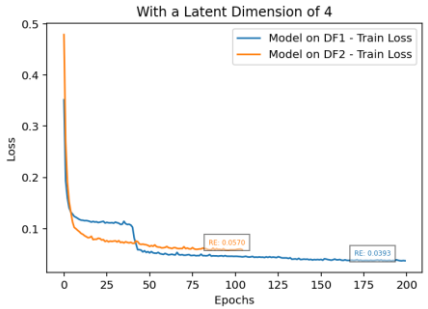


Data Aggregation

- Combining individual telematics observations into summarized information organized by spatial feature.
- Edge aggregation by applying a nearest-neighbor join, each telematics point linked to the nearest edge.
- Node aggregation by using a simple buffer approach can distort node representation.
  - Telematics points influencing the node must be located on edges intersecting at the origin buffer node.
- Statistical and Machine Learning tools were used to evaluate the new approach versus the simple buffer.







Methodological Approach

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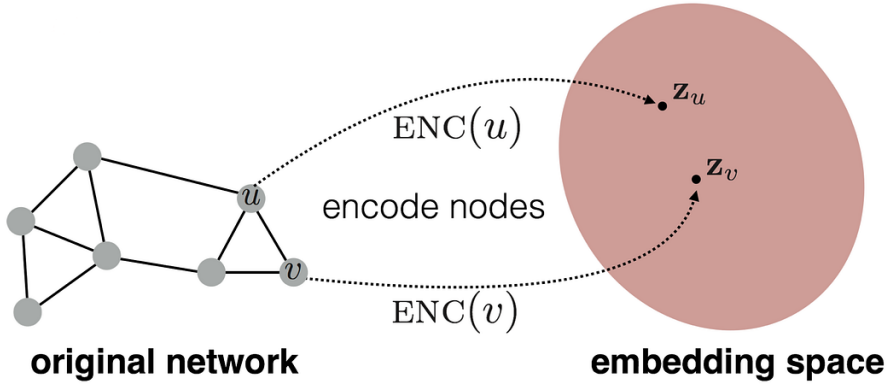
- **Graph neural network** for node and edge embeddings enriched with edge features and network topology.
  - **Graph Attention Network** (GAT) used to generate embeddings by using **attention** to incorporate both **edge** features and neighboring **nodes**.
  - GAT layer used in a model trained unsupervised via **contrastive loss**.
  - **GAT-based autoencoder** model developed.
- **Clustering techniques** to identify risky and safer geometric entities.
  - Applied to both raw features and embeddings.



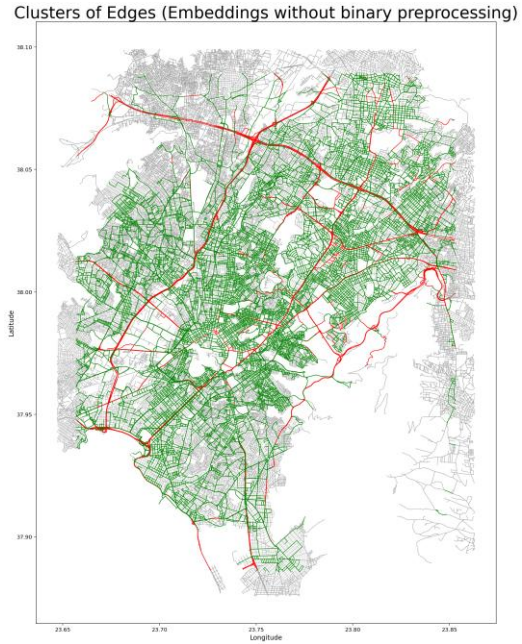
Discussion

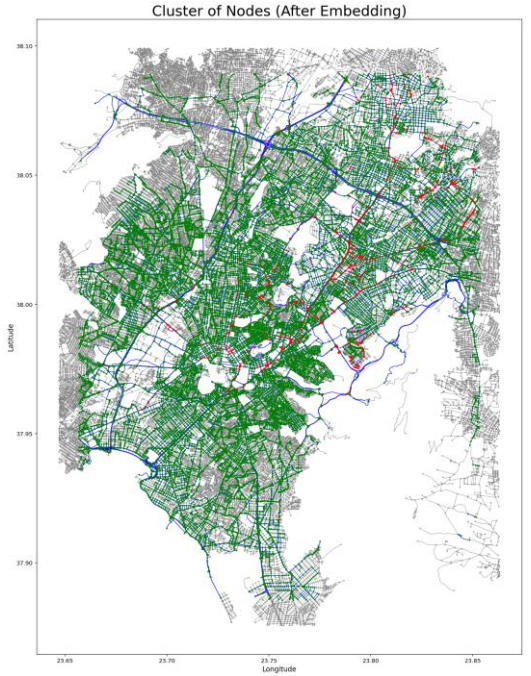
- Clustering on embeddings shows better Silhouette and Inertia scores, driven by the embedding mechanism.
- The unsupervised loss function framework outperforms the GAT-autoencoder in terms of clustering quality.
- Learned embeddings effectively brings a further level of information improving network partitioning.

Index	Simple Clustering value	Embeddings Clustering value
WCSS	145909	31409
Silhouette	0.58	0.73
DBI	1.41	0.82
CHI	8794	11309

Results so far

- Simple **buffer-based aggregation** around nodes is overly simplistic and may miss complex patterns.
- The embeddings lead to **polarization** within the clusters, enhancing separation.
- **Hierarchical clustering** enables scalable identification of geometric entity groups.
- **Dual graph approach** facilitates the use of GNNs for generating informative edge embeddings.





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- The research outputs will deliver AI applications to assist road users and improve safety management, helping to prevent crashes in high-risk areas (intersections, edges, etc.).
- The work will provide Road Authorities with actionable insights, informing on where to focus safety efforts and resources, improving overall urban traffic management and public safety.
- The developed methods will be tested on additional datasets and in different countries, emphasizing transferability to ensure global road safety improvements.

Scientific and Social Impact

- Advancing UN SDG Target 3.6 and Vision Zero by developing scalable AI models for multi-level road safety monitoring and crash prediction.

- The methods will be tested on different datasets from different countries to ensure they are adaptable and useful for improving road safety across diverse regions.

- The scalability ensures that no group of road users is excluded, while the transferability of methods allows the solutions to be applied globally, adaptable to different contexts without bias.

Future Challenges

- Ensuring the availability of high-quality telematics data in areas where data might be sparse or difficult to collect.
- Guaranteeing that models for various spatial scales are both accurate and efficient across micro to macro levels can be complex and require continuous refinement.
- Adapting methods for different regions could highlight challenges related to local road safety factors or cultural differences, requiring significant adjustments.

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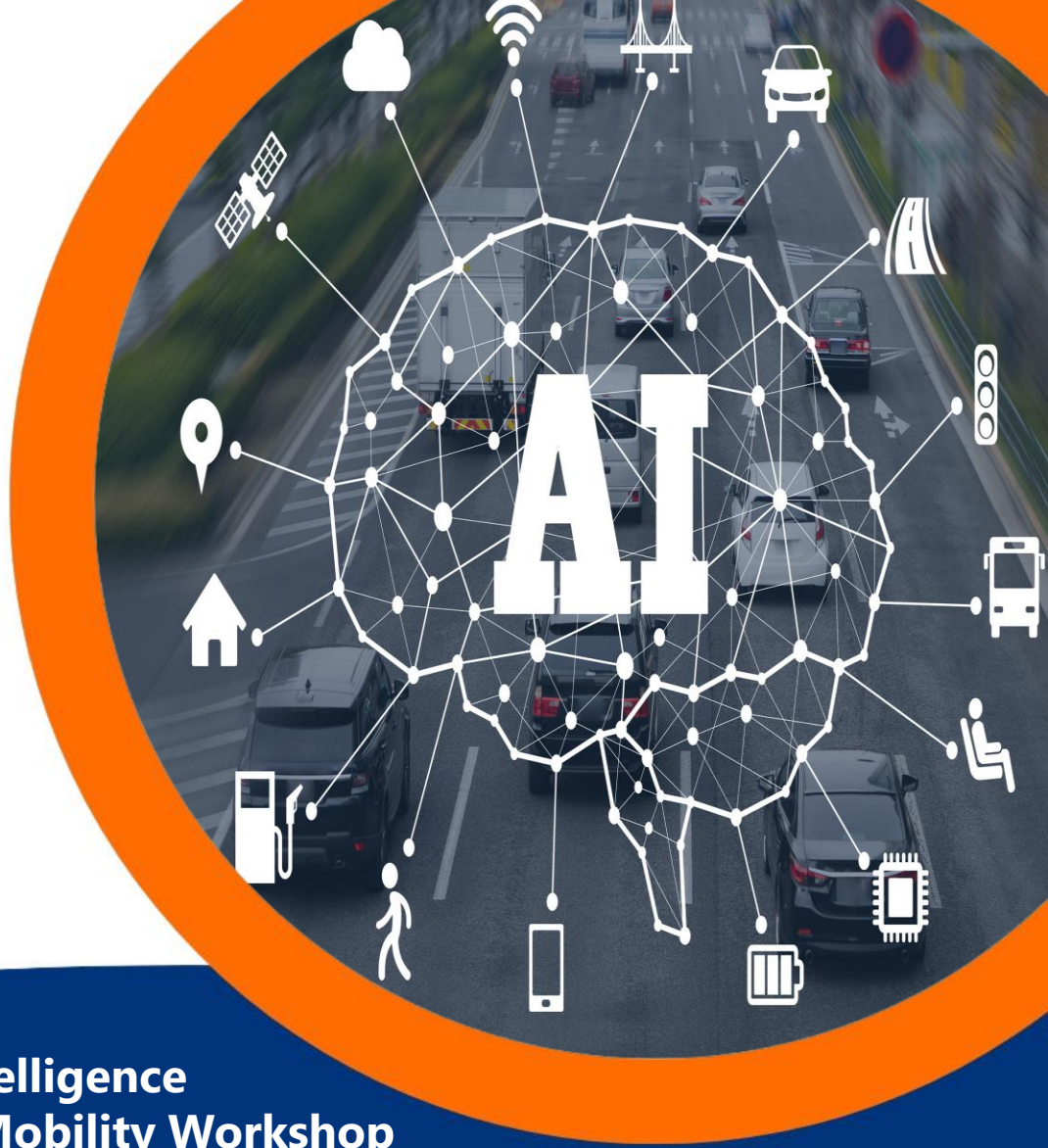

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