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Leveraging AI capabilities for advancements across road safety pillars

The IVORY Project

IVORY

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A. Tsoutsanis, J. Porto, S. Paradiso, A. Styanidis

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Marie Skłodowska-Curie Actions

Η Ελλάδα σε Κίνηση: Ευφυείς Μεταφορές Ανθρώπων & Εμπορευμάτων Σήμερα και Αύριο

23-24 Ιουνίου 2026
Σεράφειο Δήμου Αθηναίων

The IVORY Project

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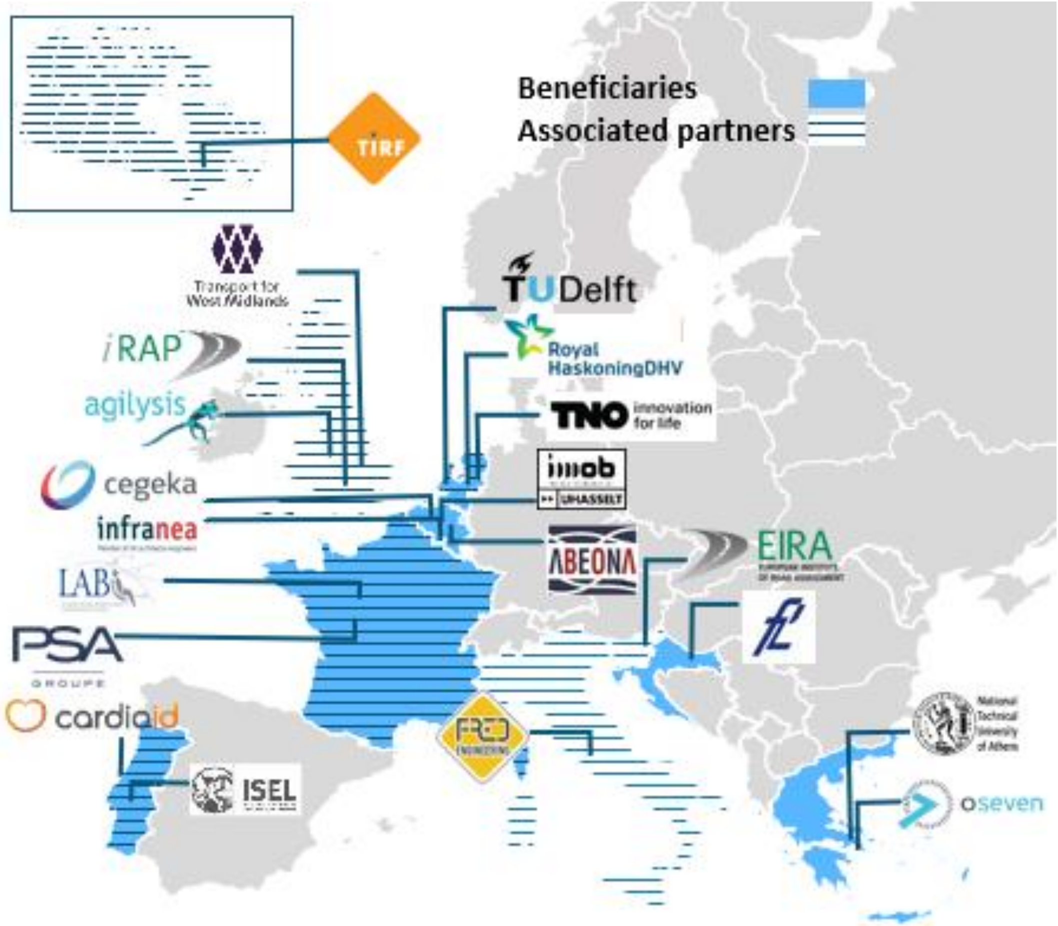
- **An EC-MSCA Industrial Doctorates Network**
  - Aims to develop a new framework for the integration of AI in road safety
- **Aspires to create a new generation of leading researchers in the field**
  - 4 Universities
  - 8 non-academic partners
  - 13 Associated Partners
  - 10 countries
- **AI creates opportunities for new ways of addressing this persistent global epidemic.**
  - However, AI is relatively underdeveloped in road safety

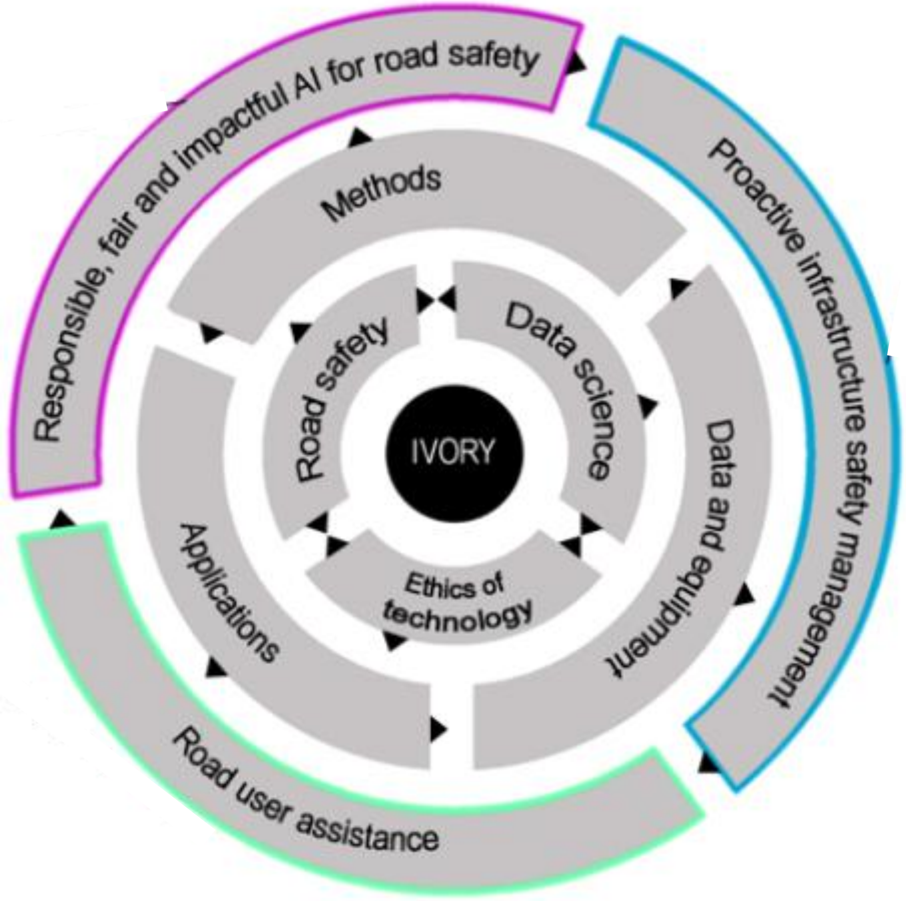


Internal Use

IVORY Objectives

- **Responsible, fair and impactful AI** for road safety
- **New ways of supporting road users** and human-vehicle-environment interaction by means of AI
- New scalable and equitable AI technologies for **proactive infrastructure safety management**
- A sustainable **learning, knowledge sharing and networking framework** on AI for road safety

→ In the following, the **research streams** of the 4 IVORY NTUA DCs are showcased.

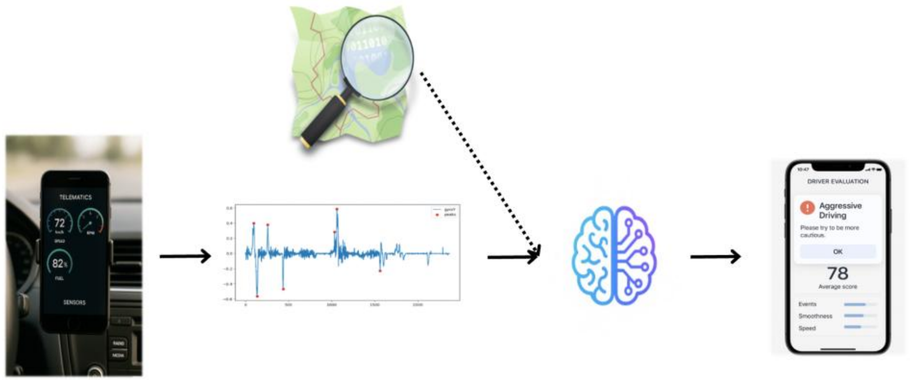


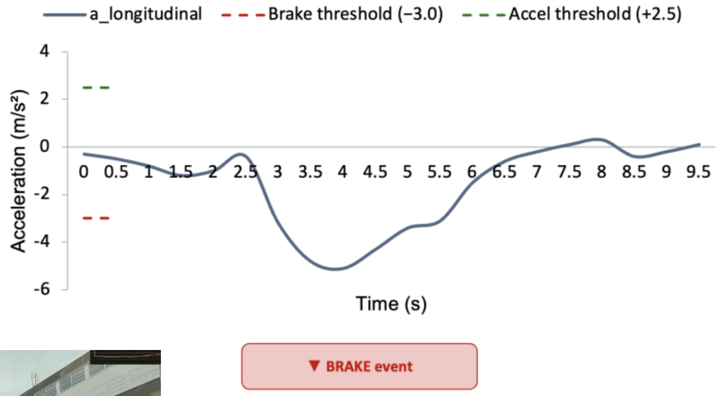
Internal Use

PhD 7 – Driver Behavior and Assistance

Aristotelis Tsoutsanis

- **Telematics data → Driver Behavior**
  - Smartphone telematics data can offer many Surrogate Safety metrics such as harsh acceleration, harsh braking and harsh cornering
- **Data fusion → Extra context and more accurate modeling**
  - Incorporate Vision, Infrastructure and other data sources
- **Lane Detection → Lane Change Behavior and Assistance**
  - Lane keeping scoring
  - Lane change behavior





Internal Use

PhD 7 – Outcomes

Aristotelis Tsoutsanis

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- **Transferable AI building blocks for driver assistance**
  - self-supervised and transformer-based representations (contrastive SSL, multimodal cross-attention) that generalize across drivers/devices and feed downstream uses:
    - risk scoring
    - insurance, fleet safety
    - personalised driver feedback (ADAS).

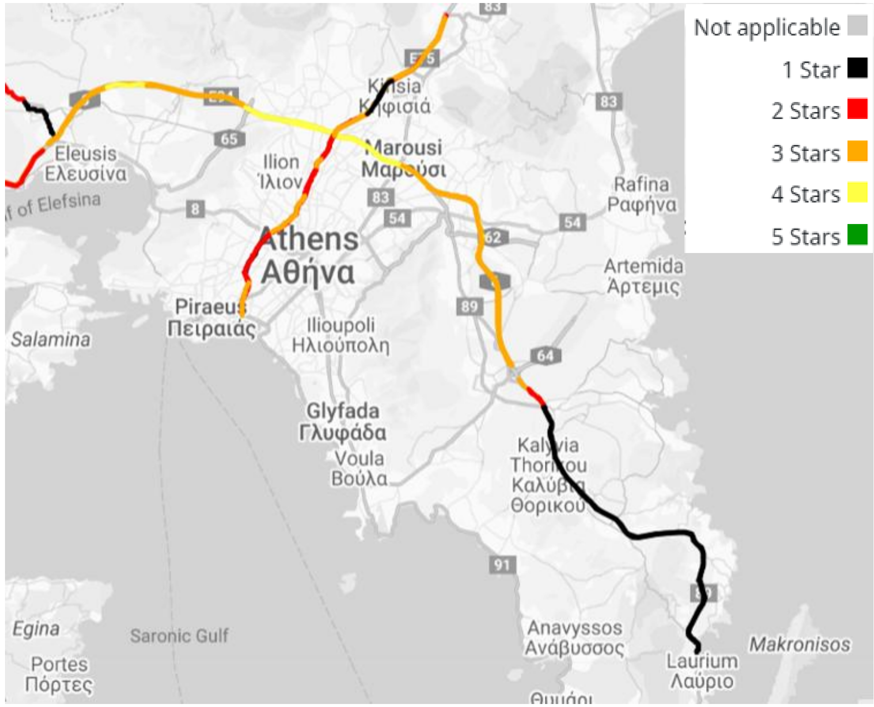
- **Harmonisation of heterogeneous data sources into comparable, actionable datasets**
  - Telematics (Smartphone / OBD)
  - Infrastructure (OpenStreetMap)
  - Vision (Front-view or Multi-view)

Internal Use

PhD 8 – Proactive Risk Mapping and Infrastructure Safety Assessment

Julia Alves Porto

- **Key Concept**
  - Infrastructure data and environmental context to map safety-related human behaviour
- **AI labeling → Data collection**
  - Data types: Street-Level Imagery, Aerial Imagery...
  - Labeling types: segmentation, object detection, classification...
- **AI modelling → Risk level estimation**
  - Reactive approach: historical crash data
  - Proactive approach: Surrogate Measures of Safety (SMoS)



iRAP Star Rating results (2013)

Internal Use

PhD 8 – Outcomes

Julia Alves Porto

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- **Attribute data collection**
  - Speed Limit and Cancellation Signs: YOLO + OCR
  - Lane Delineation Segmentation Type: LinkNet + BYOL
- **Imagery data → Harsh Event Occurrence**
  - Context: 95 motorway junctions by the IT/SL border
  - Imagery data source: Mapillary
  - Harsh-event data source: OSeven
  - Results: increase in flat (sidewalk, terrain) pixels led to fewer harsh-events
- **Manual labeling vs Computer labeling**
  - Manual: iRAP-style coding
  - Computer: multiple automated data sources

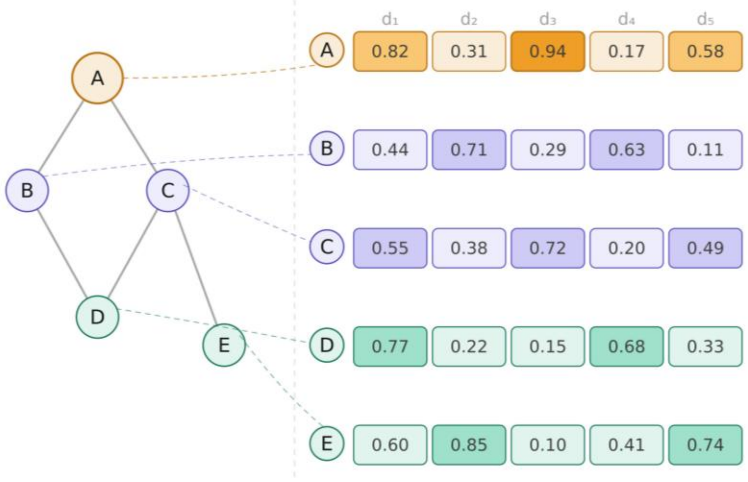
	β	p-value
Constant	-1.8787	0.199
Construction	0.2894	0.168
Flat	-0.1549	0.010
Poles and signs	-0.1098	0.217
Nature	1.1323	0.027
Road users	-0.2778	0.156
Number of Trips	0.0222	0.000
Mean speed	-0.0294	0.003
Pseudo-R^2		0.5431
AICc		105.0355

Internal Use

PhD 9 - Graph Neural Networks & Clustering

Simone Paradiso

- **Driving behavior → Road Network**
  - Trajectory Data can be mapped to roads and intersections, to capture spatial and behavioral patterns.
- **Graph Neural Network Embeddings**
  - Graph Neural Networks (GNNs) learn node representations (**embeddings**) for each intersection, capturing road network structure and driving behavior patterns.
- **Node Embeddings → Clustering**
  - The learned node embeddings are clustered to group locations with **similar driving characteristics**.
  - **More reliable** than clustering raw features.
- **Loss Function Tweak**
  - Restrict the **loss function** to a **radius-based local context** around each node and test multiple radii to improve embedding and clustering quality.



Internal Use

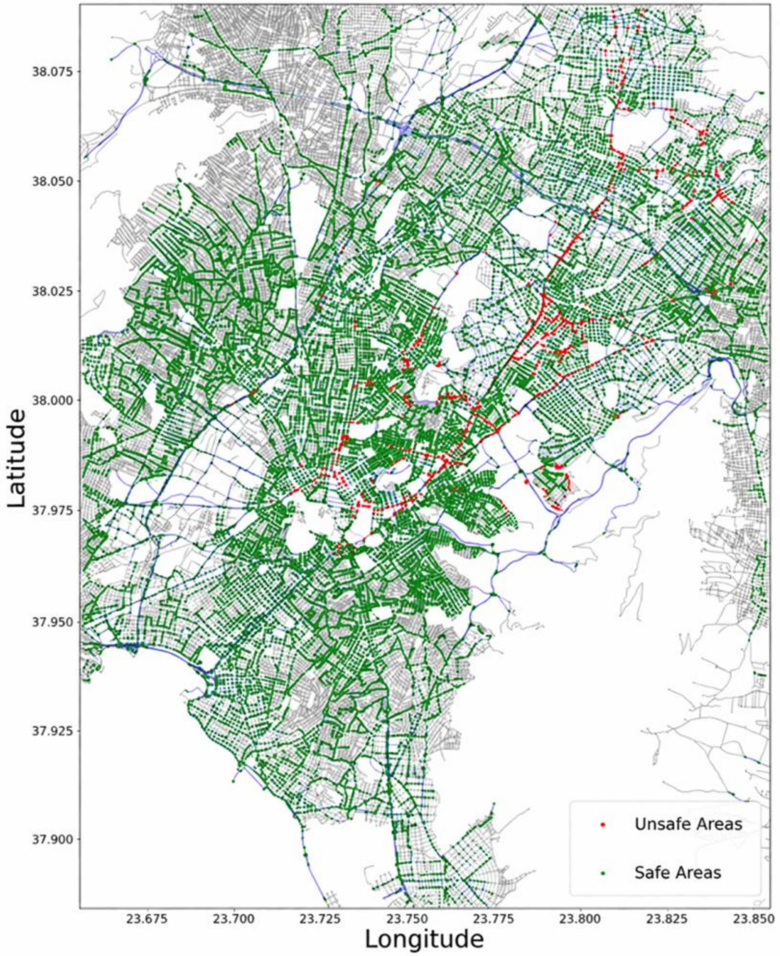
PhD 9 – Outcomes

Simone Paradiso

- **Driver Behavior Groups**
  - Calm zones: 🟢 nodes → smooth driving.
  - Unsafe zones: 🔴 nodes → aggressive or careless driving.

- **Applications**
  - The approach enables **proactive detection** of unsafe road segments, offering **actionable insights** for traffic safety.

- **Future Directions**
  - Incorporate **multiscale mechanisms** into the GNN architecture to improve detection accuracy and contextual understanding.

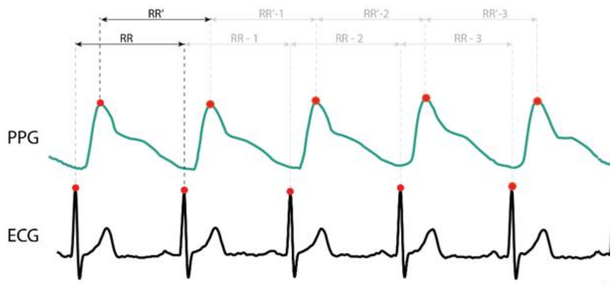


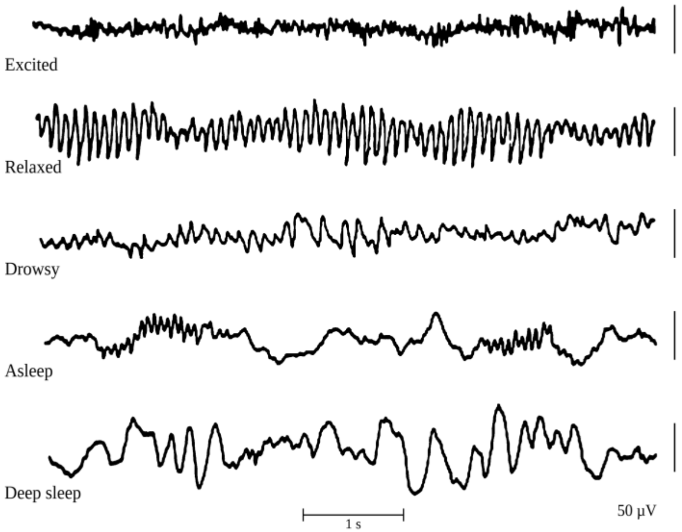
Internal Use

PhD 14 – Driver Drowsiness Detection using Physiology

Aristotelis Styanidis

- **Physiological Signals → Drowsiness Detection**
  - Physiological measures (ECG, EEG, EOG, etc.) provide objective indicators of driver fatigue and alertness.
- **Multimodal Learning → Robustness to Missing Modalities**
  - Combining multiple physiological signals provides complementary information and improves robustness when individual modalities are noisy, corrupted, or unavailable.
- **Domain Adaptation → Domain Shift (Subject / Scenario)**
  - Domain adaptation aims to reduce performance degradation across different subjects and between simulated and naturalistic driving environments.
- **Self-Supervised Learning → Leveraging Unlabeled Data**
  - Self-supervised learning enables the extraction of meaningful representations from unlabeled physiological signals, reducing reliance on costly and time-consuming annotations.



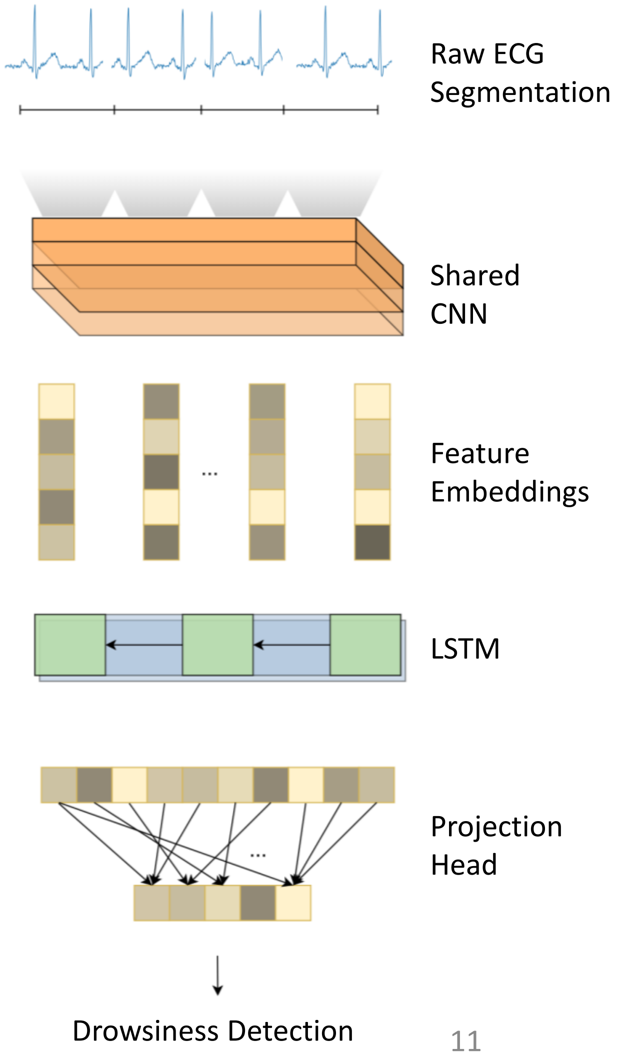


Internal Use

PhD 14 – Outcomes

Aristotelis Styanidis

- **Machine Learning for HRV-Based Drowsiness Detection**
  - Developed a state-of-the-art drowsiness detection pipeline based on Heart Rate Variability (HRV) features using Support Vector Machines, Random Forests, and Gradient Boosting. The impact of missing physiological data on model performance was also investigated.
- **Deep Learning for Temporal and Raw-Signal Modeling**
  - Developed LSTM-based models to capture temporal dynamics in HRV signals and investigated CNN-LSTM architectures on raw ECG data. Comparative analyses were conducted to assess the complementary information provided by handcrafted HRV features and raw-signal representations.
- **Ongoing Work: Domain Adaptation for Cross-Subject Generalization**
  - Currently developing a Domain-Adversarial Neural Network (DANN) using EEG differential entropy features across multiple frequency bands to mitigate domain shift and improve generalization across subjects.



Internal Use

IVORY lessons learned

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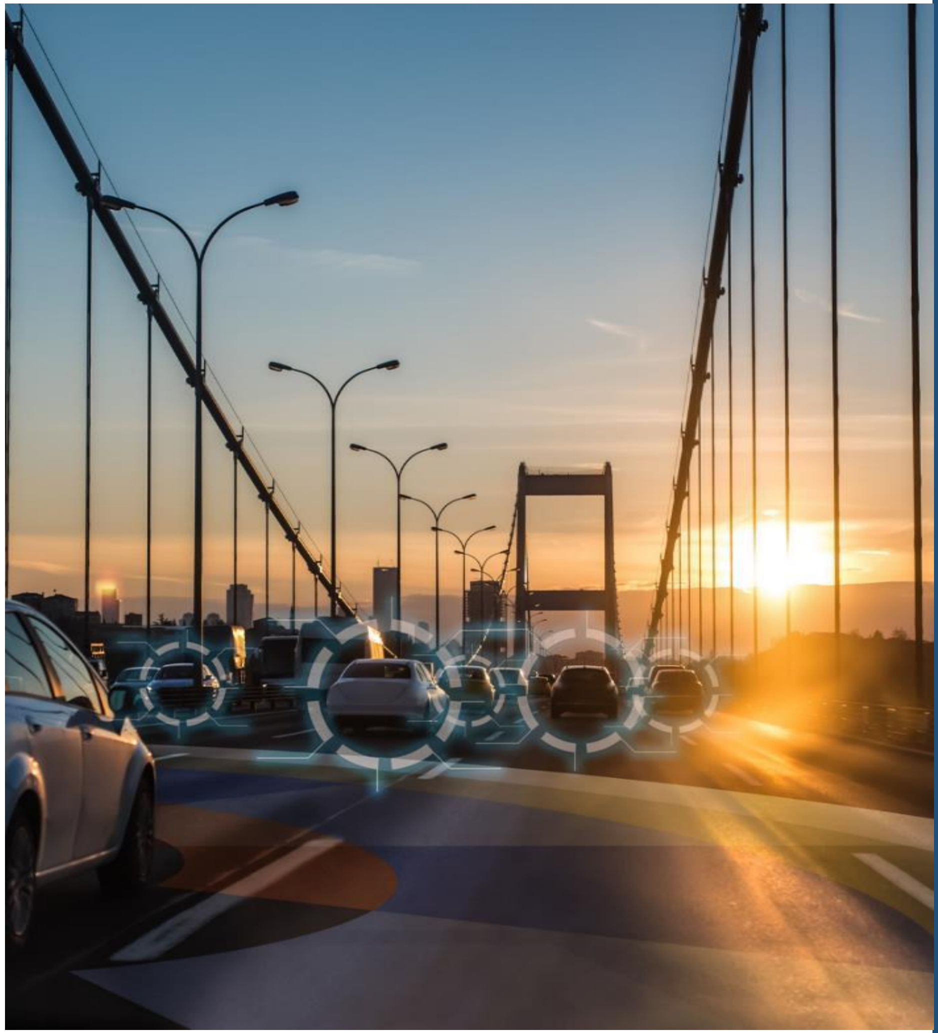
- **Meaningful human-AI interaction**
  - AI can only learn from existing data
  - It lacks the critical thinking and inspiration needed for making breakthroughs
  - Without human oversight, AI can induce unforeseen types of bias
- **Balancing AI developments in road safety**
  - Is critical to bridge the gaps between engineering, technology & society, and ensure fairness and equal opportunities for all
- **Systematic and sustainable intersectoral collaboration**
  - A need to break the silos between sectors (academia, industry and policy) and disciplines involving AI (engineering, data science, ethics of technology).



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