From Trend Observation to Risk Interpretation: A Machine Learning Analysis of Micromobility Injury Severity in 2022

Paraskevi Koliou, Eleni Maria Theodoraki, George Yiannis

National and Technical University of Athens, Athens, Greece

evi_koliou@mail.ntua.gr

TRANSPORT RESEARCH ARENA BUDAPEST 18-21/05/26

Introduction

Micromobility is rapidly expanding in European transport systems

Offers **sustainable mobility**, but users are:

- Physically **exposed**
- Operating in **mixed traffic**
- Facing **uneven infrastructure**

→ Leads to **different injury mechanisms** compared to other road users

Research Gaps:

i. Lack of **interpretable ML & multi-country comparisons**

ii. Few directly **compare micromobility vs. other users** in one framework

Objectives

Main Aim:

Identify **differences in injury severity mechanisms** between 🛴 Micromobility users & 🚗 Other road users

Specific Objectives:

- Analyze **injury trends (2013–2023)** to contextualize 2022
- Develop **mode-specific ML models** for injury severity
- Apply **SHAP** to identify key risk factors
- Support **targeted, evidence-based safety interventions**

Data collection

Dataset:

Harmonized European crash data (2013–2023)

Included cases with:

✓ Injury severity

✓ Vehicle type

User Definition:

🛴 **Micromobility**:

Pedal cycles & Mopeds *(based on official reporting standards)*

Outcome Variable:

Original: **Fatal / Serious / Slight**

Reclassified: **Serious/Fatal vs. Slight** *(binary)*

Modelling Sample (2022):

🛴 Micromobility: **63,859 cases**

🚗 Other users: **264,893 cases**

Methodology

Model Framework:

Two **Random Forest classifiers:**

🛴 Micromobility users & 🚗 Other road users

Outcome: **Binary injury severity**

(Serious/Fatal vs. Slight)

Data Processing:

- **Stratified 5-fold cross-validation**
- **SMOTE** applied to training folds *(class imbalance)*
- Missing values → **median imputation**

Evaluation Metrics:

Accuracy, Precision, Recall, F1-score

Interpretability:

- **SHAP analysis**
  - Quantifies **feature importance**
  - Explains **direction of impact on severity**

Results

Descriptive Trends (2013–2023)

Trend Overview:

- 📈 **Micromobility injuries increased steadily** across Europe
- 🟢 **Slight injuries** → consistently largest share
- 🔴 **Serious injuries** → variable but **overall increasing trend**

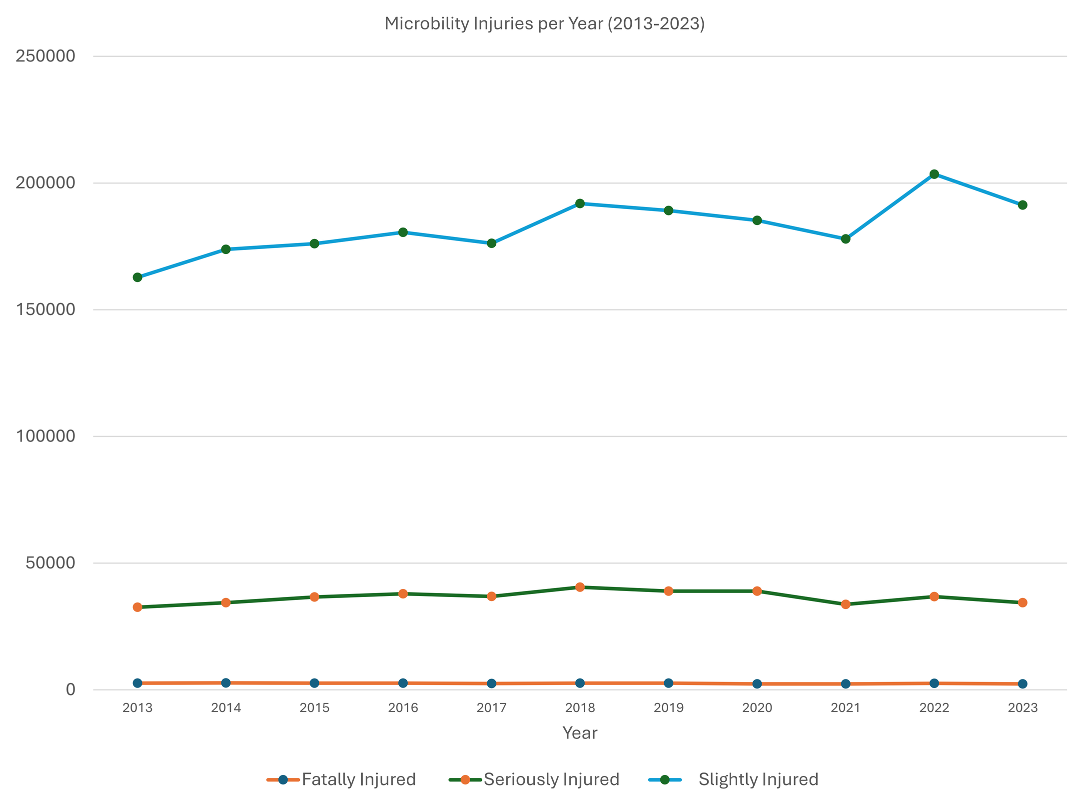
Temporal Effects:

- 📉 **2020 decline** → COVID-19 mobility restrictions
- 📈 **Strong rebound in 2022**

Severity Comparison (2022):

- 🛴 **Micromobility users**
  - Lower **fatal injuries**
  - Higher **serious injuries**
- 🚗 **Other road users**
  - Higher **fatality proportion**

→ Indicates **different exposure & severity patterns**



Model Performance

Overall Accuracy:

- 🛴 **Micromobility: 63.1%**
- 🚗 **Other Road Users: 67.2%**

Performance Metrics:

- **Precision, Recall, F1-score** → moderate but **stable across folds**
- Indicates **robust model behavior** under cross-validation

Interpretation:

- Performance aligns with **heterogeneous multi-country crash data**
- Model prioritizes:
  - **Interpretability**
  - **Risk pattern identification**
  - *(not operational prediction)*

Feature Importance and SHAP Interpretation

Micromobility Users:

- **Age** → strongest predictor
  - Higher risk: **18–24** & **65+**
- Increased severity linked to:
  - 🌧 **Adverse weather**
  - 🌙 **Low visibility**
  - 🌄 **Rural areas**

→ Indicates **user vulnerability-driven risk**

Feature Importance and SHAP Interpretation

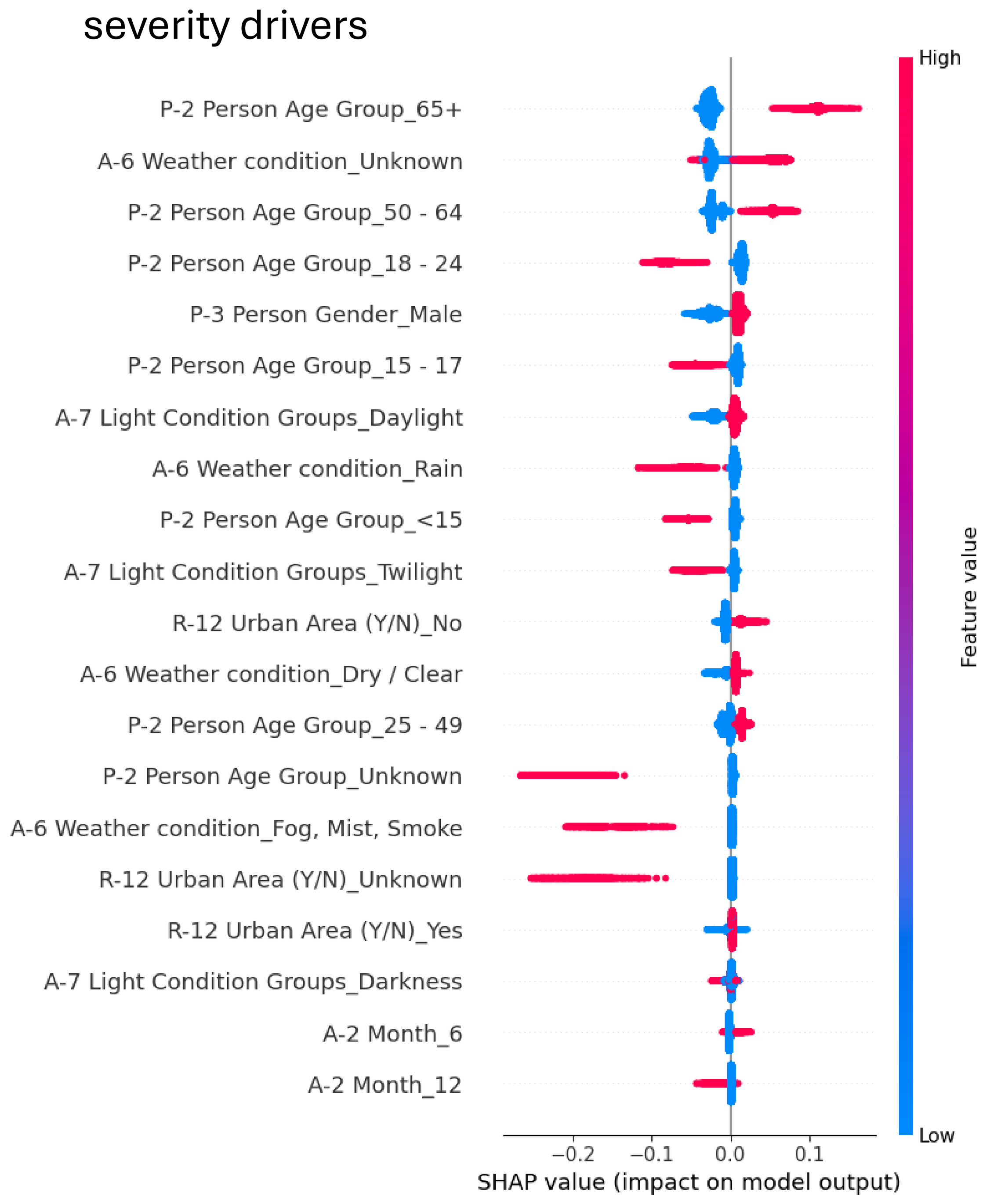
Other Road Users:

- **Rural environment** → dominant factor
- Additional contributors:
  - 👤 **Male gender**
  - 🌧 **Adverse weather**

→ Indicates **environment-driven risk**

Model Insight:

- SHAP analysis provides **transparent, interpretable feature contributions**
- Enables **policy-relevant understanding** of severity drivers



Conclusions

Key Findings:

- Micromobility injury severity is mainly driven by **age-related vulnerability**
- Other road users are more affected by **environmental and contextual factors**
- **Rural settings** significantly increase the risk of severity for non-micromobility users

Implications:

- Supports **targeted, mode-specific safety interventions**
- Demonstrates the value of **interpretable machine learning** in road safety analysis

Future Work:

- Extend to **multi-year modelling** for temporal stability
- Include **multi-class severity outcomes**
- Integrate **spatial & infrastructure variables**
- Explore **policy simulation approaches**

Acknowledgements

The present work is related to the metaCCAZE Project (Flexibly adapted MetaInnovations, use cases, collaborative business and governance models to accelerate deployment of smart and shared Zero Emission mobility for passengers and freight). This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101139678.

Contact Information

Dr. Paraskevi Koliou

Iroon Polytechniou 5-9, 15772, Athens, Greece

Tel: +30 2107724715

Email: evi_koliou@mail.ntua.gr