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PIARC

ARTIFICIAL INTELLIGENCE IN PROACTIVE ROAD INFRASTRUCTURE SAFETY MANAGEMENT

SESSION: AI FOR SAFER ROAD MOBILITY

ANASTASIOS DRAGOMANOVITS

SENIOR RESEARCHER – TRANSPORTATION ENGINEER

NATIONAL TECHNICAL UNIVERSITY OF ATHENS

PRESENTATION OUTLINE

- Background & Introduction
- Advances of AI in Road Safety
- Proactive Methodologies:
  - Surrogate-Safety Measures
  - EGRIS Network-Wide Assessment
- Pending Barriers
- Conclusions

BACKGROUND

- Road transport is responsible for the majority of transport fatalities (more than 1,3 million fatalities worldwide/year).
- In 2022, about 20.600 road traffic fatalities were recorded in the 27 EU Member States.
  - Almost 40% of road fatalities occur in urban areas.
  - Vulnerable road users account for 70% of road deaths in urban areas.
- Innovative data-driven solutions could contribute to a proactive approach of addressing urban road safety problems, being a core principle of the Safe System Approach.
- The rise of smartphones, sensors and connected objects offers deeper and broader transport data.
- The interpretation of these data can be made possible thanks to progress in computing power, data science and artificial intelligence (AI).

AI ADVANCES IN RISK ESTIMATION

- New AI methods and machine/deep learning models are available to road safety researchers, stakeholders and authorities for real-time crash risk estimates.

- Big data on crash occurrence and road and traffic characteristics from infrastructure sensors can be transformed into multi-dimension static or dynamic maps of road risk prediction and road & driver star rating.

- Crash datasets are imbalanced, rare event cases which find new approaches and venues of analysis through AI methods.

- Infrastructure assessment frameworks start embracing AI methodologies (e.g. the i-RAP offshoot of Ai-RAP). Pattern recognition has received heightened attention (e.g. 84% accuracy of pedestrian detection from video recording using Convolutional Neural Networks)

- A large number of model configurations show very promising performance, albeit on specific datasets; transferability capabilities are yet uncertain.

AI ADVANCES IN TELEMATICS & DRIVER MONITORING

- The insurance industry is heavily investing in telematics, offering reduced premiums for safer driving.
- AI and data fusion technologies are increasingly used in all stages of road safety data collection, transmission, storage, harmonization, analysis and interpretation from telematics.
- Personalized feedback can be obtained almost instantaneously.
- Algorithm-based route analysis and personalized hotspot detection features are actively being examined.
- During-trip and post-trip interventions are enabled, best administered with gamification and reward systems.

AI + BIG DATA = ROAD SAFETY

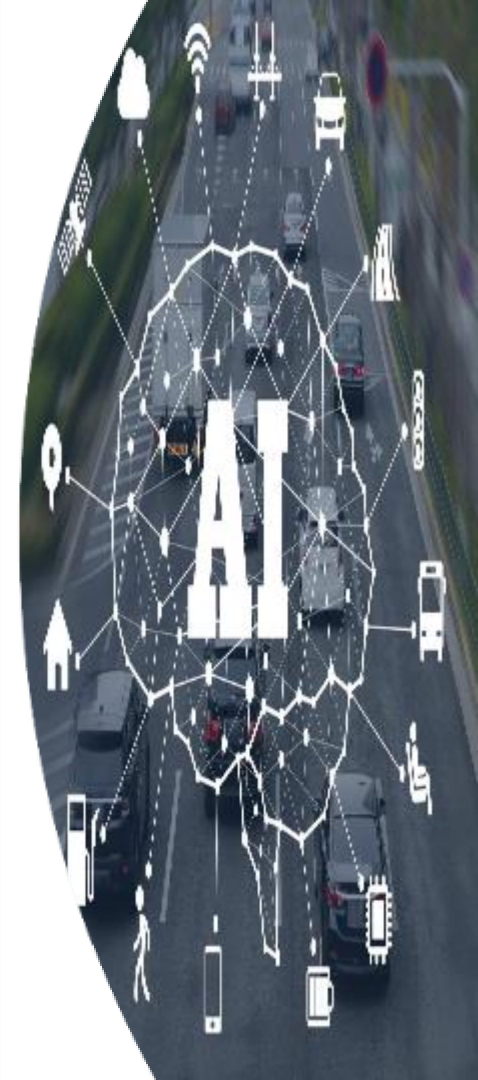
AI facilitates the proactive management of traffic safety in various ways:

- Collection of data on road infrastructure conditions and traffic events through wide and broad-scale sensors and systems such as real-time computer vision.

- Identification of high risk locations proactively, through predictive multi-layer models.

- Enabled by multiparametric big data, AI pushes the limits of pattern recognition and reaction times beyond human capabilities and may thus uncover new crash-prone road configurations.

- Recent developments in the field of so-called “explainable AI (XAI)” begin to cope with the challenge of the “black box” phenomenon.



SURROGATE SAFETY MEASURES (1/2)

- Surrogate road safety measures [SSMs] are the key to proactivity.

- SSM examples are:
  - traffic conflicts
  - harsh driving events (accelerations, decelerations, cornerings)
  - spatial/temporal headways
  - post-encroachment time [PET]
  - time-to-collision [TTC]

  ..and many others

- SSMs become readily available for proactive analyses before crashes occur or in areas with limited or no crash data availability.

- SSMs show less underreporting and can even aid with crash reporting.

SURROGATE SAFETY MEASURES (2/2)

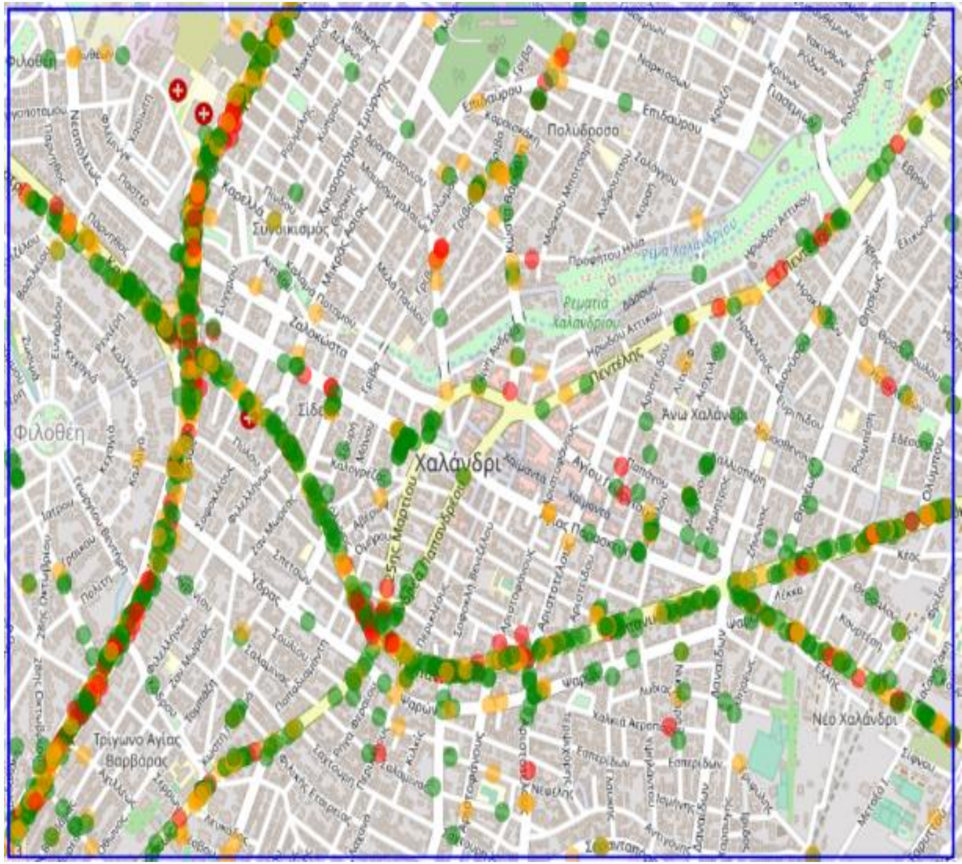
Research on the validation of surrogate safety metrics is essential…

1. to reveal which metrics not only are correlated with reported crashes but also have predictive capabilities
2. to predict the number of fatalities and/or injuries
3. to determine how these metrics can integrate crash participant fragility, speed, mass and crash type consequences

The adoption of surrogate safety metrics leads to the review of statistical training needs, so that data are not misused/misinterpreted.

PROACTIVE SSM ANALYSIS EXAMPLE (1/3)

- Smartphone driving behavior data & OpenStreetMap geometric data are exploited and map-matched.
- Harsh braking counts are spatially analyzed in an urban road network.
- 869 road segments (removal of 14 footways) with 4293 nodes (of which, 49 road with traffic lights, 80 with pedestrian crossings)
- Trips between 01-10-2019 & 29-11-2019 - 2 months
- 3294 trips from 230 drivers, 1,000,273 driving seconds (average trip duration 304s)
- 1348 harsh brakings (& 921 harsh accelerations…)



PROACTIVE SSM ANALYSIS EXAMPLE (2/3)

- Statistical models GWPR, CAR, and machine learning XGBoost models (randomly and spatially cross-validated) were trained.

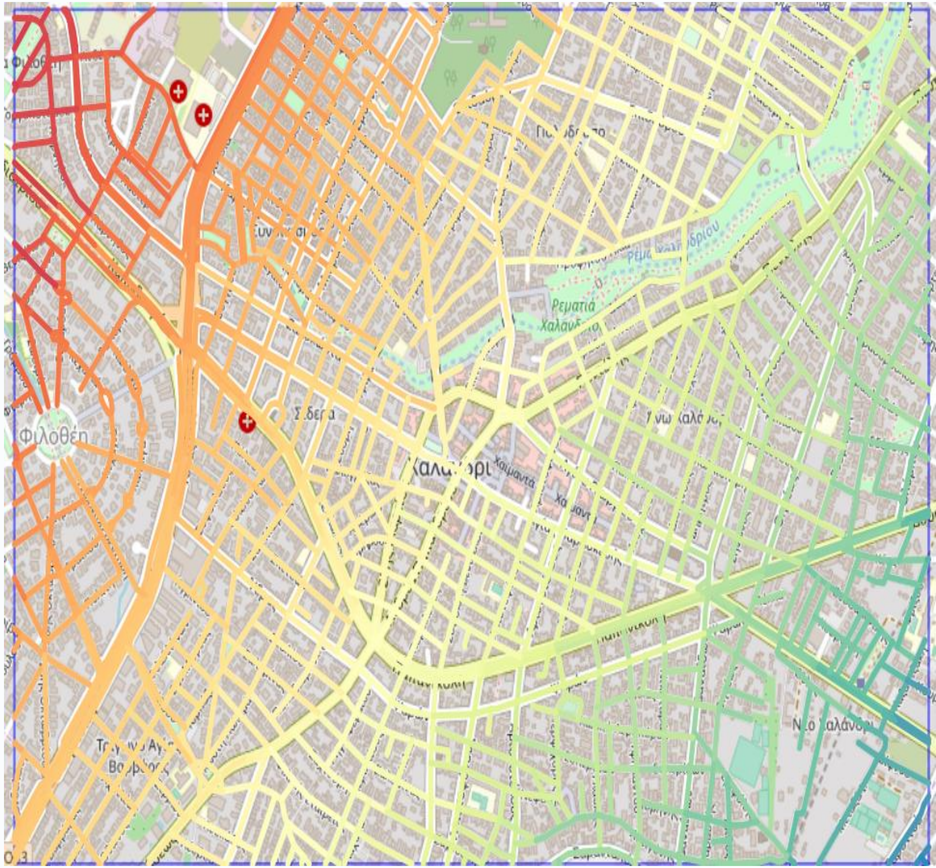
- After adjustments, counts are predicted in another network to assess transferability.

- 87.6% accuracy of harsh braking frequencies was achieved, in a fully proactive analysis (no crash data).

- Indicative correlations:

  Segment length and pass counts are positively correlated with HBs

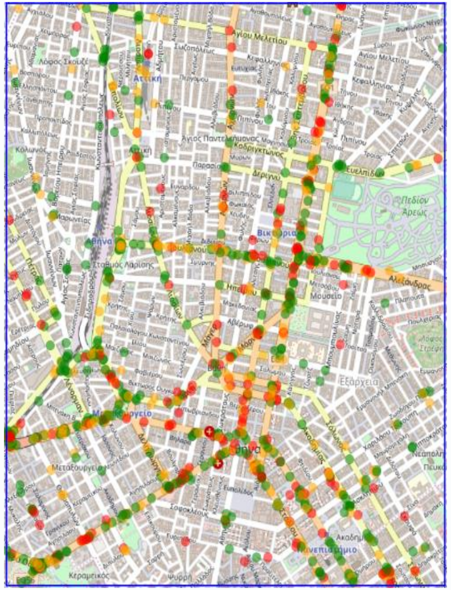
  Gradient and neighborhood complexity are negatively correlated with HBs.

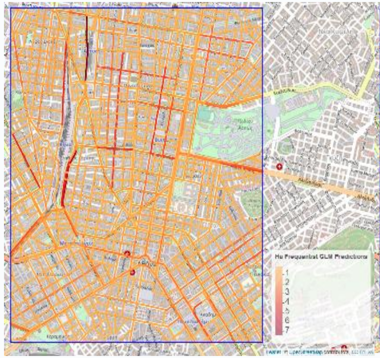


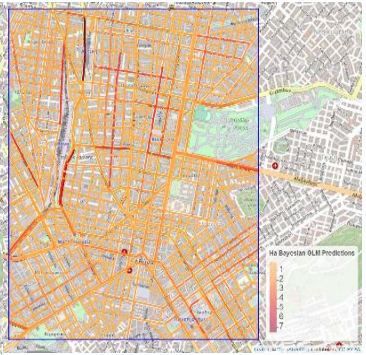
PROACTIVE SSM ANALYSIS EXAMPLE (3/3)

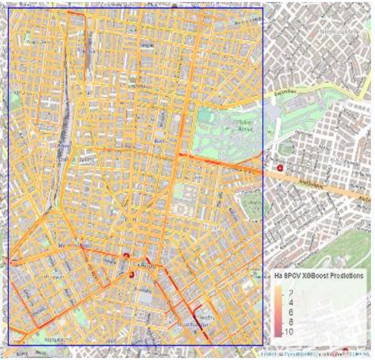
Model weaknesses are covered and strengths are enhanced with combined prediction techniques

Therefore the averaged output is closer to real measurements.









CRASH AND SURROGATE DATA COLLECTION

- Automated data collection is possible through:
  - Instrumented/floating vehicles
  - Smartphone sensors (harsh braking, harsh accelerations, harsh cornering, driving distraction via cellphone use, speeding, poor road surfaces).
- Technologies like automatic crash notification (eCall) and event data recorders enable data-driven responses to post-crash problems.
- Street imagery, also collected by floating vehicles, supports the assessment of road safety performance (star-rating for roads).
- Drones and satellites complement the range of data, capturing solutions with increased market penetration.
- Active safety system activation can also be considered among surrogate safety metrics, for systems such as:
  - Anti-lock Braking System [ABS]
  - Electronic Stability Control/Program [ESC/ESP]
  - Autonomous Emergency braking [AEB]

THE EGRIS NWA METHODOLOGY

- The EC in 2019 extended and modified Directive 2008/96/EC on Road Infrastructure Safety Management (DIR 2019/1936/EC), establishing the process of network-wide road safety assessment (NWA).
- NTUA (GREECE), FPZ (CROATIA) & FRED Engineering (ITALY), in a EC funded project developed a common NWA methodology, endorsed by EGRIS.

NWA considers the following pillars:

1. Parametrization of road characteristics with a distinction against their influence zone (e.g. point vs area vs network)
2. Definition of a causal relationship, supported by research findings, connecting sets of parameters with safety outcomes.
3. Balancing accuracy and level of detail, being mindful of resources and data costs
4. Consideration of specific needs of Member States (data availability, different environments etc.)

NWA ANALYSIS

- To apply NWA-proactive, the road network is divided in smaller parts, known as “road sections”.
- Sections are assessed based on the condition of a set of road characteristics, each one corresponding to a parameter.
- A safe road section receives the maximum score.
- A “ Reduction Factor ” (RF) is estimated per parameter to represent the identified unsafe conditions of the respective road characteristic. For safe conditions RF=1, while for unsafe RF<1.
- The safety score for a road section is estimated as:
  $Section\_Score = 100*RF_1*RF_2*…*RF_N$
- Each road section is then classified as Low/Intermediate/High risk based on its calculated score.
- NWA conducts subsequently a reactive analysis as well, integrating the on-site information by crashes recorded in the field. Sections are classified as of Low/High risk or as of Unsure results and finally the results are merged.

POTENTIAL NWA ENHANCEMENT WITH AI

AI can be employed to expand/enhance NWA at all stages, indicatively:

- Automatic collection and coding of parameters for NWA-proactive, exploiting open databases (e.g. Google Earth/Google Maps, OpenStreetMaps, Waze, etc.).
- Enhancing the proactive approach through AI-supported rapid collection & exploitation of SSMs (e.g. image processing).
- Using AI & reinforcement ML to select the most informative SSMs for each region/section.
- Using advanced ML models to compute composite safety scores.
- Using advanced time-series and Neural Networks to more accurately model and forecast causal relationships.

PENDING BARRIERS FOR AI (1/2)

- Safe, road-worthy AI systems face significant challenges that are only hesitantly tackled:
  1. Interfaceability
  2. Interoperability
  3. Timelessness
  4. Scalability

- Absence of monitoring and accountability limits seriously road safety performance. To counter this, increase acceptance and public trust by monitoring and reporting: e.g. operation of the AI Incident Database.

- Legal and operational frameworks are considerably lagging compared to technical developments. Self-updating mechanisms are direly required.

PENDING BARRIERS FOR AI (2/2)

- Research and innovation efforts on the use of AI in computer vision and risk prediction needs more support.

- Thorough evaluation and assessment criteria must be established across platforms, in research and industry, to deliver robust AI vehicular systems that will actively contribute to fatality reductions.

- Cybersecurity/malicious hacking concerns may cause several implications (vehicle manufacturers, software engineers, vehicle owners, automated fleet operators).

- AI feedback loops on road safety interventions and countermeasures:
  A completely unexplored field, which can be dynamic!

BARRIERS FOR PROACTIVE ROAD SAFETY (1/2)

- Road safety cannot be improved based on accurate forecasting alone – causal factors must be determined.
- Therefore, priorities should include the development of “explainable AI (XAI)” – “white box” techniques.
- Emphasis should be placed on collaborations across countries for the integration of all road realities and road safety cultures.
- Funding must also be available to road safety multi-disciplinary professionals to conduct post-intervention assessments and validate or re-calibrate the risk prediction tools.

BARRIERS FOR PROACTIVE ROAD SAFETY (2/2)

- New tools need to be aligned with, and enable, precise policy objectives.

- Stakeholders should commission research to assess the capability of proxy data and risk mapping tools.

Researchers and practitioners have to:

1. Develop new skills and a digital infrastructure.
2. Promote a multi-disciplinary approach to road safety that combines expertise from the fields of data science, technology and safety.
3. Design user-friendly risk mapping tools to be adopted by road users.
4. Update estimates of the benefit/cost ratio of interventions in a dynamic manner, along with accessible user-friendly interfaces.

CONCLUSIONS

- Great potential for seamless big data driven procedures from safety problem identification to selection and implementation of optimal solutions.
- Newfound net present value in road safety data, available for (real-time) early problem detection and prompt and customized decision support on every level.
- Considerable ground remains to be covered for existing road safety AI applications (telematics SSMs & crash analysis).
- Completely unexplored directions remain in several road safety aspects (crowdsourcing options, measure effectiveness, data harmonization).
- Artificial Intelligence in proactive approaches can become an efficient catalyst for achieving Vision Zero road fatalities by 2050.

National Technical University of Athens

ANASTASIOS DRAGOMANOVITS
SENIOR RESEARCHER – TRANSPORTATION ENGINEER

Tel: 0030 2103301515
Email: dragoman@central.ntua.gr
Website: www.nrso.ntua.gr

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