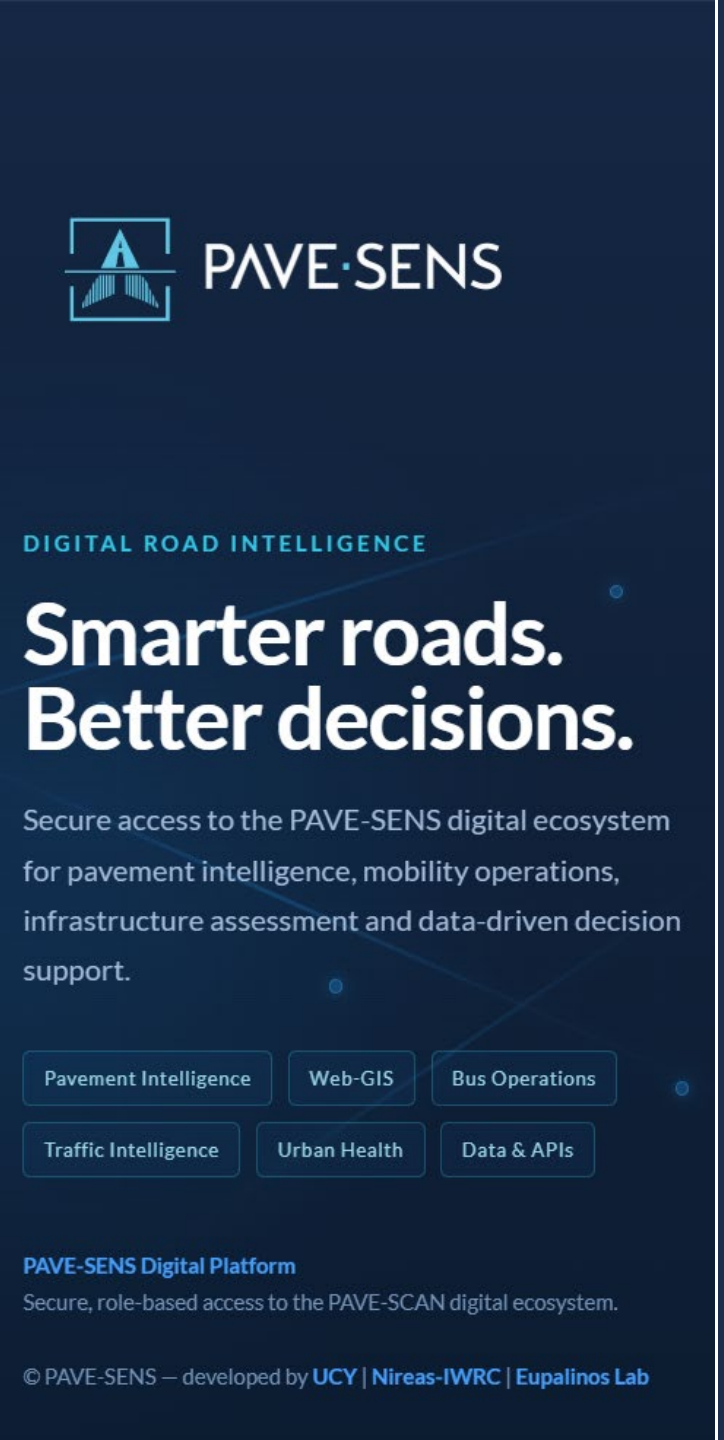

Intelligent Pavements

An Integrated Hardware–Software Platform for EGNSS-Enabled Digital Pavement Intelligence and Low-Cost Continuous Roadway Monitoring

Symeon E. Christodoulou

University of Cyprus

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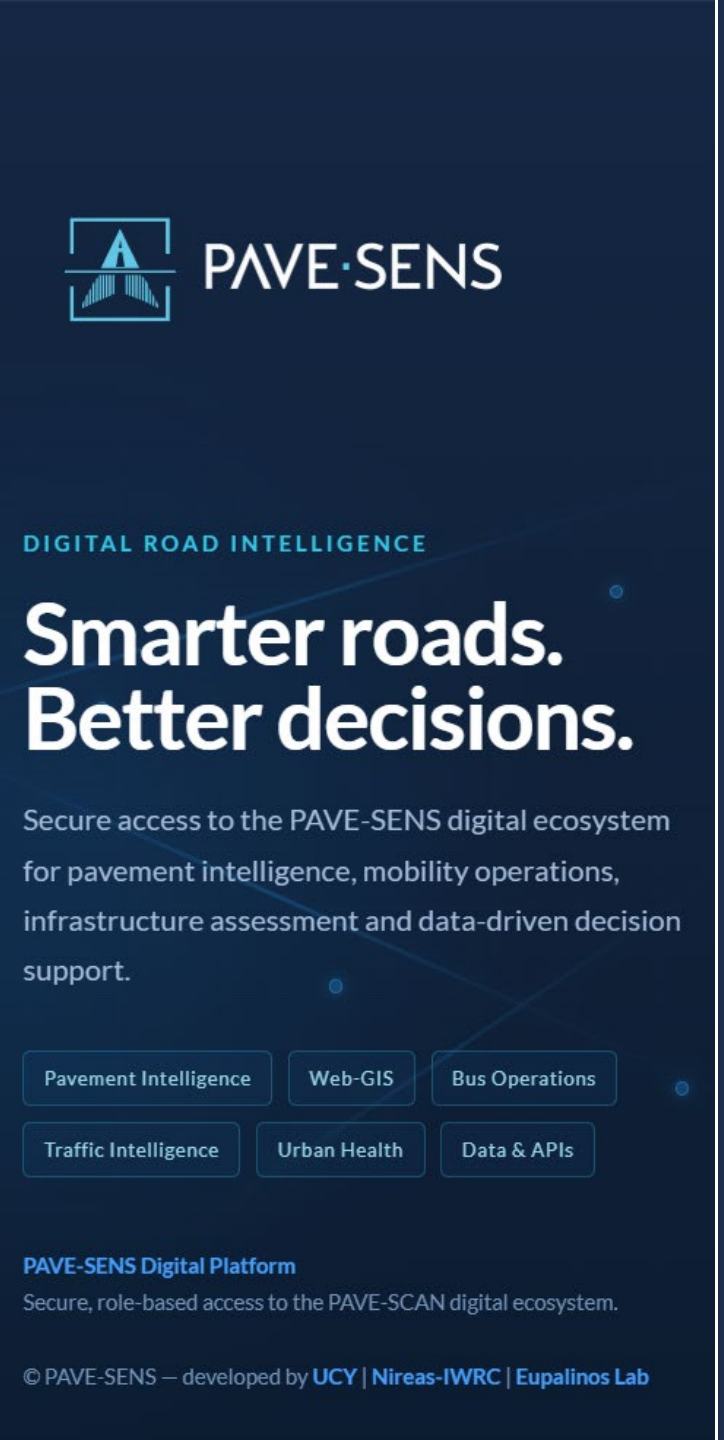

The pavement information gap

Periodic surveys

Detailed measurements, separated by inspection cycles

Daily deterioration

Road conditions evolve between those cycles

Continuous fleet sensing

Routine journeys supply repeated observations for engineering review

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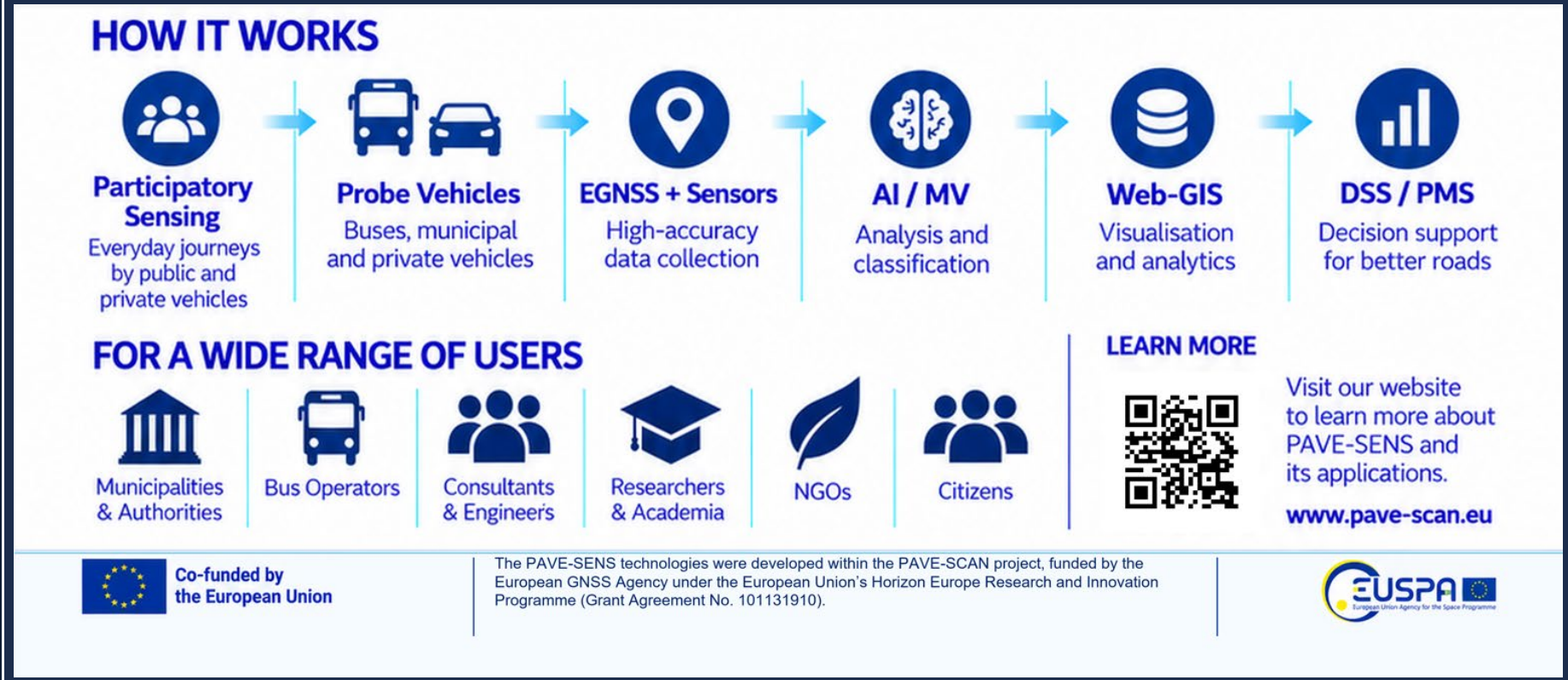

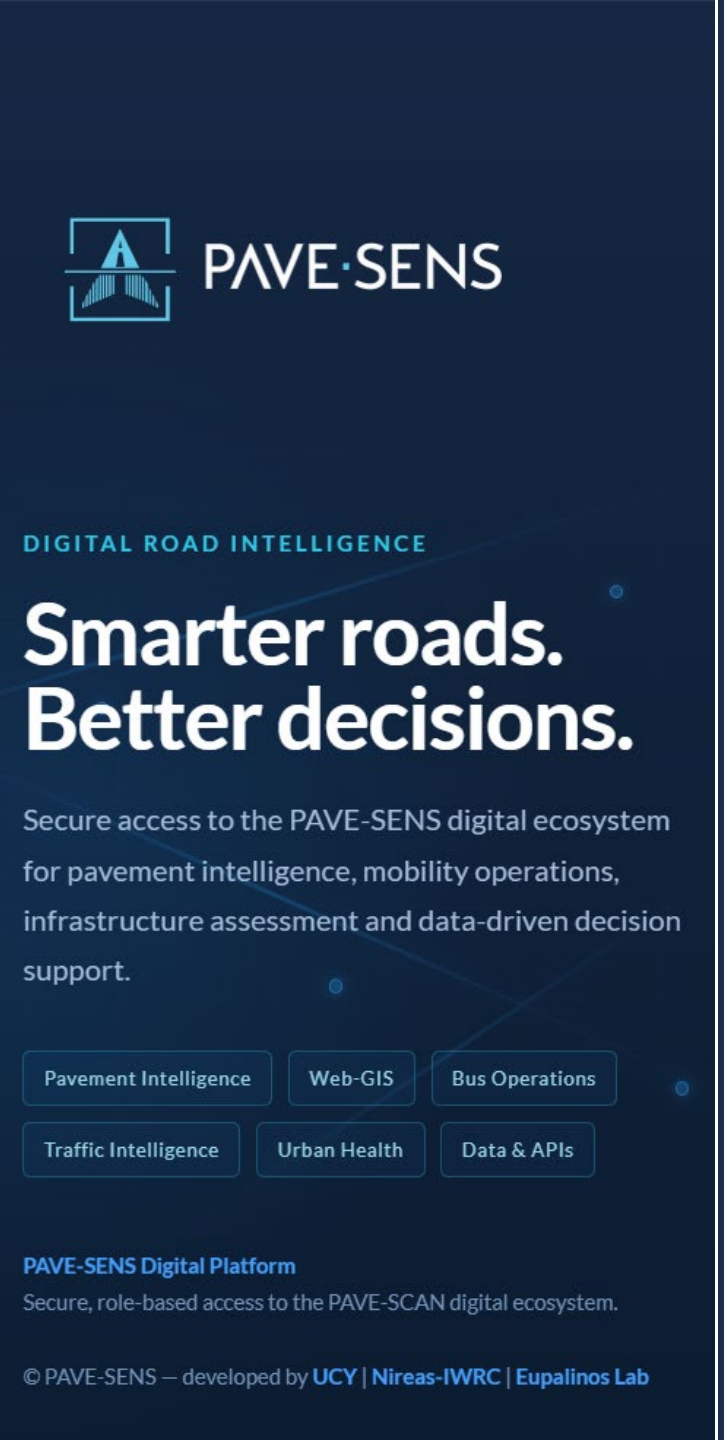

Our intelligent pavement concept

A digital representation that improves as evidence accumulates

$$I = F(S, G, V, H, P)$$

S Synchronized sensing
V Visual evidence
P Participatory observations
G Geospatial context
H Historical knowledge

Confidence inputs

Anomaly intensity and observation support
Spatial persistence and temporal recurrence
Orientation consistency and visual confirmation
Participatory evidence

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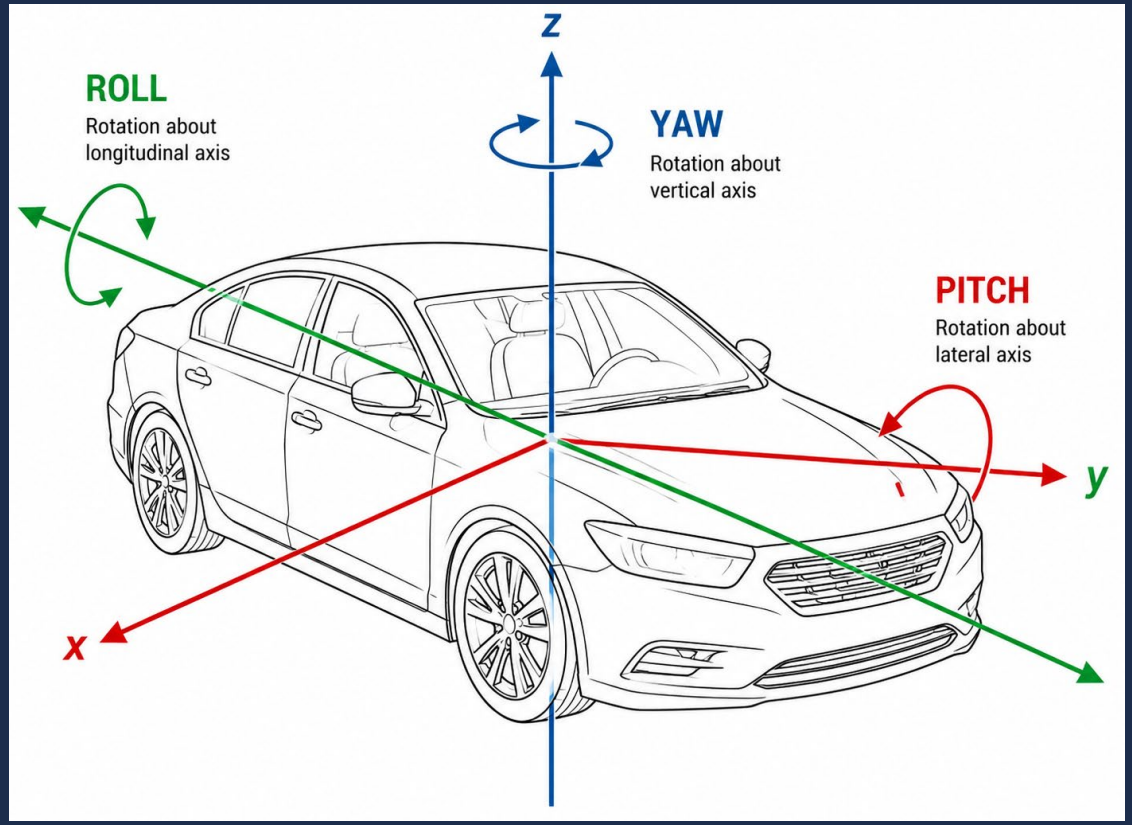
The road–vehicle interaction



Vehicle dynamics provide essential context for pavement inference

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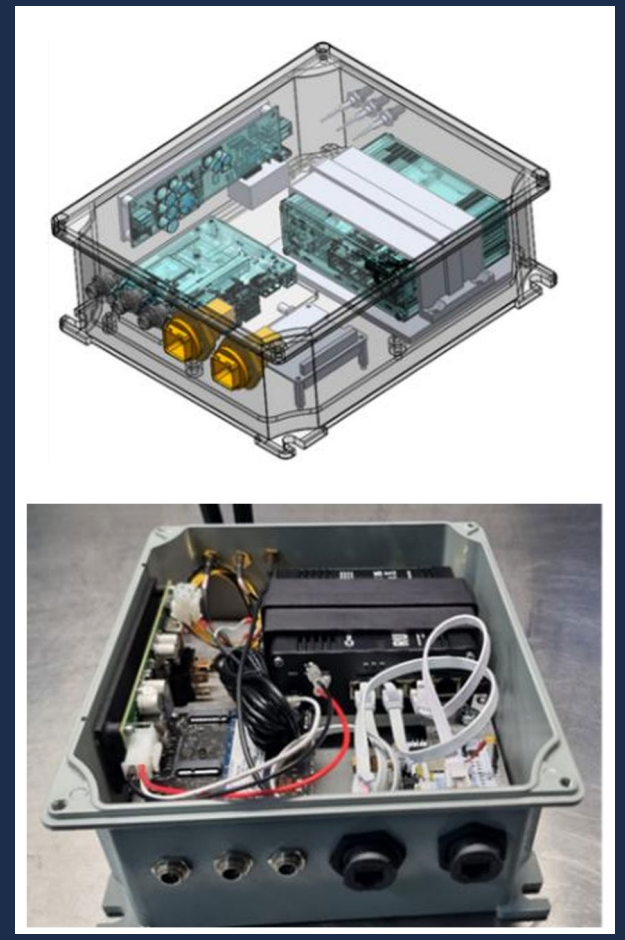
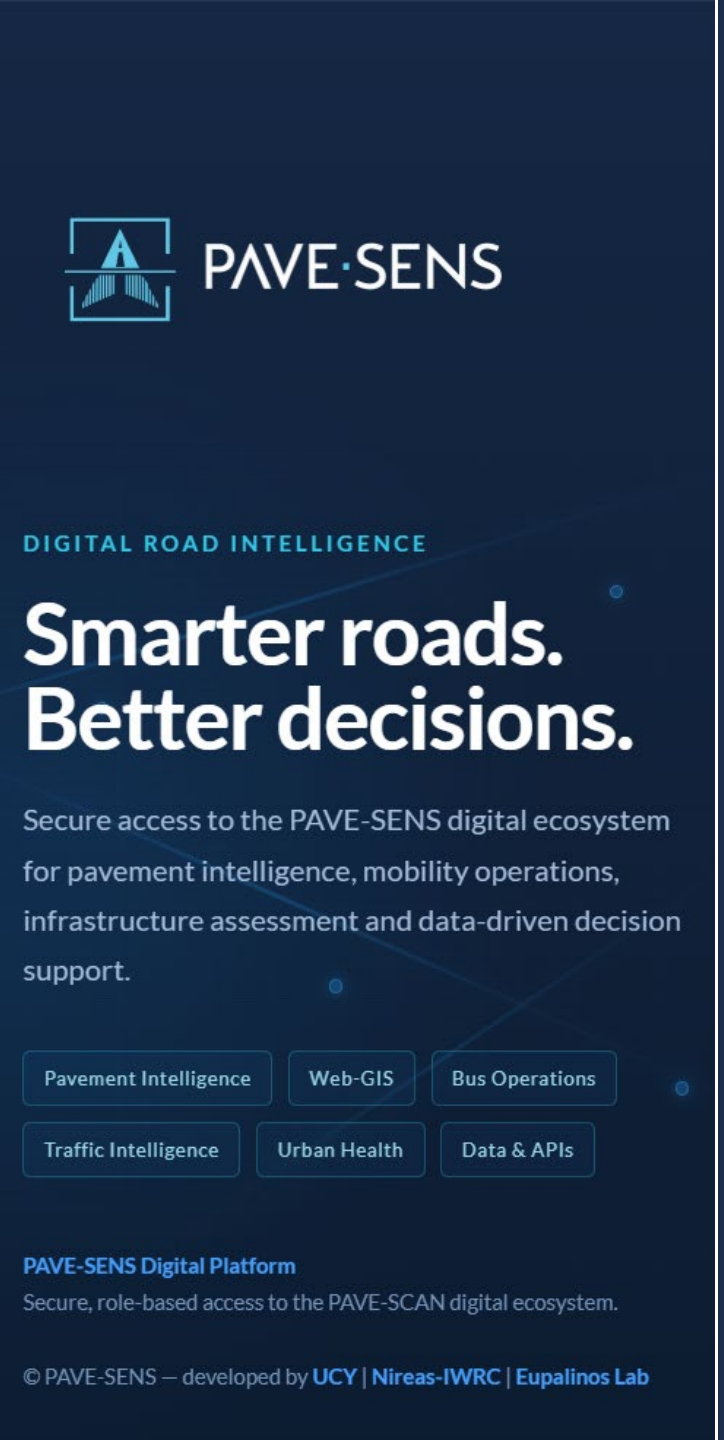
Routine journeys as surveys

Ordinary vehicles
Public transport buses

EGNSS positioning
Inertial measurements
Synchronized roadway imagery
Edge processing and LTE/5G



Modular configurations share one analytical framework



Complementary sensing evidence

EGNSS answers where

Associate observations with the same roadway location

IMU captures the response

Interpret vibration alongside orientation and operating context

Vision supports verification

Inspect visible defects and corroborate recurring events

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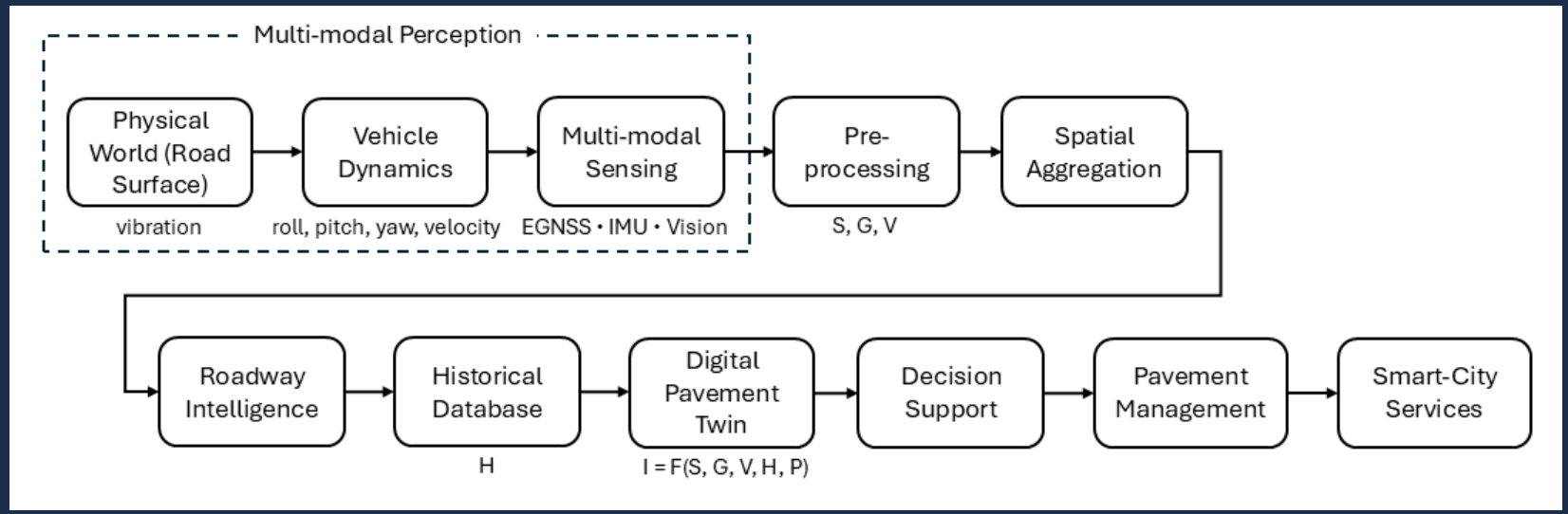
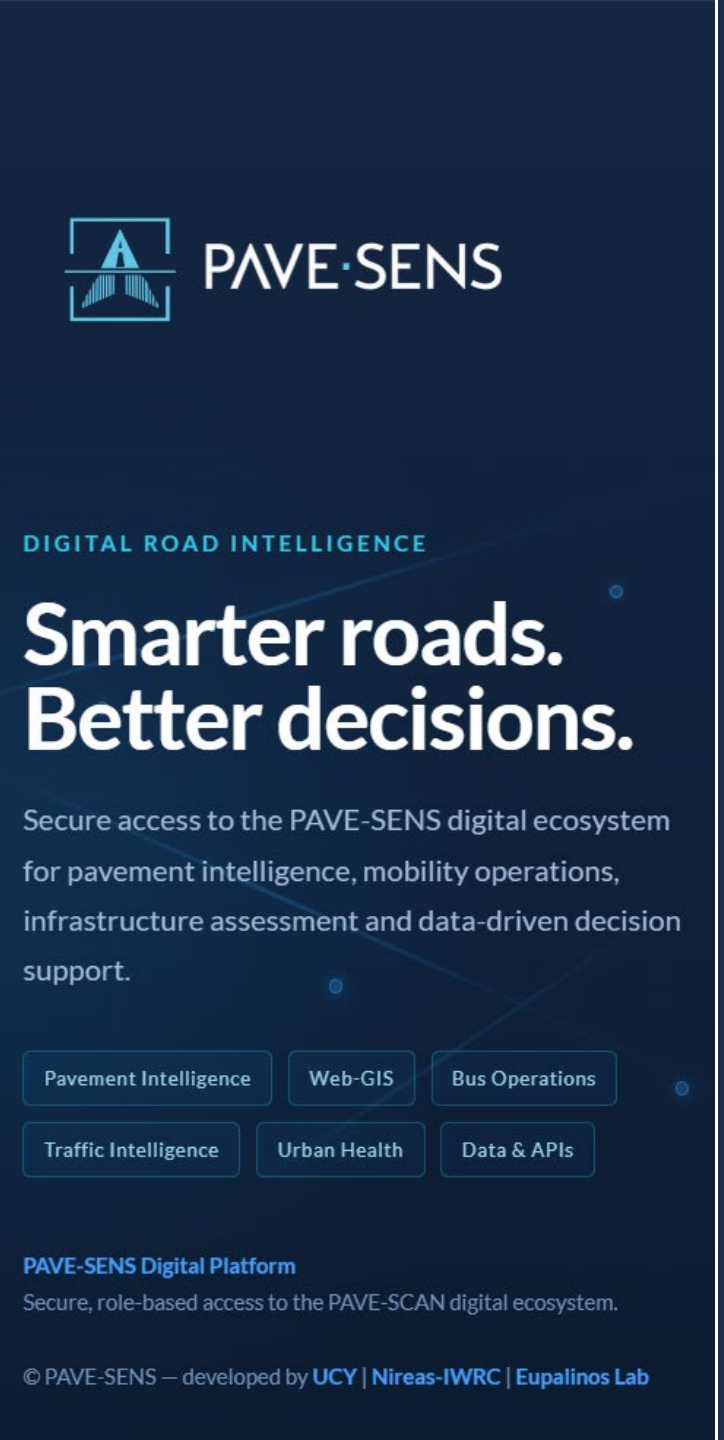
The intelligence workflow



Repeated observations connect sensing to a persistent road record

Operational output: evolving digital pavement representation



Confidence follows the evidence

A recurring event becomes more useful when independent evidence agrees

Repeatability

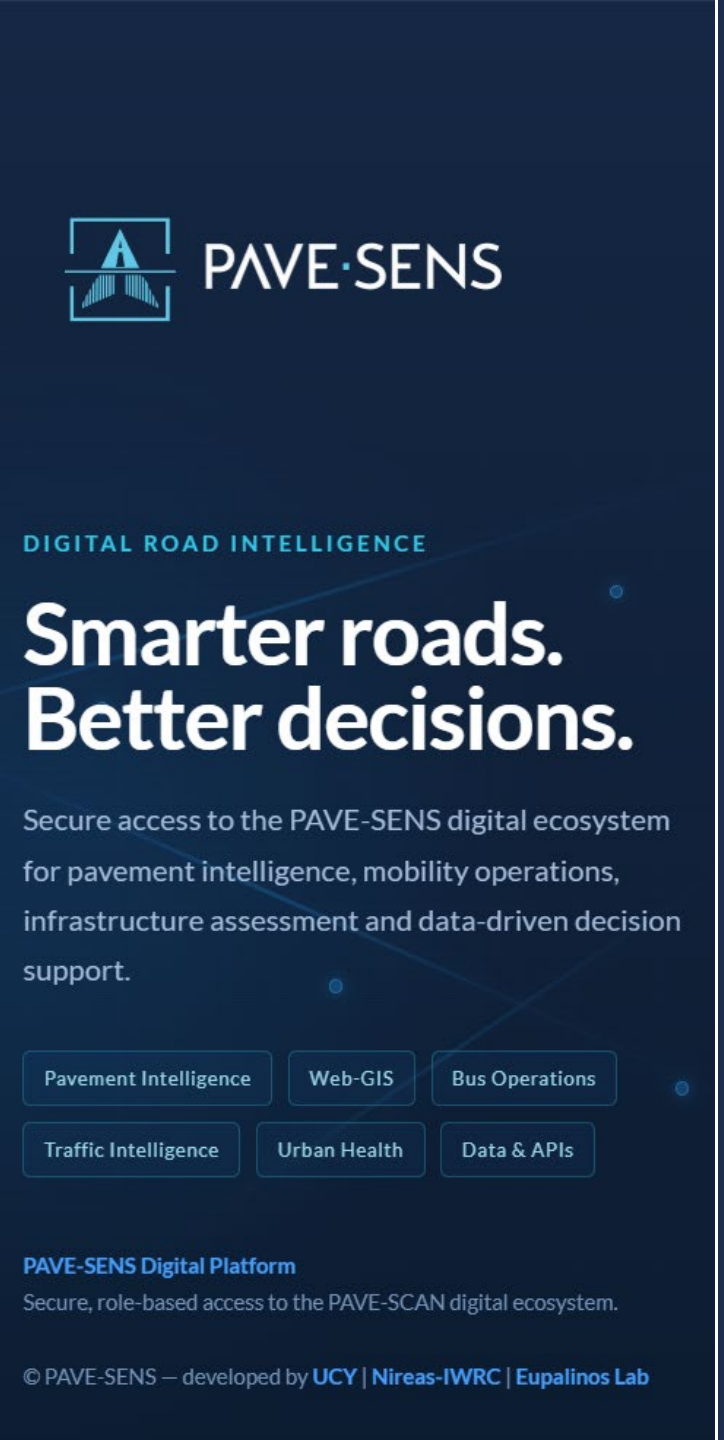
Spatial persistence across passes and vehicles

Corroboration

Synchronized imagery and participatory observations

Acquisition quality

Orientation consistency and observation support



Nicosia operational deployment

≈2.5 million

synchronized vibration observations

70,000+

georeferenced roadway videos

January–June 2026 Passenger vehicles and public transport buses

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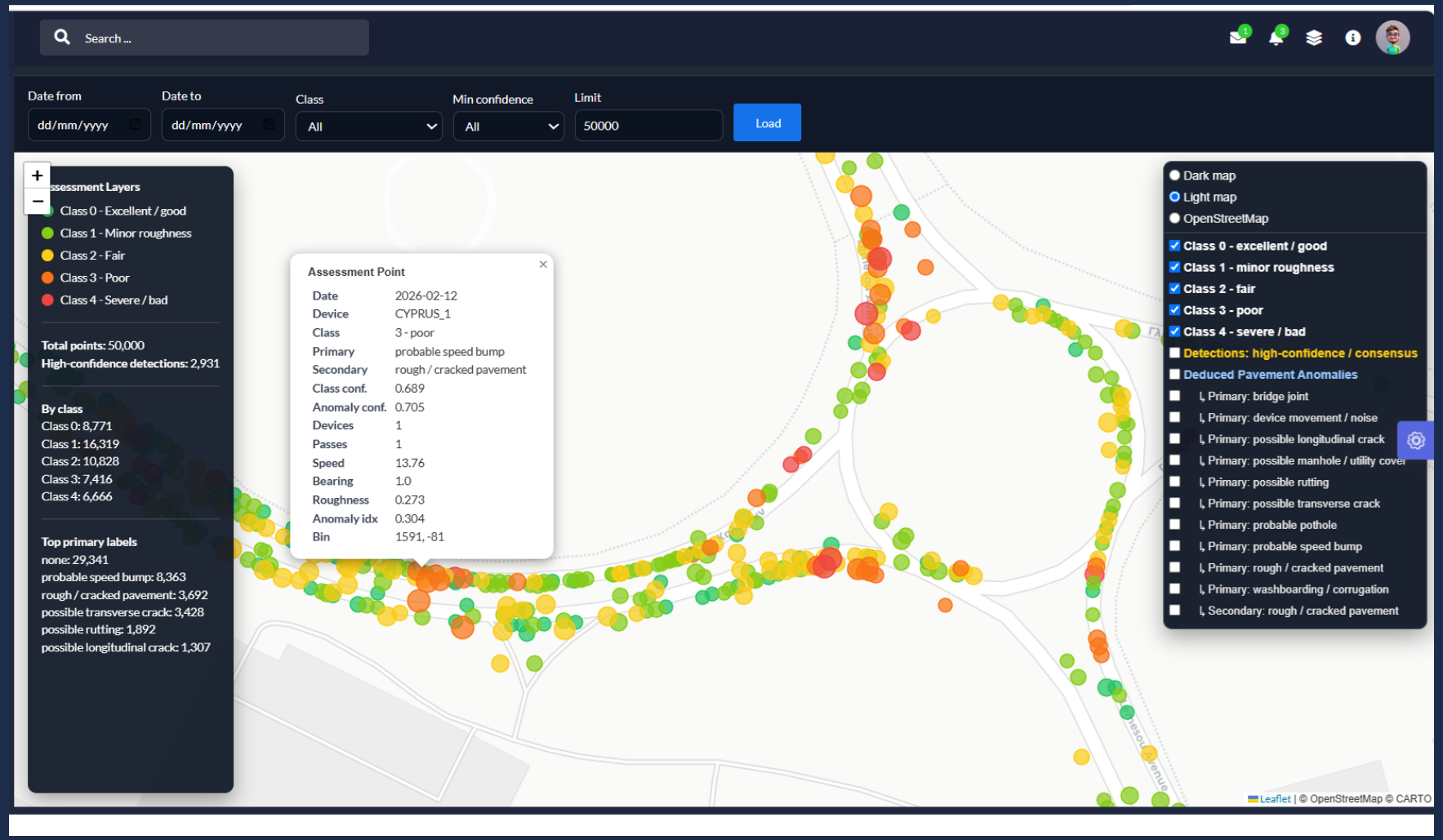
Point-level engineering inspection

Condition class, defect type, confidence and vehicle context



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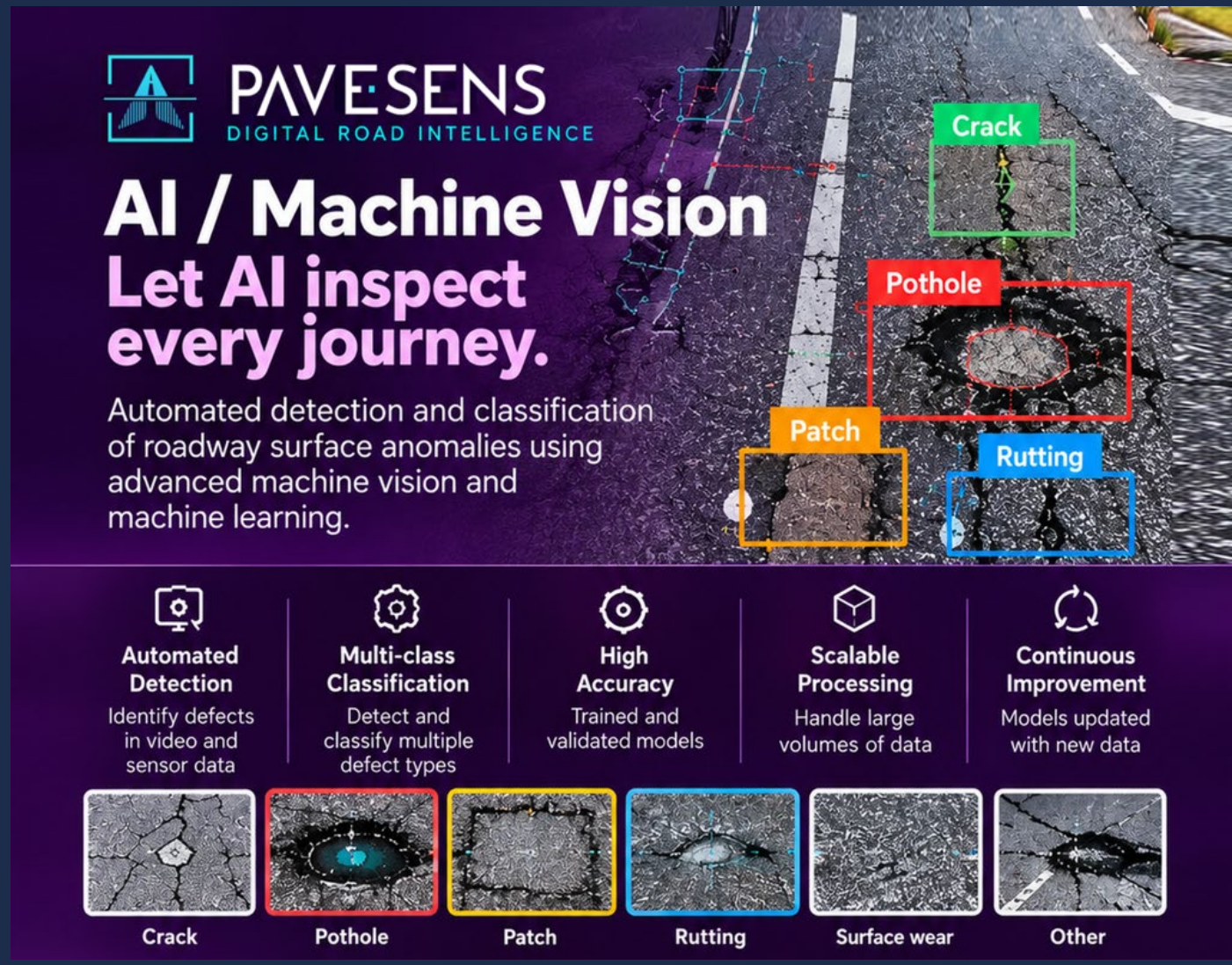
Is vibration sensing enough?



Condition class, defect classification, confidence and vehicle context

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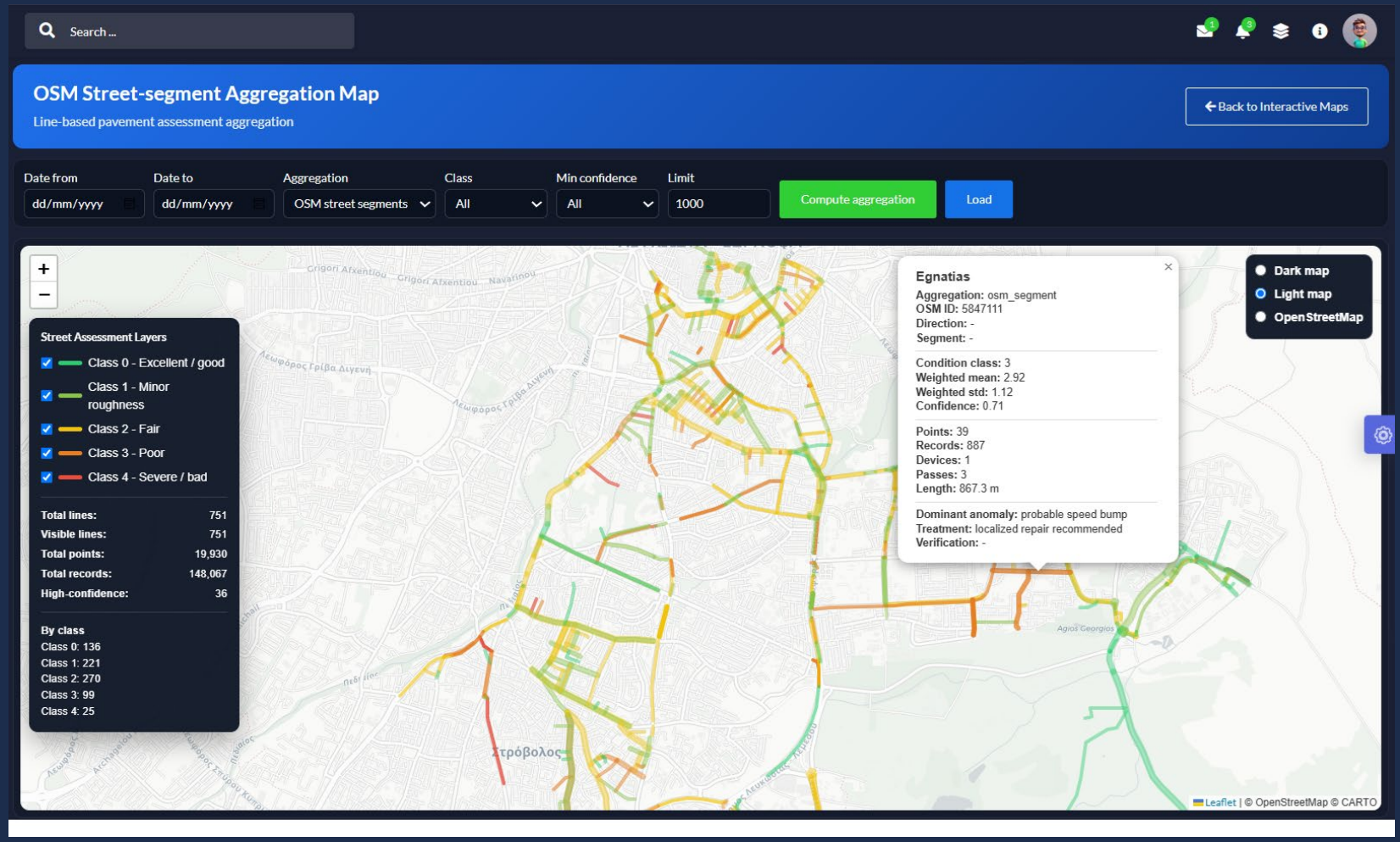
From point-level to segment-, street-, and district-level roadway condition assessment



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From Sensing,

to DSS

…



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…

to PMS,

and

beyond.



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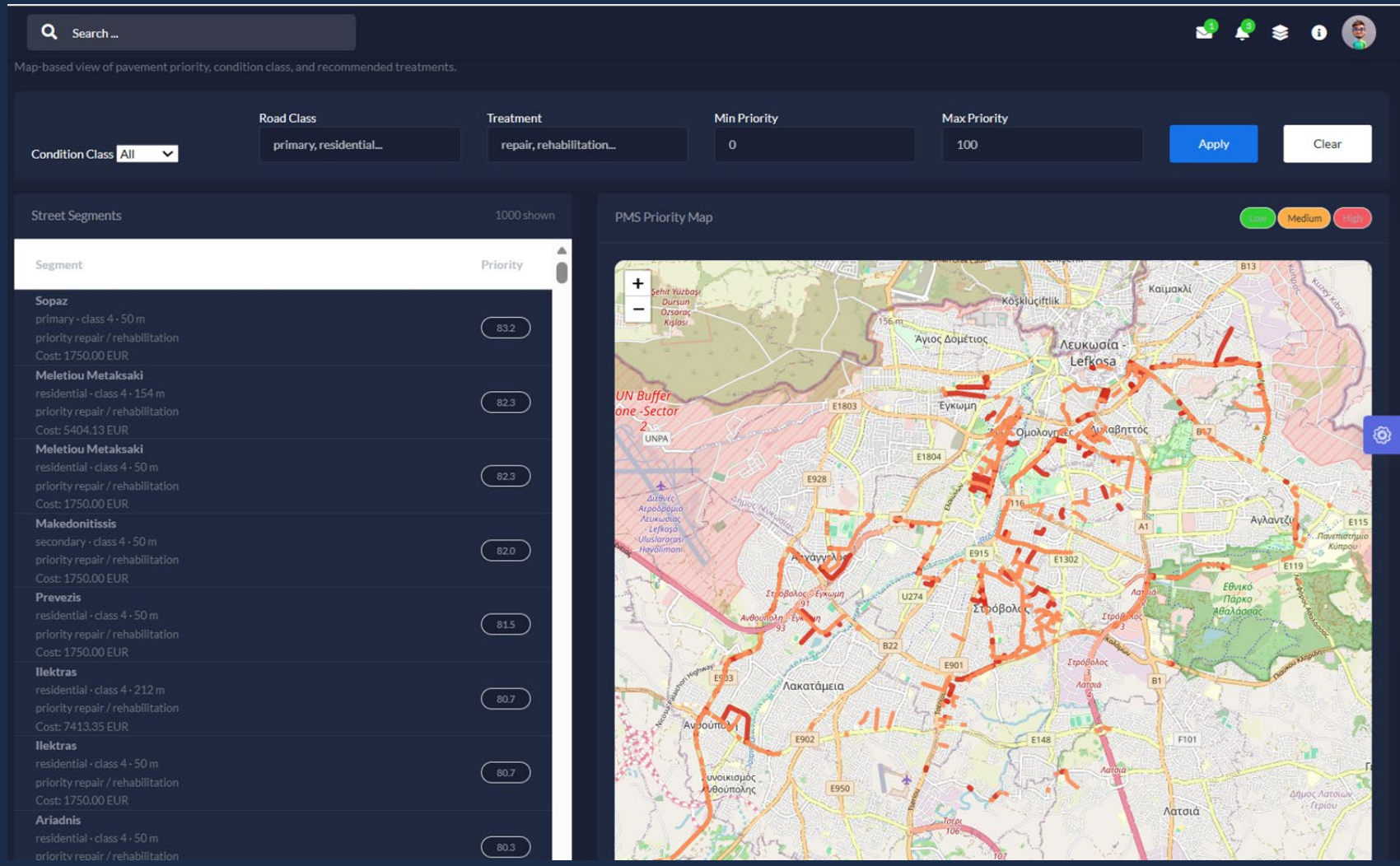
Maintenance priorities and treatments



Ranked priorities support engineering judgement and field verification

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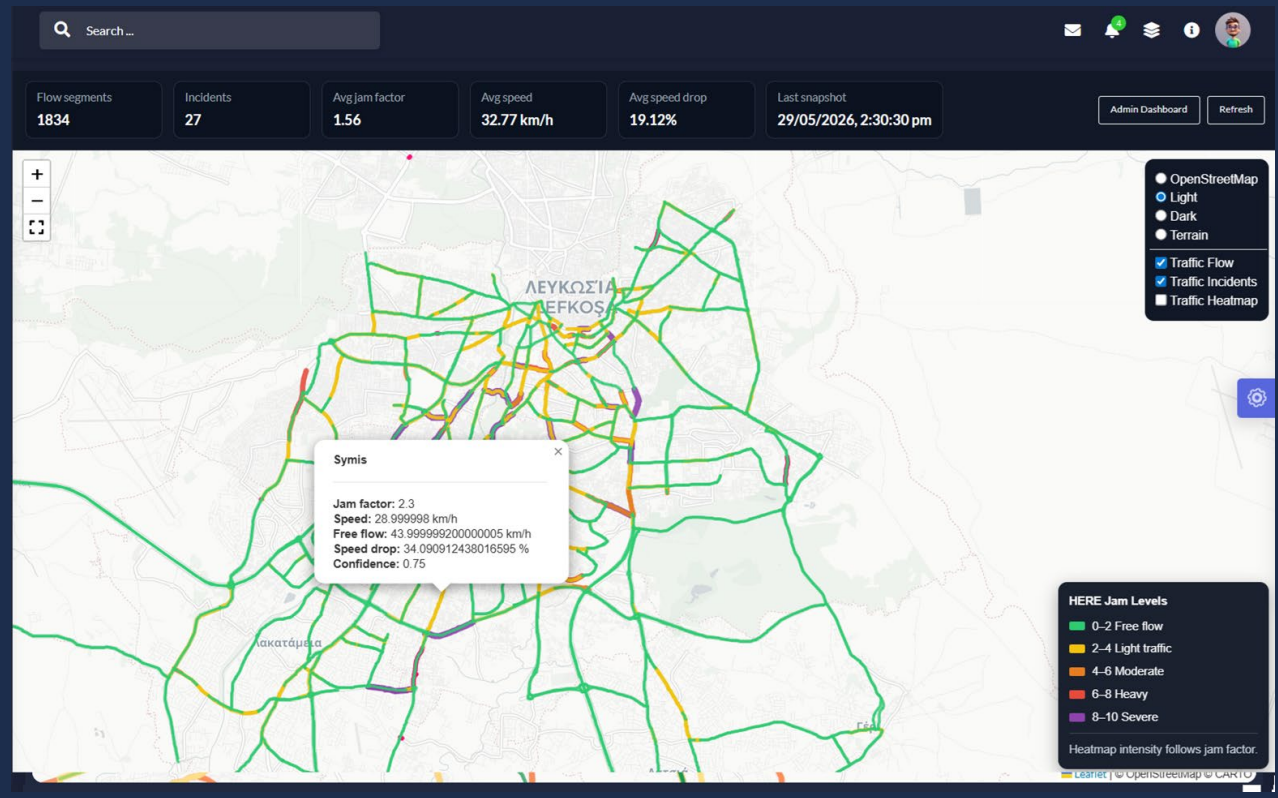
A shared platform for city services

- Traffic monitoring
- Air-Quality monitoring
- Urban mobility and infrastructure health
- AR mobile app
- Bus Operations and their exposure to pavement conditions

- APIs
- Video and Data Hubs



Urban mobility and infrastructure health

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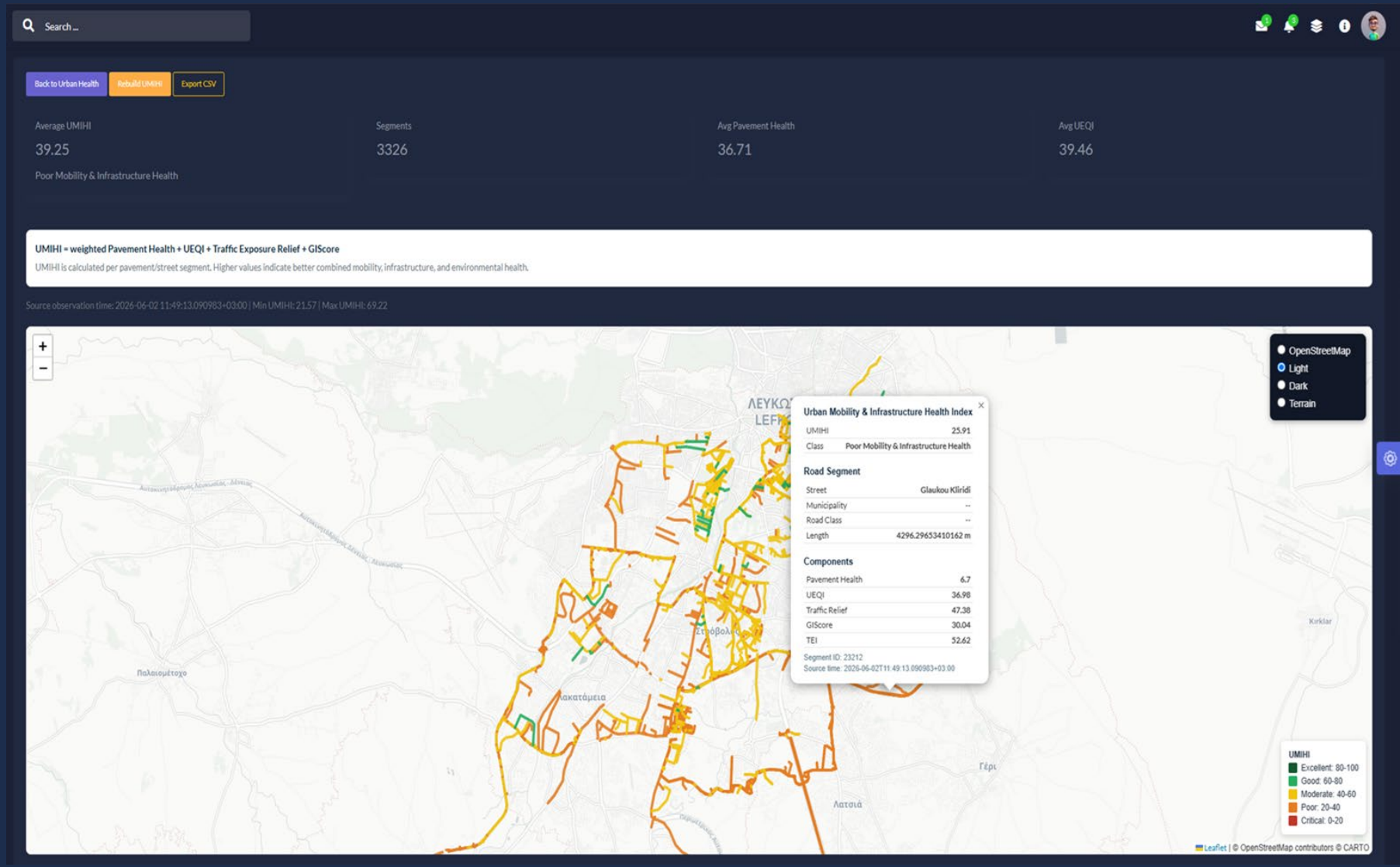

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Bus Operations

Better roads. Better bus operations.

Use pavement and infrastructure intelligence to support safer, more efficient and more reliable public transport operations.

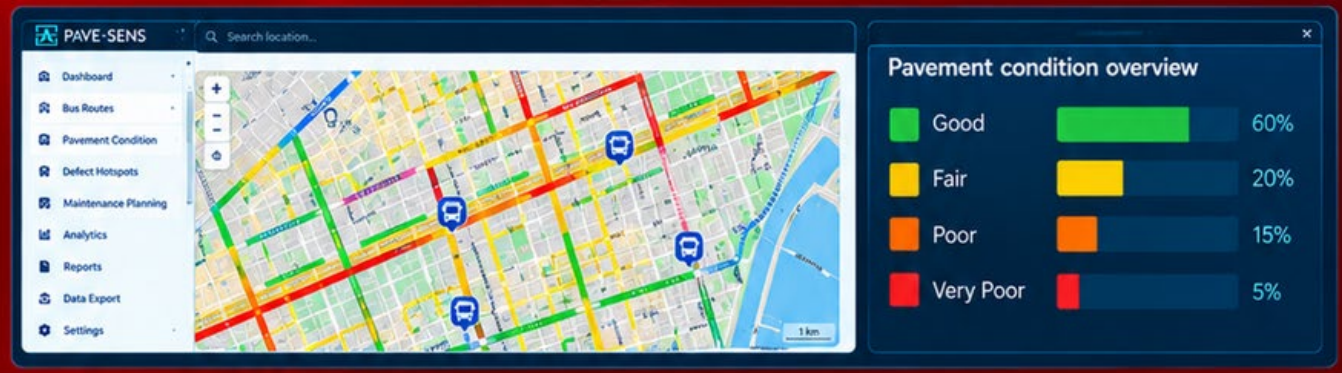


Route Assessment
Analyse pavement condition along bus routes

Risk Identification
Detect issues that affect safety and comfort

Operational Insights
Support maintenance and routing decisions

Improved Service
Enhance reliability and passenger experience



KEY BENEFITS

SAFER OPERATIONS
Reduce risks and vehicle damage

HIGHER RELIABILITY
Support consistent service delivery

COST SAVINGS
Optimise maintenance planning

IMPROVED PASSENGER EXPERIENCE
Smoother and more comfortable journeys

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HOW IT WORKS

1. Capture
Take a photo or short video of the road issue

2. Locate
Automatic EGNSS location with high accuracy

3. Report
Add description and submit

4. Track
Monitor status and contribute again

Technical backup: platform services

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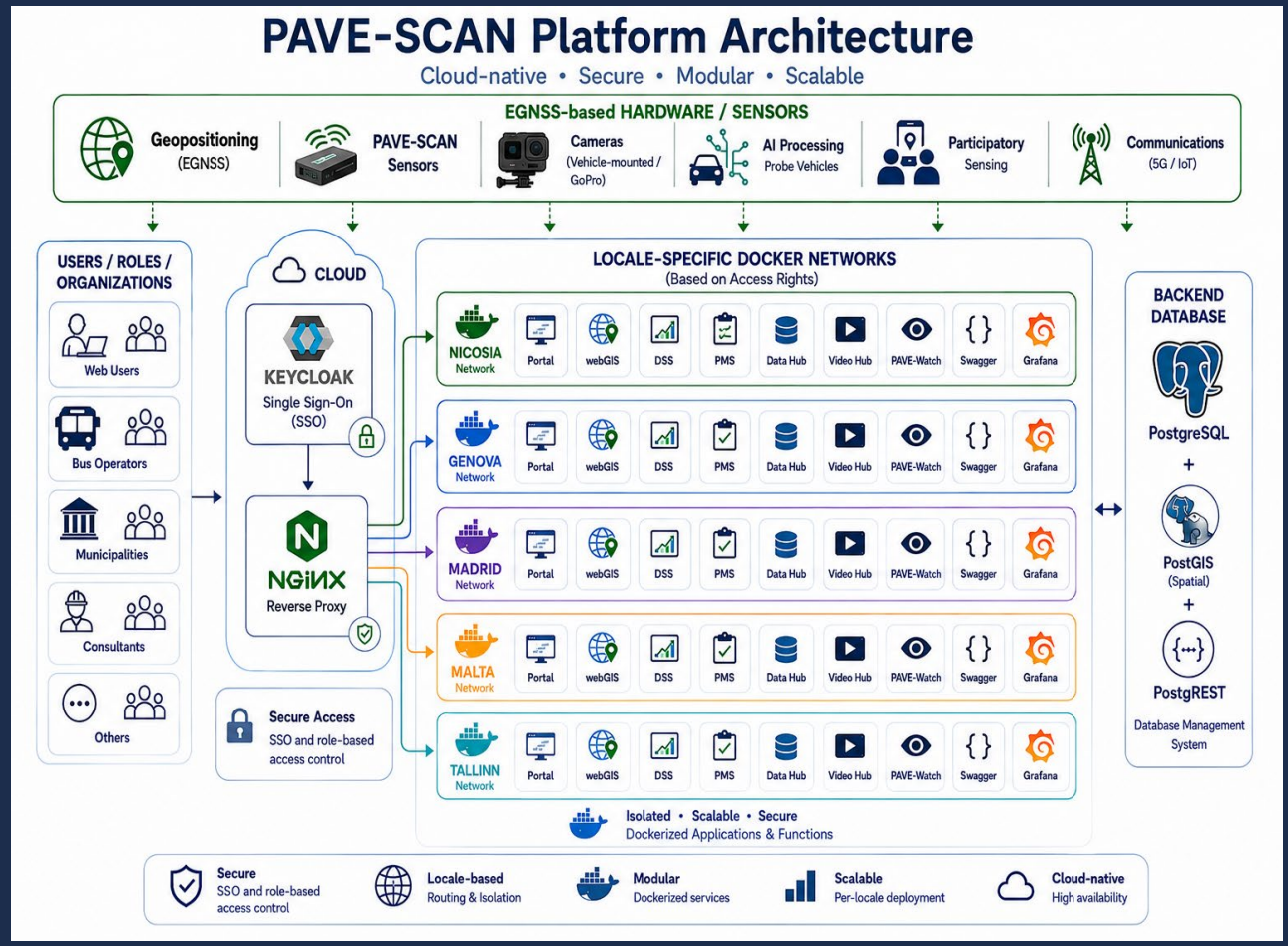
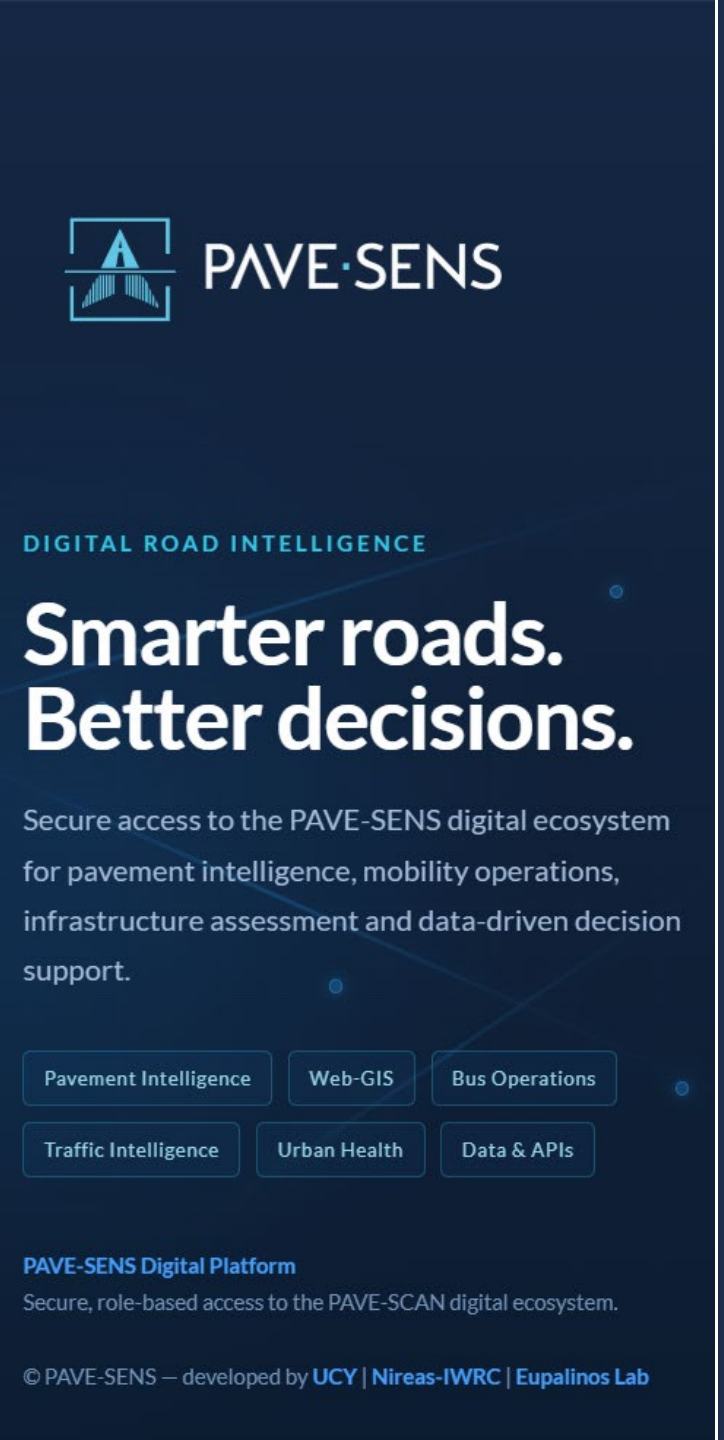
- **Deployments In:**
  - Nicosia
  - Tallinn
  - Malta
  - Madrid
  - Genova



Detailed reference view. City rows describe the deployment architecture



Sustainability pathways

Monitoring during existing journeys

Potential to reduce additional inspection travel

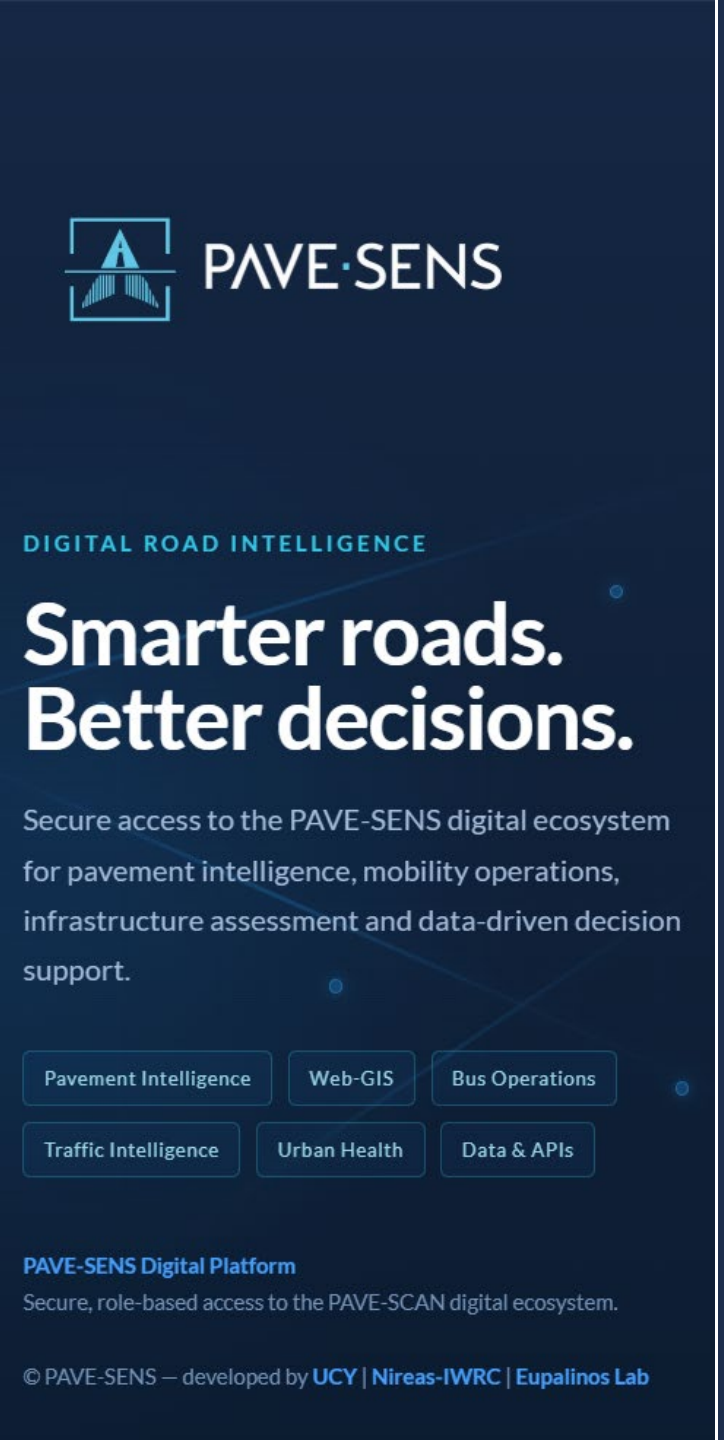
Earlier, targeted intervention

Potential to preserve assets and avoid unnecessary material use

Coordinated maintenance planning

Potential to reduce disruption across the road network

Potential benefits require lifecycle and operational evaluation



Discussion

Intelligent pavements begin with evidence we can use

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www.pave-scan.eu

