Dalan-AI: A Three-Layer Framework for AI-Powered, Low-Cost Road Condition Assessment

Frederico Soares Cabral

National University of Timor-Leste

Co-Authors

Vosco Pereira, Hidekazu Fukai, Ruda Barbosa, Sara Rinela Putri Tilman

Background: road condition monitoring today

Manual surveys

- Rely on inspectors' expertise and experience
- Time-consuming
- Results vary with each inspector's judgment

Commercial equipment

- Reliable, specialized measurement
- Substantial investment cost
- Ongoing maintenance cost

THE NEED IN TIMOR-LESTE

Timor-Leste relies primarily on manual surveys. It needs an alternative that gives reliable results at minimal operating cost.

OUR DIRECTION: A LOW-COST ALTERNATIVE

Smartphones and dashboard cameras → **Machine Learning and Deep Learning** → **Reliable road condition information at low cost**

Targets: research that serves a national need

FOUNDATION

Almost eight years of low-cost assessment research

- Road roughness estimation
- Paved and unpaved road classification
- Pothole detection
- Road width and pothole size estimation
- Crack detection
- Road anomaly detection

Dalan = road in Tetum · **AI** = Automated Inspection and Artificial Intelligence

THE PRINCIPLE

Research should serve a national need and contribute to society.

TARGETS OF DALAN-AI

- Give every study a path from experiment to operational use
- Standardize all research outputs in one common data schema
- Turn results into GIS maps that support maintenance planning
- Plan for scalable, always-on monitoring through crowdsensing

Proposed method: the Dalan-AI three-layer framework

LAYER 3

Production

Crowdsensing and an automated, always-on pipeline, applied to each application as it becomes ready (RR first)

Roadmap

LAYER 2

Application

Dalan-AI Platform · one integrated map, reads the API of each application

Dalan-AI RR API

Road roughness from phone sensors

Released

Dalan-AI RD API

Road distress from dashcam images: potholes, cracks

Planned

Dalan-AI RA API

Road assets from dashcam images: markings, guardrails

Planned

Shared core: base points (25, 50, 100 m) · aggregation (continuous and discrete rules) · multi-scale GIS view

validated methods up, improvements back

LAYER 1

Research

Each track, one per road asset, delivers its result in the common data schema.
Discovers and improves

Common schema Waypoint ID · coordinates · timestamp · asset category · result · confidence · provenance

Proposed method: from research tracks to GIS maps

LAYER 1 · RESEARCH

One track per asset

Roughness, surface type, potholes, cracks, anomalies. Each is developed independently, at a different stage.

Data and AI that fit the task

Images, video or sensor signals from smartphones and dashboard cameras, each with its own ML or DL method.

STANDARDIZED OUTPUT

Common data schema

Waypoint ID · coordinates · timestamp · asset category · result (continuous, class or binary) · confidence score · method and version

LAYER 2 · APPLICATION

1 Base points

Shared fixed-interval points (25, 50 or 100 m) on the road centerline

2 Snap

Each result is assigned to its nearest base point

3 Aggregate

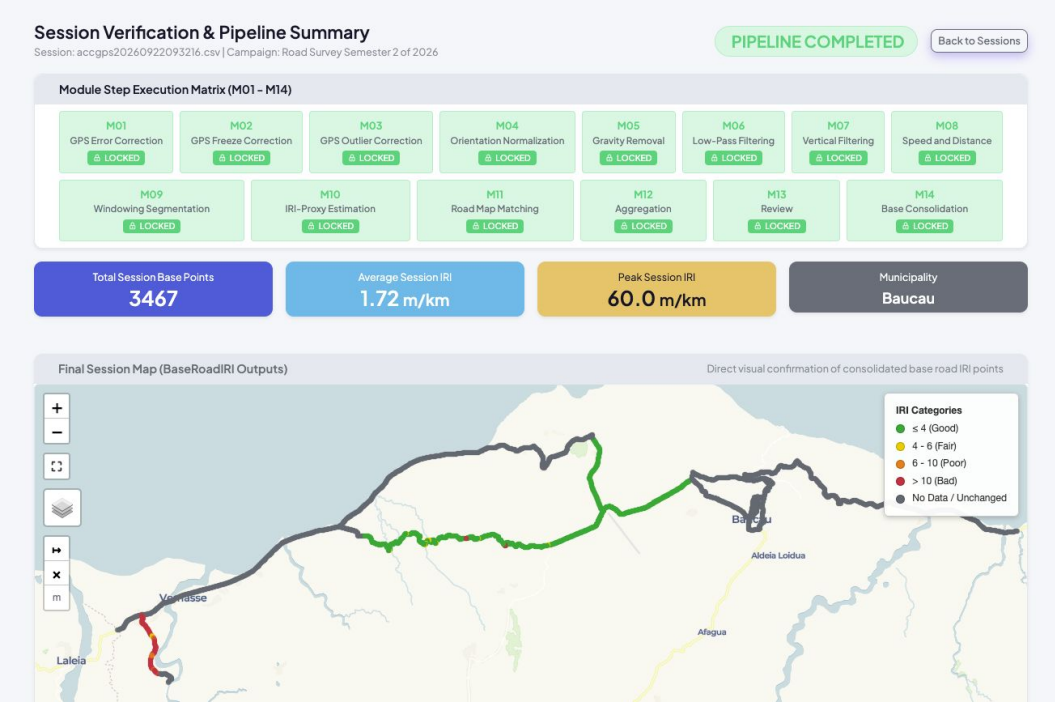
Continuous: mean, min, max, SD.
Discrete: count, density, class

4 Visualize

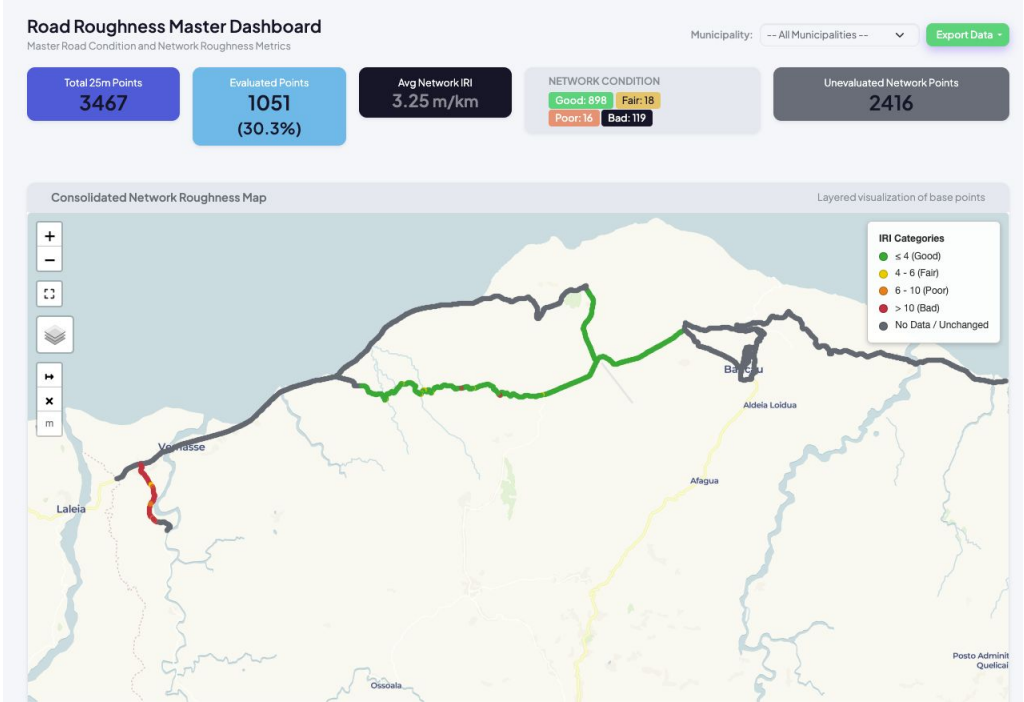
GIS maps that support maintenance planning

Four scales of view: National · Municipal · Segment · Asset

Field test: Dalan-AI RR, the first released application



Pipeline: one survey session through 14 modules (M01–M14), completed steps locked



Dashboard: current sample, data collection ongoing (600 km planned)

M01–M10 · Layer 1 research result

iri_engines: phone sensors to an IRI-proxy score, in the common schema

M11–M14 · Layer 2 processing

base_map and aggregation: map matching, aggregation, review, consolidation

Impact: scientific and technological

APPLICATIONS ARE SEPARATED BY DATA MODALITY AND RESULT TYPE

	Sensor-based	Image-based
Input	Smartphone accelerometer, gyroscope, compass, GPS and timestamp	Dashboard camera video, converted to image frames
Technique	Signal processing and IRI-proxy estimation	Computer vision and object detection
Result type	Continuous values (IRI-proxy)	Discrete values: counts, classes, presence
Example	Dalan-AI RR (Road Roughness)	Dalan-AI RD and RA (planned): potholes, cracks, road assets
Status	Released (Dalan-AI RR)	Research stage: experiments in Layer 1

Integrates heterogeneous methods

Independent research tracks plug into one common platform.

Low-cost and scalable

Phones and dashboard cameras make monitoring affordable at national scale.

One point, many modalities

A shared base point can hold a roughness score and a pothole detection.

Impact: societal and collaborative

Societal: for Timor-Leste

- Road condition data at low operating cost
- Maps that support maintenance planning
- Information for road infrastructure agencies, beyond manual surveys
- Consistent results, less dependent on individual inspectors

Collaborative: for the ASEAN region

- Smartphones and dashboard cameras are widely available
- The common schema can be adopted by other countries
- Other teams can contribute their own research tracks
- Suited to resource-constrained environments

An invitation: bring your own road-asset research track and connect it through the common schema.

Output and outcome: what Dalan-AI delivers

Scientific

- Three-layer framework from research to production
- Common schema, shared base points and aggregation
- Research tracks for road condition and road assets

Societal

- Dalan-AI RR released
- Roughness dashboard and GIS map for decision makers
- Read-only access to preliminary scores

Collaborative (target)

- New partners who add research tracks or applications
- Adoption of the schema in other countries
- Shared platform for ASEAN road-asset research

Outcome: road condition research that reaches national use through one shared platform.

Output and outcome: roadmap toward Layer 3 production

NOW

RR released

- Application in Layer 2, with a roughness dashboard and GIS map
- Roughness research continues in Layer 1

NEXT

RD and RA

- Image-based tracks move from experiments to standard output, and then become RD and RA
- Each application exposes an API to the integrated map

LATER

Future plan

Layer 3 production

- Crowdsensing and an automated pipeline
- Applied to each application as it becomes ready

CHALLENGES AHEAD FOR LAYER 3

Data quality

Filter noisy or unreliable submissions

Device variety

Phones and mounting positions differ

Privacy

Especially video: faces and license plates

Incentives

Reasons for road users to take part

Conclusion: research that serves national needs

Targets

Connect road condition research to national use, at low operating cost.

Method

Three layers and one common schema. RR is released; RD and RA are planned, to connect by API to one integrated map.

Impact

GIS-based condition information for Timor-Leste, and a schema other ASEAN teams can adopt.

Thank you

Questions and collaboration are welcome

Backup: Dalan-AI RR processing modules

Modules	Step	Method
01	GPS error correction	Boundary Average Interpolation (BAI)
02	GPS freeze handling	Average Predictive Boundary Interpolation (APBI)
03	GPS outlier handling	Speed-Threshold Boundary Interpolation (STBI)
04	Orientation normalization	Euler angles, rotation matrix, gravity vector
05–07	Signal conditioning	Gravity removal, Butterworth low-pass filter, vertical (Z) axis
08–09	Speed, distance, windows	Speed and distance estimation, sliding-window segmentation
10	Roughness estimation	IRI-proxy with speed filtering
11–12	Spatial integration	Map matching, point aggregation
13–14	Review and consolidation	Comments, manual scores, interpolation flags, consolidation