How Artificial Intelligence is Transforming Transportation Asset Evaluation and Management

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University of Missouri-Columbia &
Tiger Eye Engineering

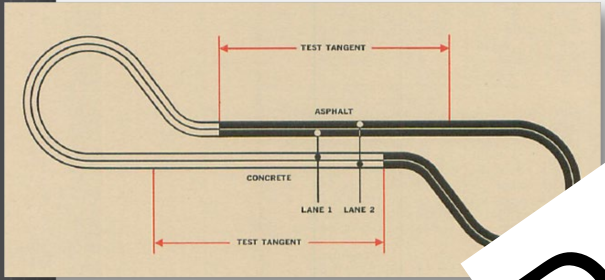
TEAM Conference, Branson MO
March 14, 2024

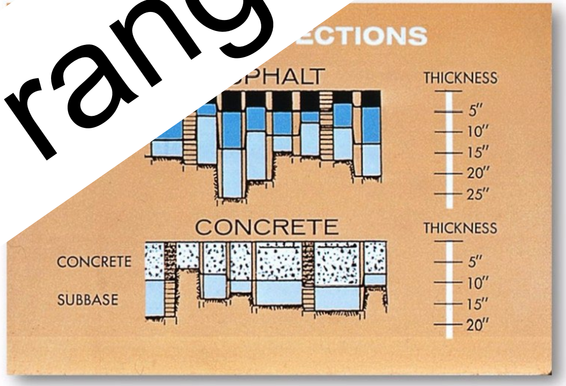
Topics du jour

- Data science in pavements…historical perspective
- Crowd-sourcing, pavement roughness
- Learning and predicting lab performance data
- Assessing field performance

Pavement Data – 1950's

- AASHO road test: Ottawa, IL, late 1950s
- Design guide finished in 1961; revised in 1972, 1986 … revision)





Data ~ kB range

- No electronic sens… …r PCs

Benkelman Beam Testing of Pavement Deflection

Modern Pavement Data Streams

Data Collection Vehicles

est Roads, ALFs

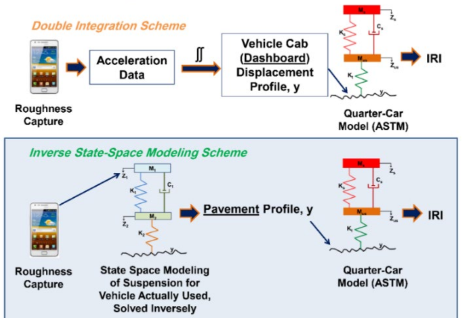
Can be…Messy

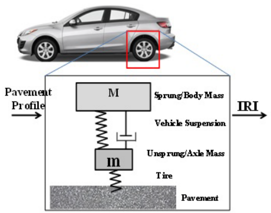
ed

Fixed Sensors

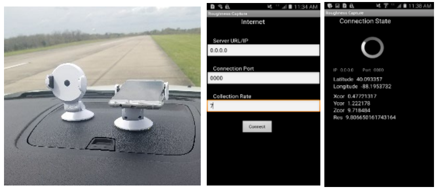
Modern Vehicle Fleet (Moving Sensors, Crowd Sourcing)

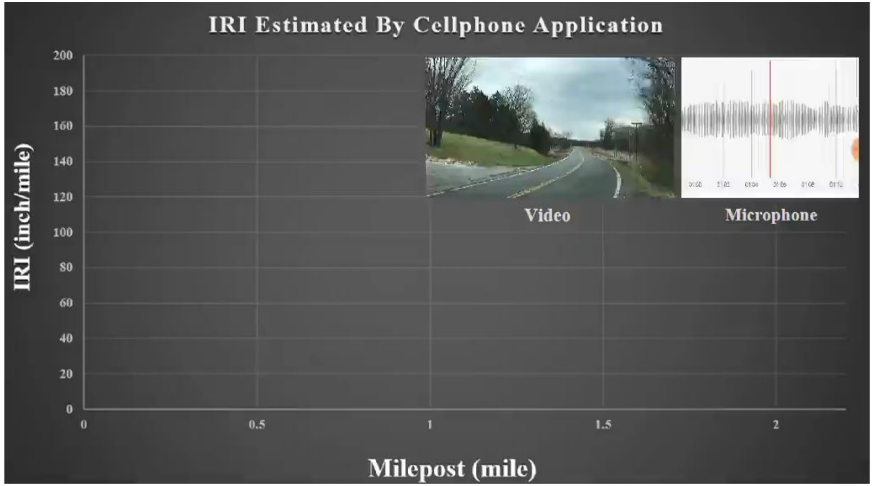
Measuring International Roughness Index (IRI) w/ Smartphone





Quarter-car Model

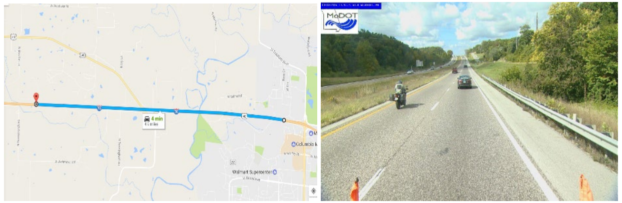


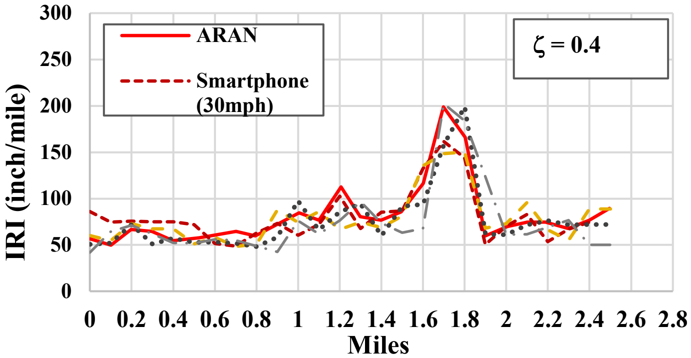


Islam, M.S., Buttlar, W.G., Aldunate, R.G., and W.R. Vavrik, "Measurement of Pavement Roughness Using an Android-Based Smartphone Application," TRR 2457 (2014).

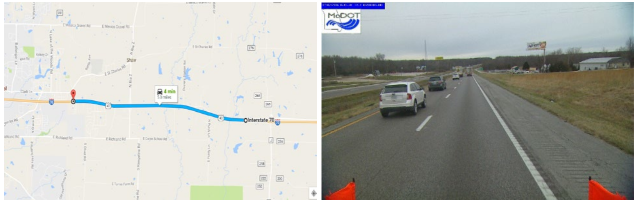
Buttlar et al., MoDOT Report, Proj. TR201709, "Pavement Roughness Measurement Using Android Smartphones: Case Study of Missouri Roads and Airports" (2018).

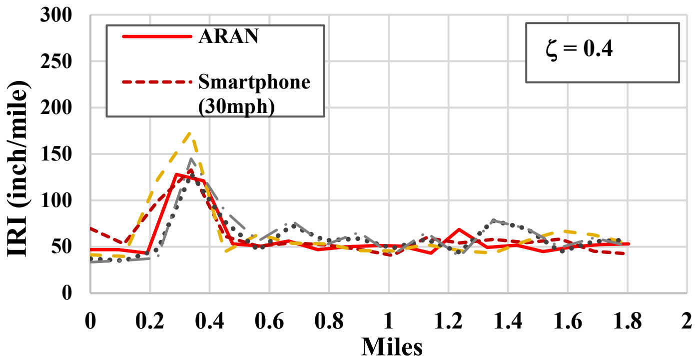
MoDOT Study - Validation





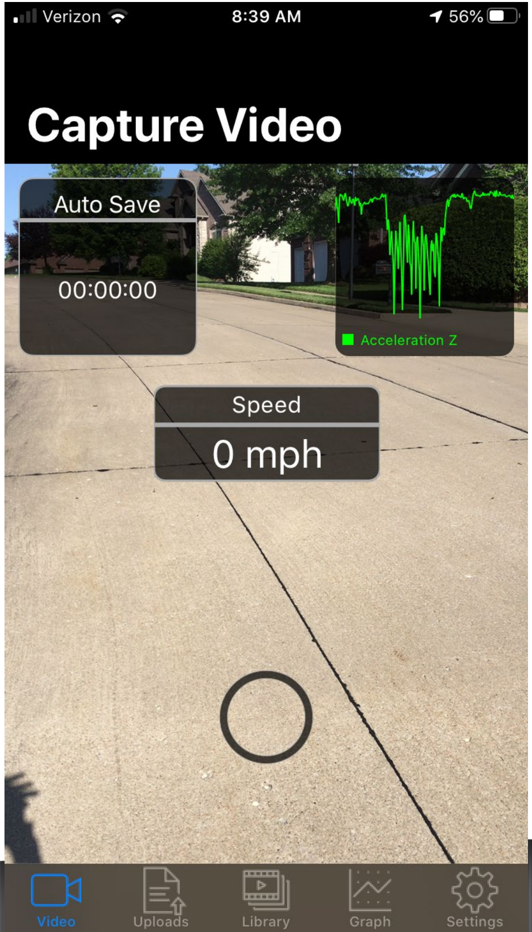
IS 70 W (Log 126 -129), Travelway Id 3506





IS 70 W (Log 113 -115), Travelway Id 3506

* ARAN-based IRI measurements were taken 2 years earlier. Source: MoDOT’s TMS (https://vdi.modot.mo.gov)


Verizon
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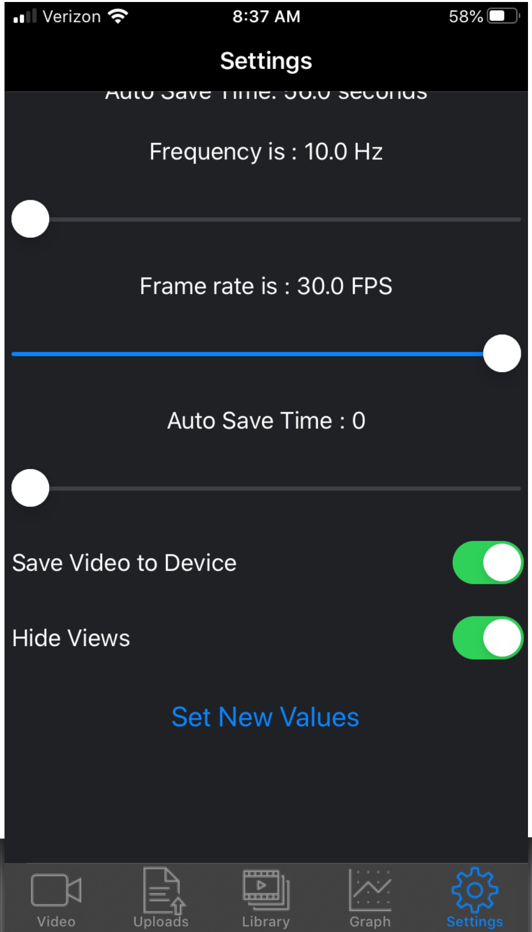
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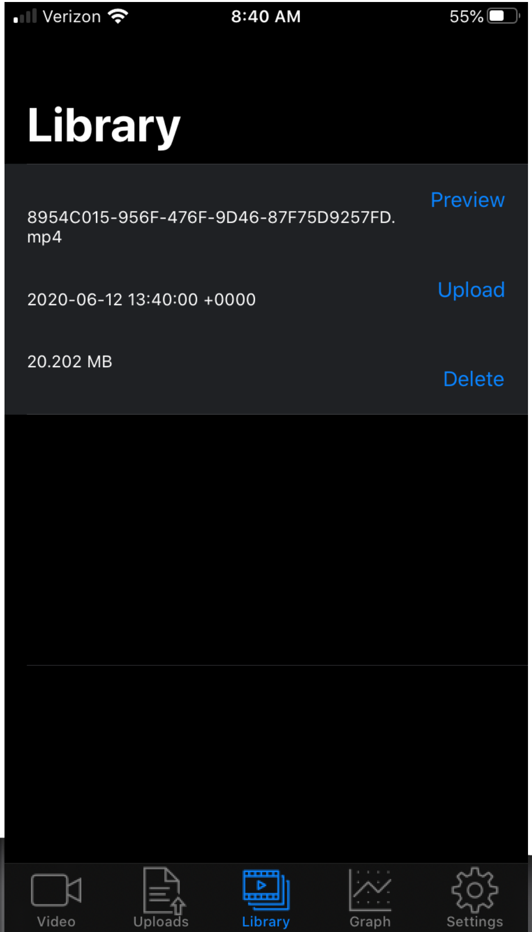
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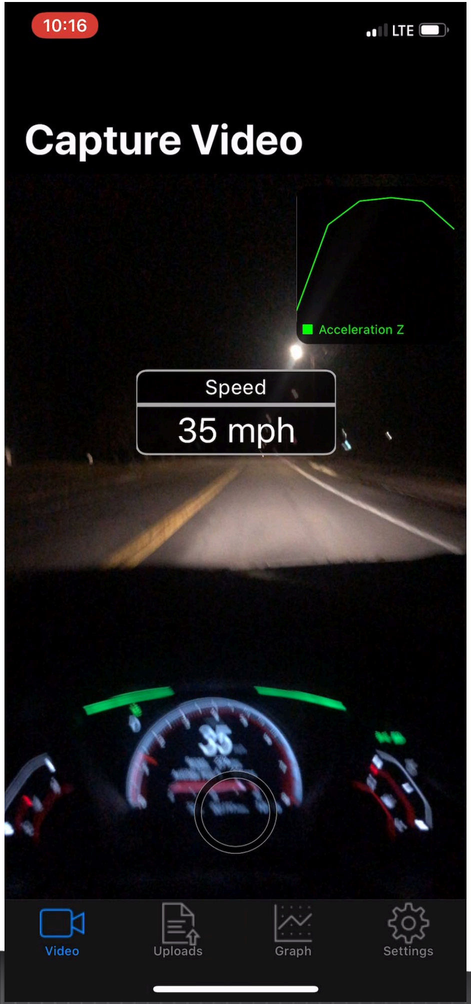
Upload
20.202 MB
Delete
Video
Uploads
Library
Graph
Settings

Mobile App Data Collection

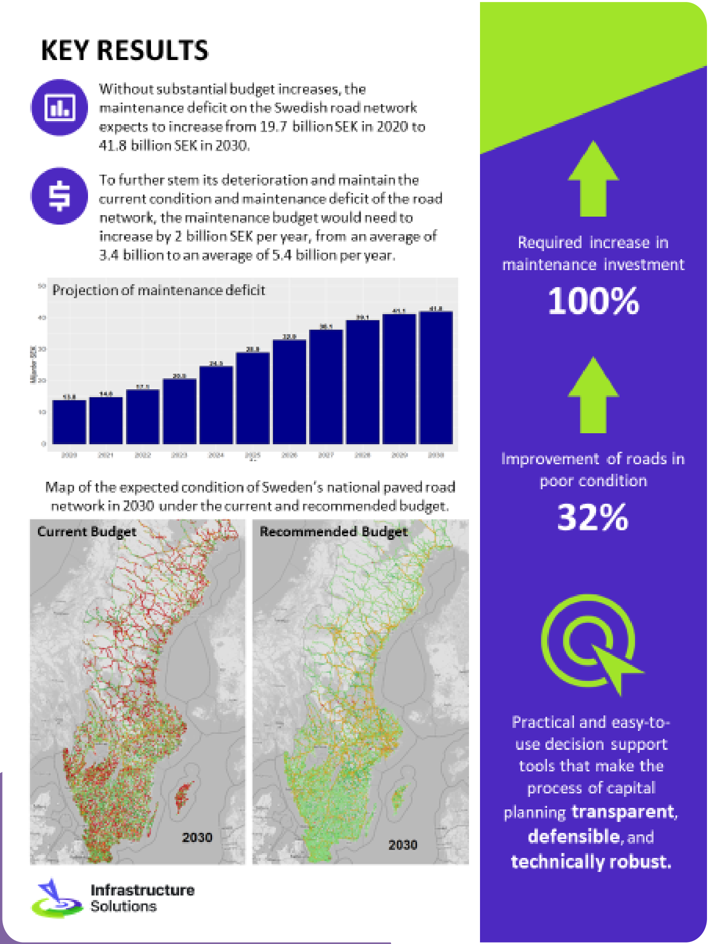
Data Capture: Store on phone → upload to database later.

- Video
- Accelerations in x, y, z
- Rotations in x, y, z
- Heading
- Speed

- **Output:**
  - International Roughness Index



IRI/Condition Crowd-sourcing in Sweden (NIRA, Univrses, Salbo AI, ISI)



Transportation Research Record: Journal of the Transportation Research Board

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Impact Factor: **1.7** / 5-Year Impact Factor: **1.9**

Restricted access | Research article | First published online August 19, 2023

Lifetime Performance of Polymer-Modified Bitumen in Swedish Roads Evaluated With Survival Analysis

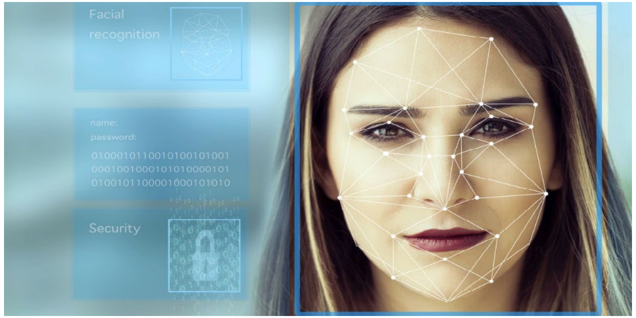
Kristin Eklöf and Mats Wendel View all authors and affiliations

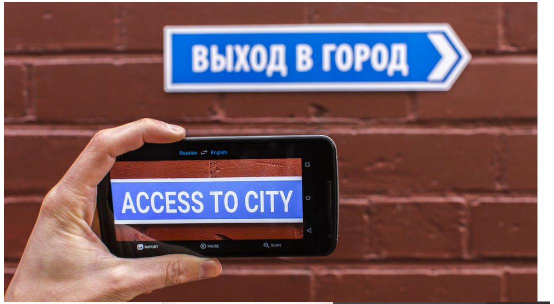
OnlineFirst | https://doi.org/10.1177/03611981231183713

NIRA Dynamics' core product is its tire pressure indicator; however, NIRA is developing sensor fusion based systems for different vehicle applications. It is working on road surface conditions analysis using data from connected vehicles, RWIS, radar/satellite images and weather prognoses to provide a real-time picture of the road status.

Source: www.worldhighways.com/wh1/news/nira-and-univrses-swedish-road-data-project

Machine Learning Is Changing The World





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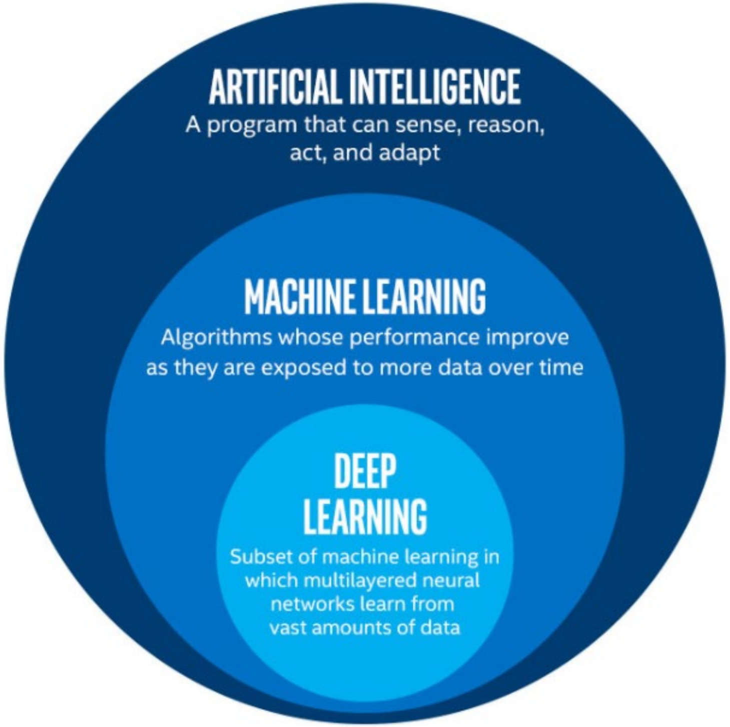
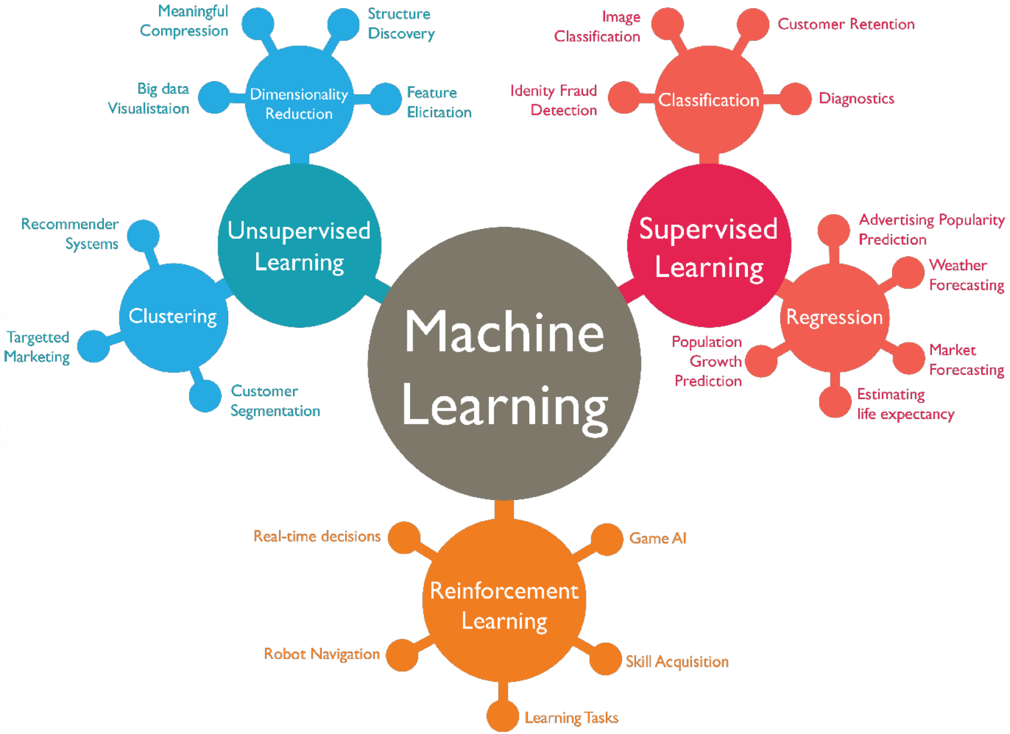
AI and Machine Learning

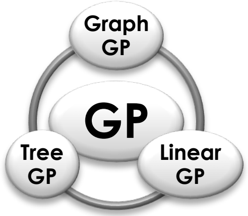


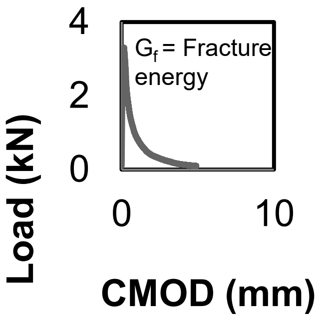


Machine Learning in Materials

Example: Development of a model using an innovative machine learning technique ~ **Genetic Programming (GP),** to predict the **fracture energy of asphalt** mixture specimens at **low temperatures**

Mix Quality Characteristics: (voids, aggr. structure, asphalt content, recycling type/amt….)





Our initial GEP-based prediction model

$$G_f\left(\frac{j}{m^2}\right) = \left(\left(\left((NMAS - 9)AT - RAP\right)(5.36 + T - LTPG)\right) - LTPG\right)$$

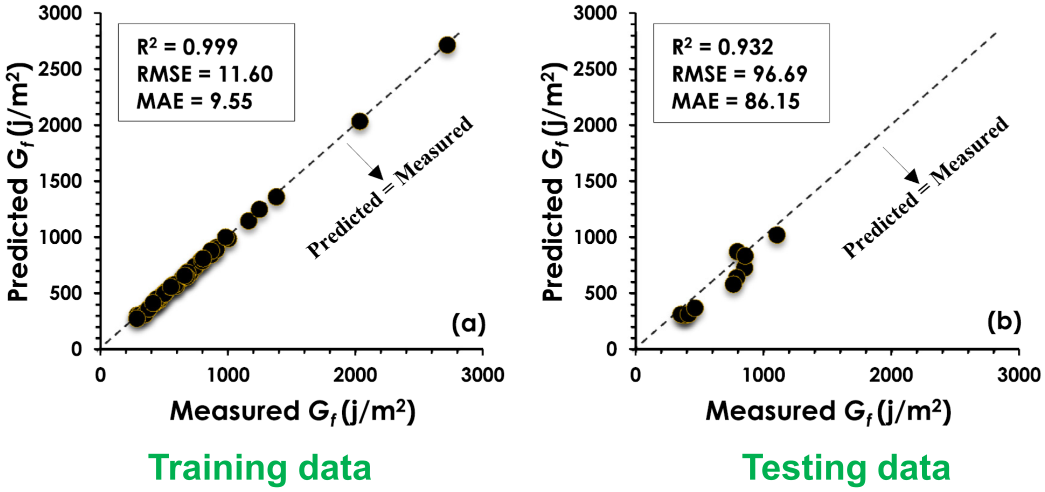
$$+ AT(G^4 - 1.7 + UTI) + \frac{NMAS - UTI}{\left((T + NMAS)AT\right) - AT + 6.45} - RAS + RAP$$

$$+ \frac{LTPG}{AT} + LTPG^2 + 3.49T + AC \times RAP$$

$$+ T\sqrt{CRC^3 - 10T - RAP \times AC - 6.461 + UTI}$$

* Derived after controlling millions of highly nonlinear models, which is not feasible via other nonlinear regression approaches

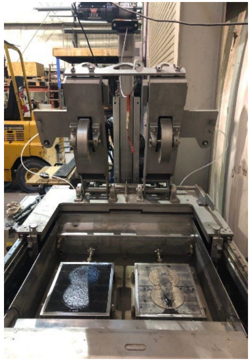
Measured vs. Predicted G_f



Actually, three portions – Learning (70%), Validation (10%), and Testing (20%). Here we combined Learning and Validation in the figure (both are involved in model selection process).

Majidifard, H., Jahangiri, B., Buttlar, W. G., & Alavi, A. H. (2019). New machine learning-based prediction models for fracture energy of asphalt mixtures. *Measurement*, 135, 438-451.

Hamburg Machine Learning Project @ MAPIL

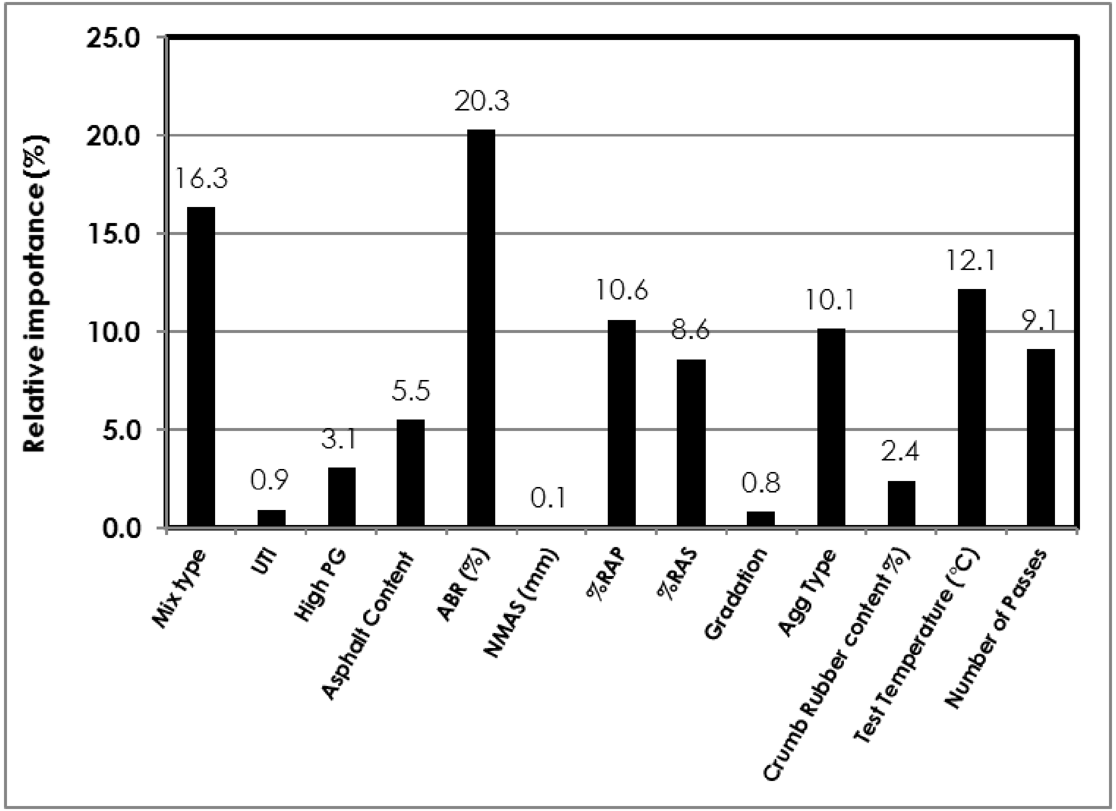


	Parameter	Setting
General	Chromosomes	20, 30, 50
	Genes	3, 4, 5
	Head size	8, 10, 15
	Linking function	Addition
	Function set	+, -, ×, /, √, 3√, ln, Log, Power, exp, Min, Min 3, Min 4
Complexity increase	Generation without change	2000
	Number of tries	3
	Max. complexity	5
Genetic operator	Mutation rate	0.00138, 0.044
	Inversion rate	0.00546
Numerical constants	Data type	Floating-point
	Lower bound	-10
	Upper bound	10

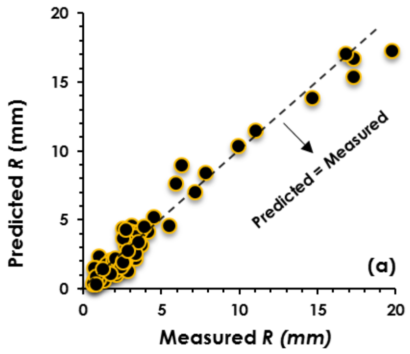
Table 1. Statistical parameters of the dependent and independent variables.

	Mix type	UTI (°C)	HTPG (°C)	AC (%)	ABR (%)	NMAS (mm)	RAP (%)	RAS (%)	G	AT	CRC (%)	T (°C)	Passes	R (mm)
Mean	1.1	87.8	58.9	5.9	28.8	11.3	20.9	8.0	1.2	1.2	2.3	52.2	13131	3.8
Median	1.0	86.0	58.0	5.7	32.5	12.5	20.4	0.0	1.0	1.0	0.0	50	10000	2.7
Range	1.0	18.0	24.0	2.8	48.4	14.3	35.3	33.0	1.0	1.0	10.0	24	15000	19.2
Max	2.0	98.0	70.0	7.9	48.4	19.0	35.3	33.0	2.0	2.0	10.0	64	20000	19.7
Min	1.0	80.0	46.0	5.1	0.0	4.8	0.0	0.0	1.0	1.0	0.0	40	5000	0.6

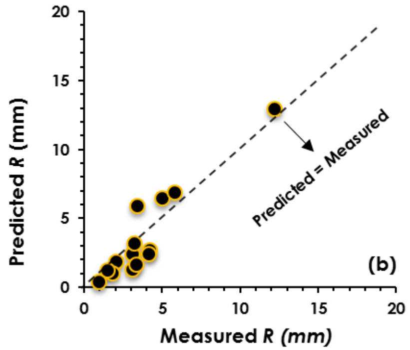
Sensitivity of Variables



Initial Hamburg Machine Learning Model Results

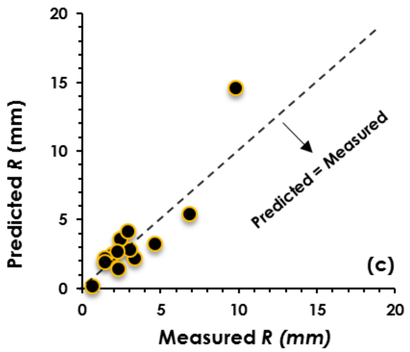


Learning Result

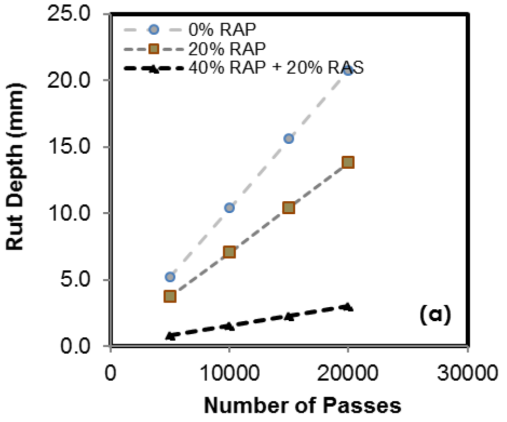


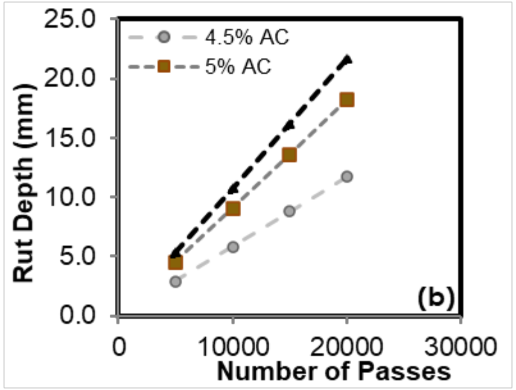
Testing Result

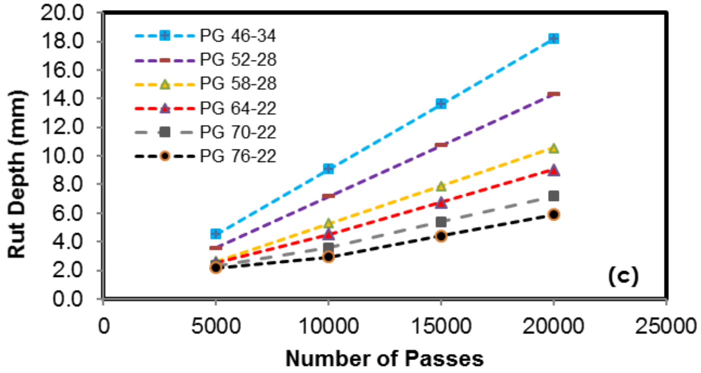
Validation Result



Trends Predicted by Machine Learning Model







Majidifard, H., Jahangiri, B., Rath, P., Contreras, L. U., Buttlar, W. G., & Alavi, A. H. (2021). Developing a prediction model for rutting depth of asphalt mixtures using gene expression programming. *Construction and Building Materials*, 267, 120543.

Majidifard, H., Jahangiri, B., Rath, P., Alavi, A. H., & Buttlar, W. G. (2021). A deep learning approach to predict Hamburg rutting curve. *Road Materials and Pavement Design*, 1-22.

New AI-Based Tools for Rapid Pavement Evaluation

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TODD MORRILL
INSTRUCTOR

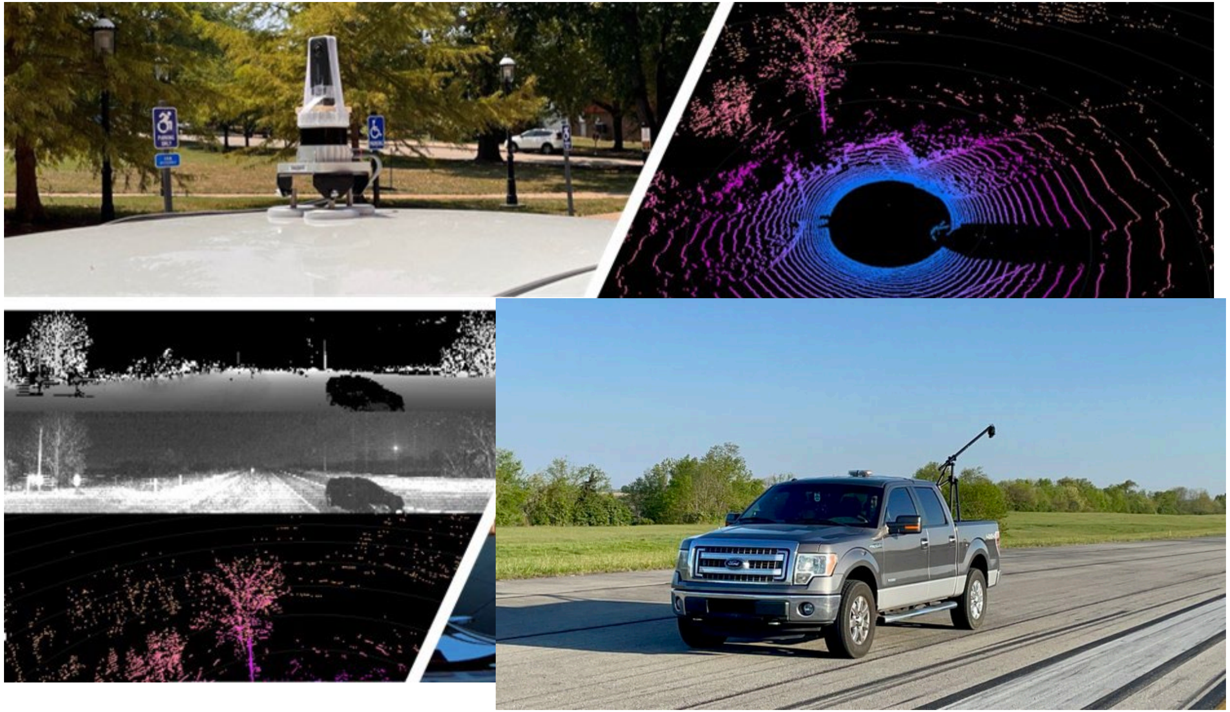
RHONDA SHRADER
INSTRUCTOR

ALEXIS SLUPE
INSTRUCTOR

TIGER EYE ENGINEERING

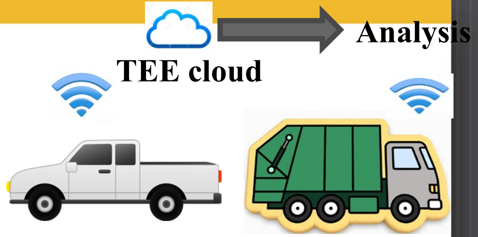
Data collection

Option 1. Using series of high-resolution cameras and Lidar to capture videos in top-down view

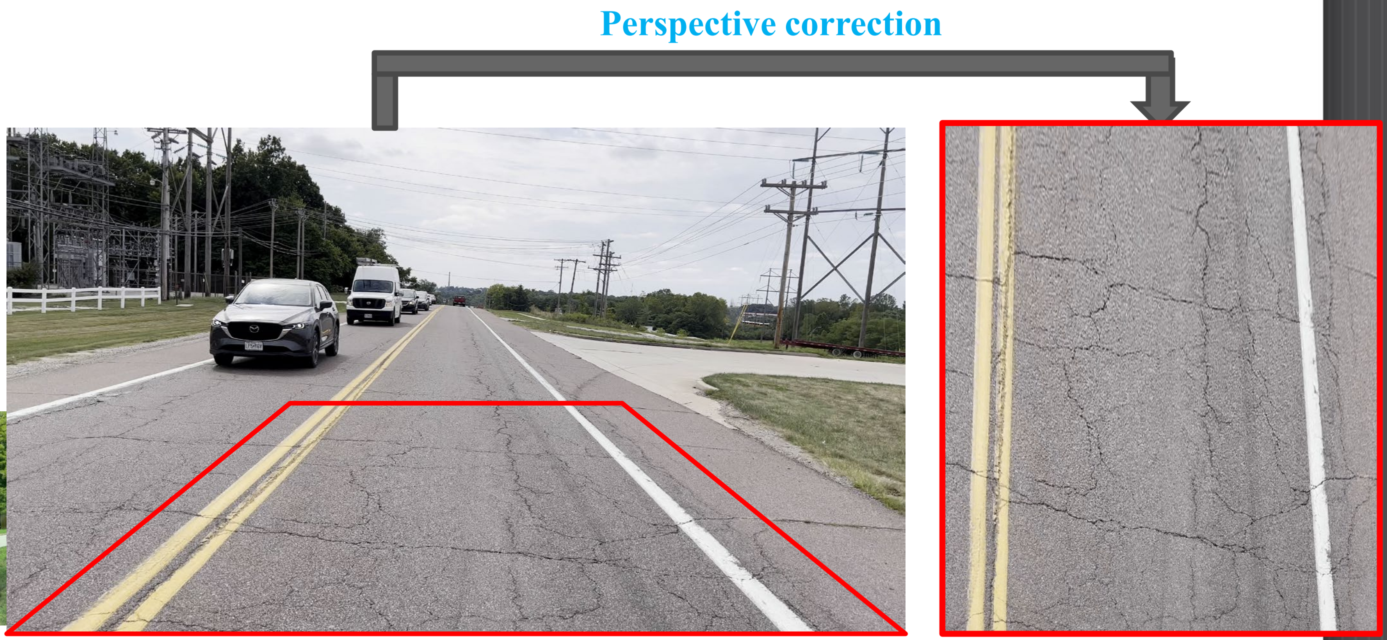


https://www.blankenshipasphalttech.com/batt-vision

Data collection



Option 2) Mount phone, camera and/or GoPro to a vehicle to collect wide-view video (can be collected by city/public vehicles)



Prediction Results (Flexible Pavement)

Representative images and automated distress detection results

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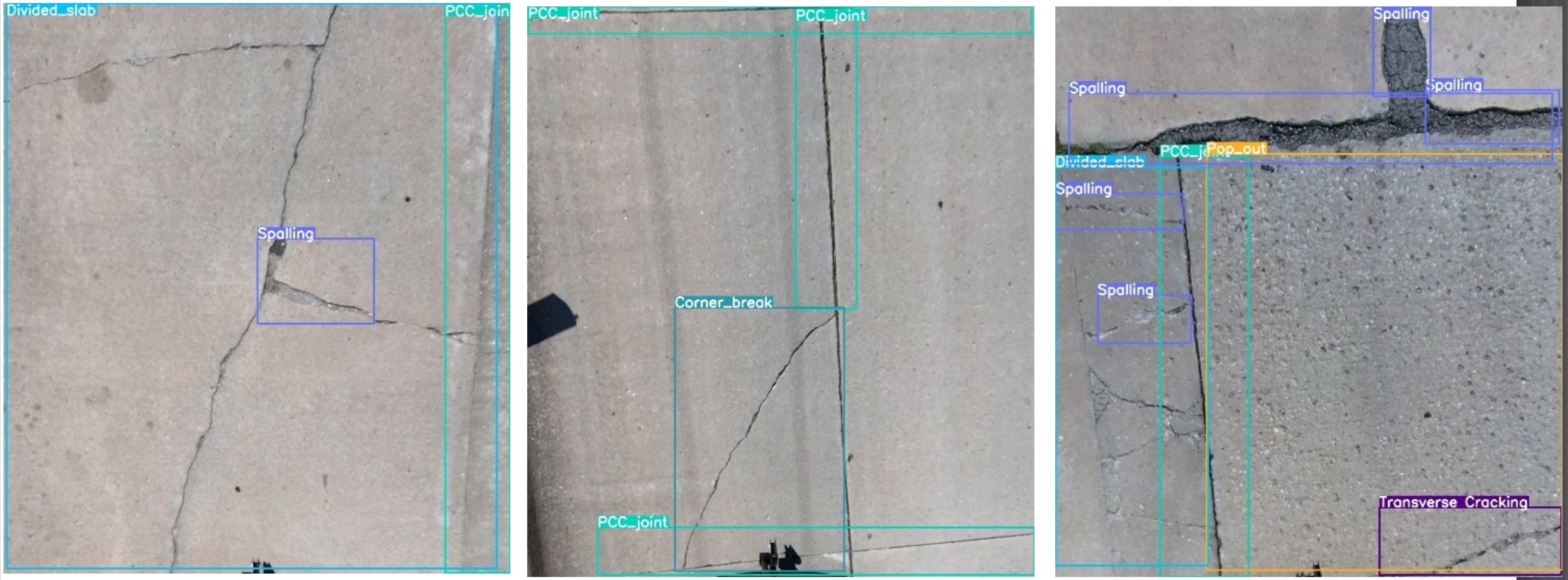
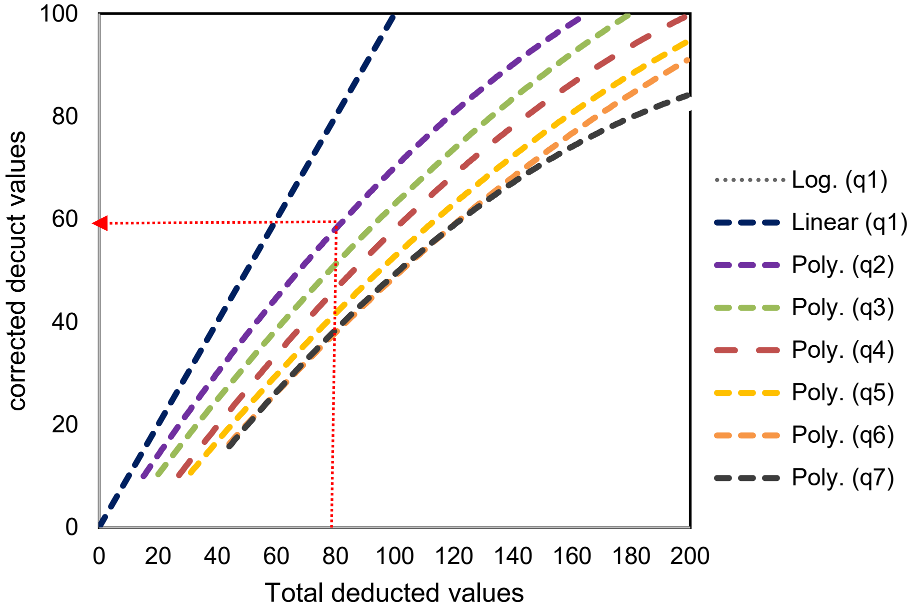
Prediction Results (Rigid Pavement)

Representative images and automated distress detection results



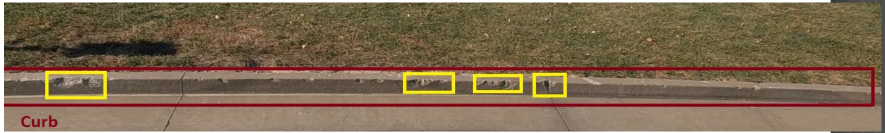
IRI Computation – Instructional Video

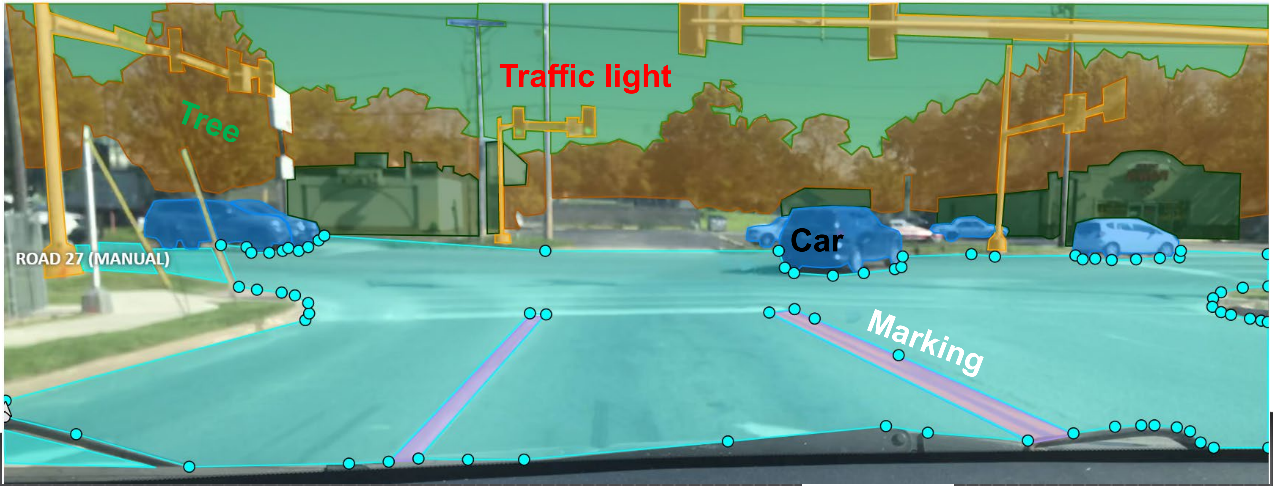
https://www.linkedin.com/feed/update/urn:li:activity:7149713049401163776

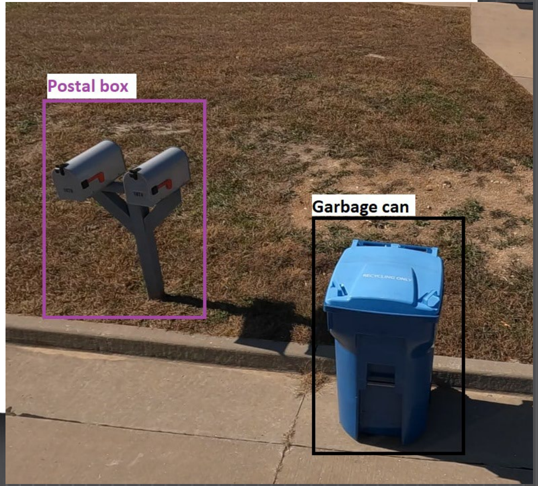


Asset Inventory & Evaluation

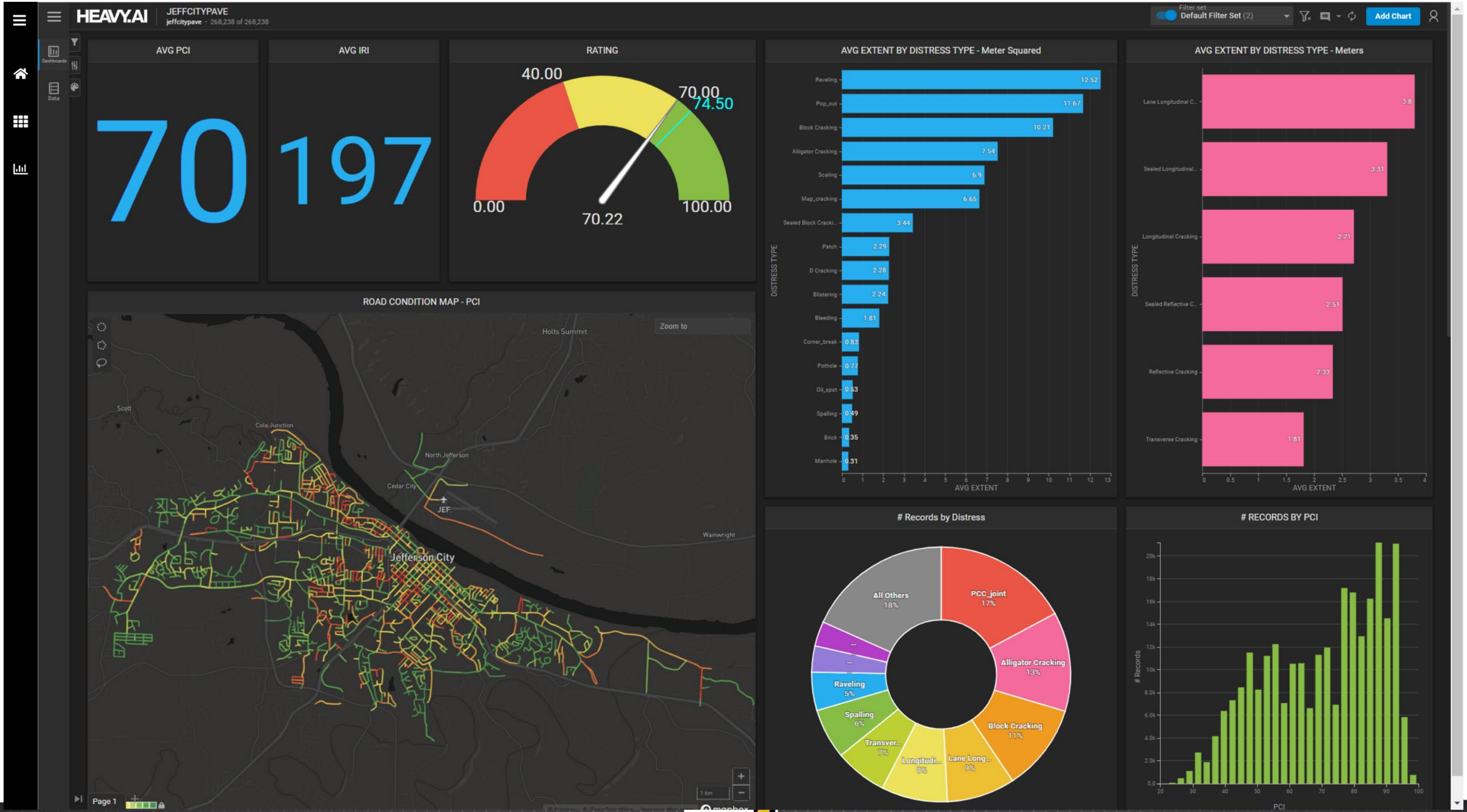
- Curb and gutter evaluation
- Fire hydrant locations
- Garbage can/bin locations (& tags)
- Guardrails, sidewalk inspection
- Sign condition inventory and evaluation
- Pavement marking detection & evaluation
- Utilities, etc…







Visualization Dashboard



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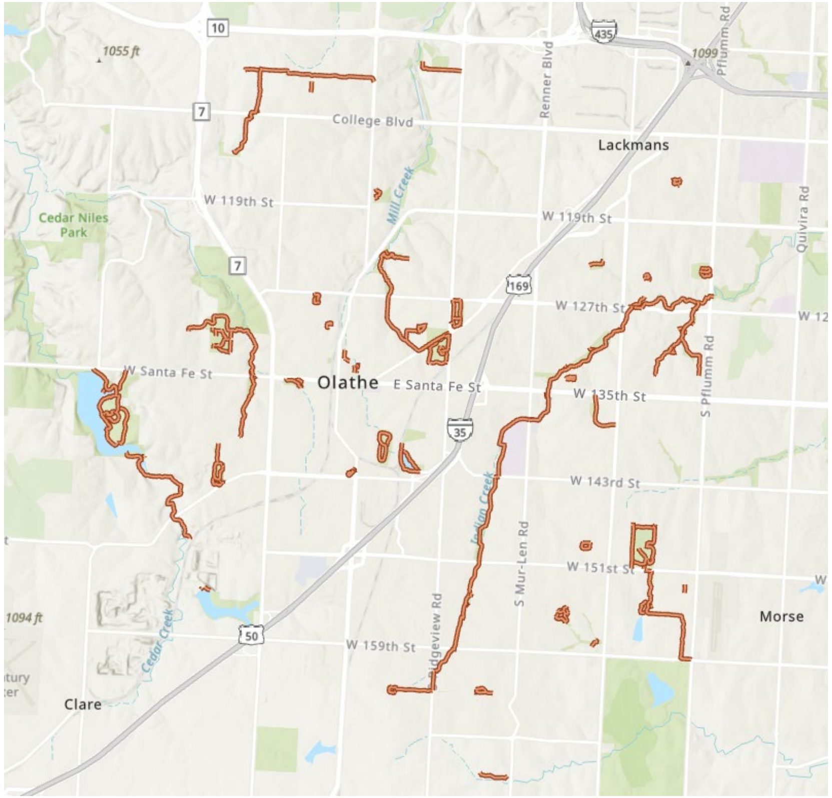
Sidewalk evaluation

Can quantify faulting, buckling (or blow-ups), and slope variance, including geometrical details of ADA ramps

Trail Condition Assessment

City of Olathe, Trail Inspection



Network size: 40 miles

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Data Collection for Trails/Sidewalks (Via eBike)

Video

+

GPS

Frames

Sidewalk surface condition

Slope evaluation

Buckling detection (roughness)

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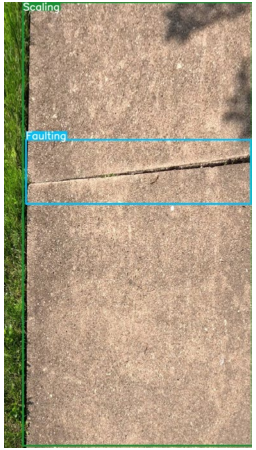
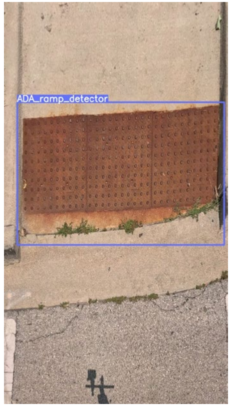
Sidewalk Evaluation via eBike





Examples of sidewalk distress/asset detections

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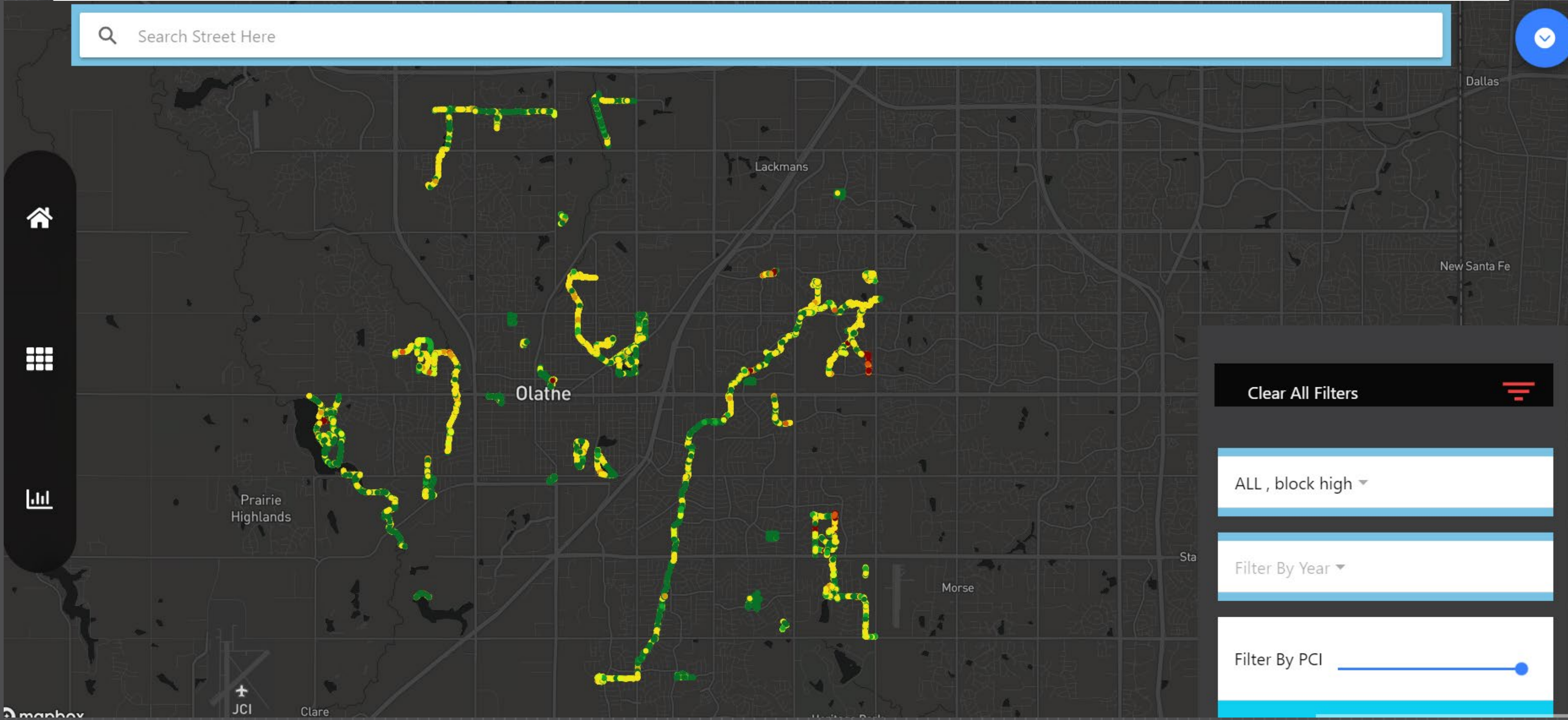
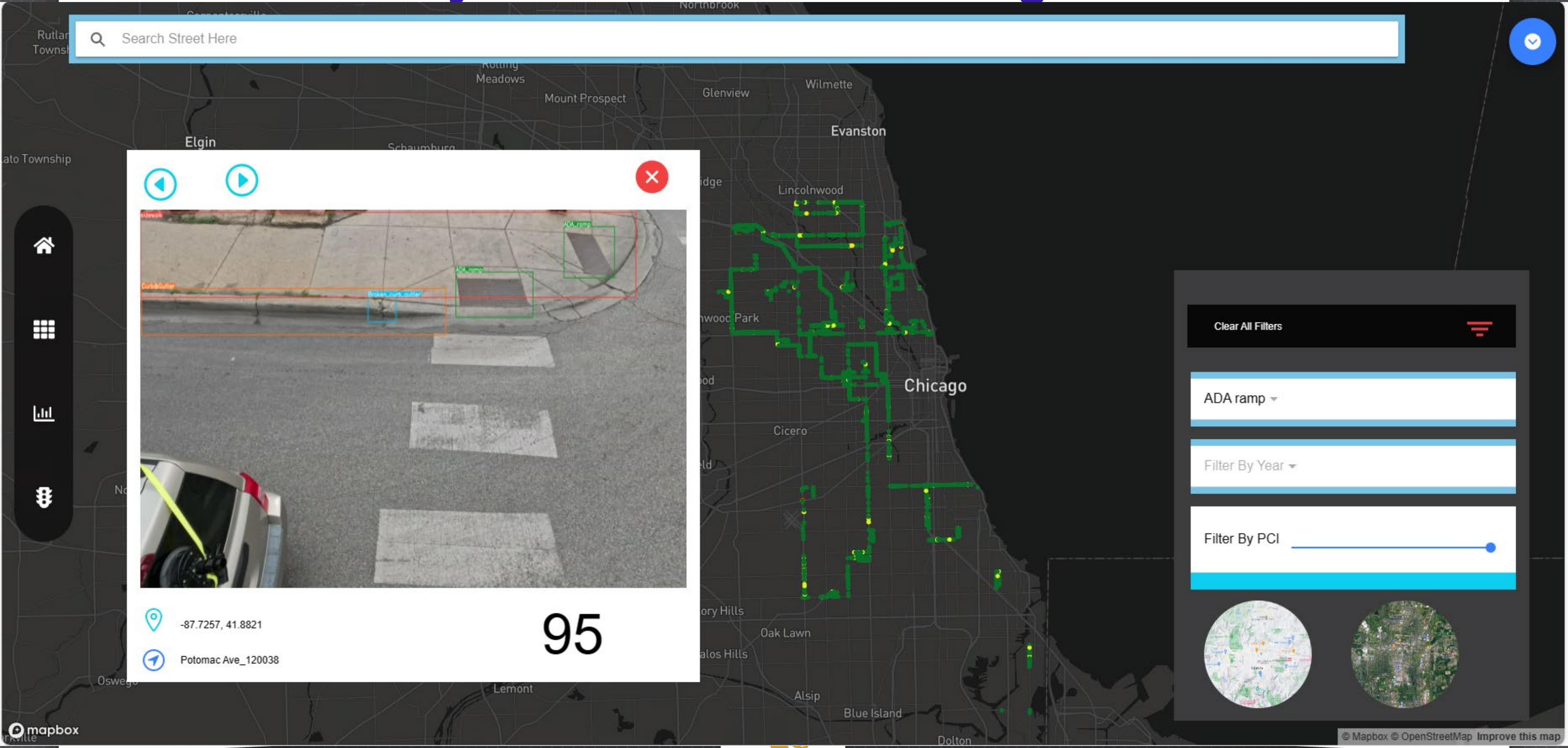
Trail Evaluation, Olathe, KS



Asset Inventory Demonstration Chicago



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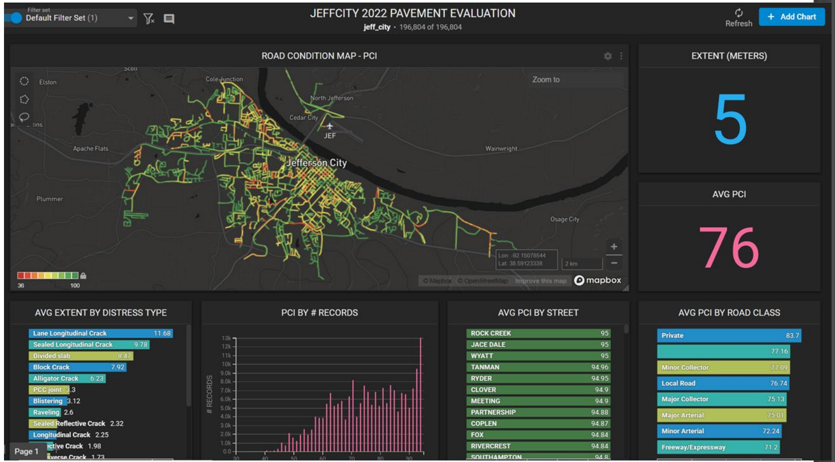
Data-Driven Optimization of Maintenance, Rehabilitation, Sustainable Approaches



- Patching, crack sealing
- Fog seal, chip seal
- Slurry seal, cape seal
- Microsurfacing
- Diamond grinding
- Thin, bonded wearing courses
- Asphalt overlay (thin, thick/structural), BMD
- Reconstruction
- Use of recycled/sustainable materials
- Vetting of trial/experimental materials

Decision Optimization Technology Platform

- Pavement Management and Optimization Tool, in partnership with Hanson
- Can be added to projects/pilots, when a formal pavement management system is desired (other assets can be managed on the same platform – mixed asset optimization)

How AI is Transforming Asset Mgt…

- Machine learning is fast, unbiased, accurate
- Data architectures are cloud-centric, ingest unstructured data, capitalize on data fusion, compatible with GIS/ESRI databases
- Saves time
- Saves $$$
- More data (100% coverage, more frequent inspections, crowd-sourcing possible)
- Easily visualized
- Leads to optimized, mixed-asset management

3rd International

DSPS

Data Science for Pavements Symposium 2024

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Workshops & DOT Presentations

Roundtable & Student Data Competition

Cutting-Edge Research

Industry Networking

pavementdatascience.com

Thank you!

buttlarw@missouri.edu

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References – AI and Machine Learning in Pavements

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