VOTERS
Versatile Onboard Traffic Embedded Roaming Sensors

Data Driven Monitoring and Management of Pavements based on large amounts of surface and subsurface sensor data

Salar Shahini Shamsabadi, Ralf Birken, and Ming Wang
Northeastern University

Pavement Evaluation 2014
Blacksburg, Virginia

This work was performed under the support of the U.S. Department of Commerce, National Institute of Standards and Technology, Technology Innovation Program, Cooperative Agreement Number 70NANB9H9012

VOTERS Project

The Versatile Onboard Traffic Embeded Roaming Sensors (VOTERS) project was an $18 million NIST funded project started in 2009. It aimed to develop measurement systems that are low-cost, autonomous and affordable to be deployed on many vehicles already on city roads, e.g. UPS, Fedex, postal trucks.

VOTERS system is a simple, inexpensive way to detect surface and subsurface roadway defects, enabling continuous network-wide health monitoring of roadways without setting up hazardous and expensive work zones, and providing accurate up-to-date pavement condition information to decision-makers.

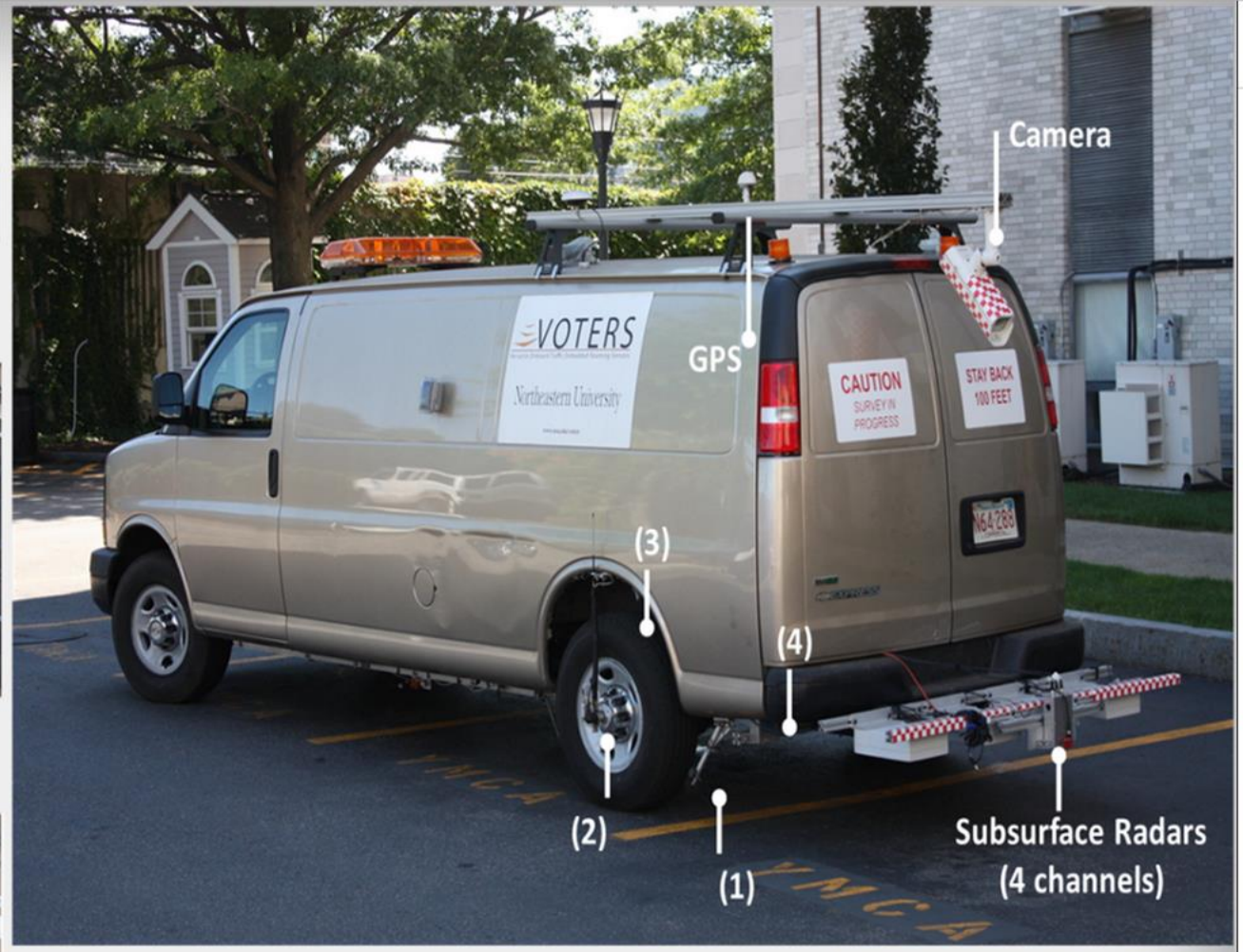
Traveling in traffic, multiple sensor subsystems will obtain measurements and data using a variety of innovative sensing methods and an optical system:

- Acoustic Waves
- Surface Radar
- Subsurface Radar

Portable real-time monitor

System control monitor

Data acquisition and processing

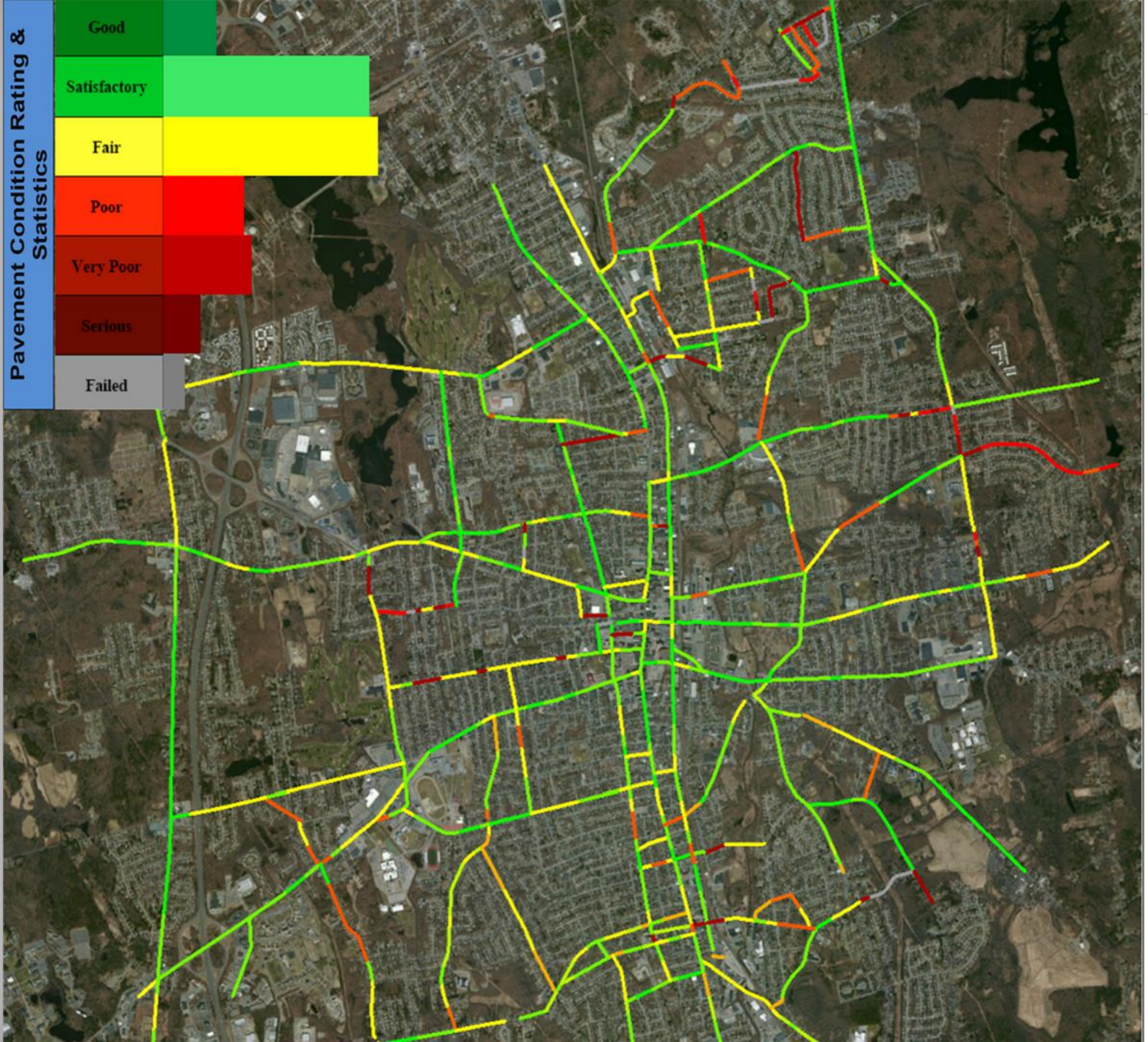


Directional Microphone

Dynamic tire pressure sensor

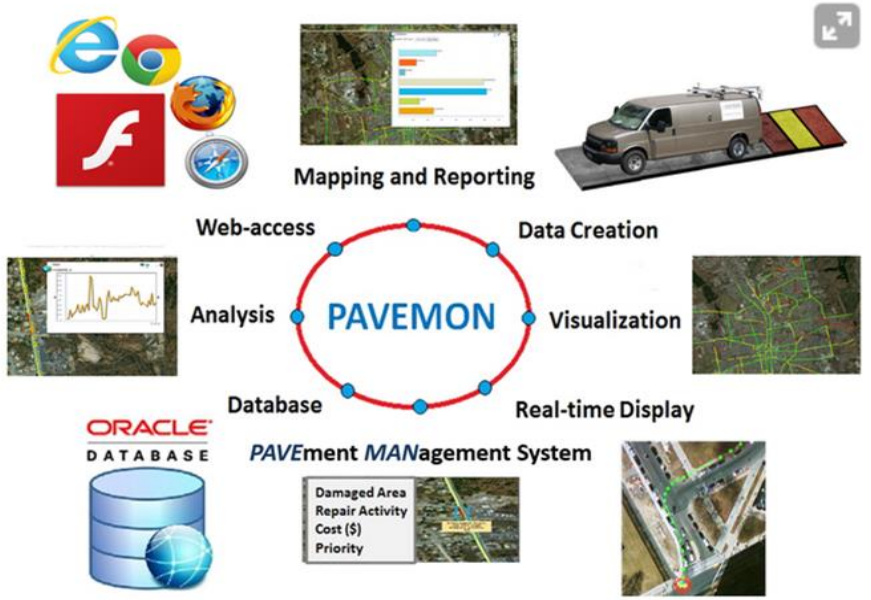
Rear axle accelerometer

Surface radar array (5 sensors)



PAVEment MONitoring system

PAVEMON is a GIS Web-based PAVEment MONitoring system. It is designed to visualize and perform spatial analysis on large amounts of multi-modal sensor data that contain surface and subsurface information of pavements. This system allows for a deterioration process monitoring at unprecedented time and spatial scales to improve life-cycle cost analysis models.



Brockton Field Tests

In late 2013, VOTERS conducted three field tests in Brockton City, MA, to survey 200-lane miles of roads.

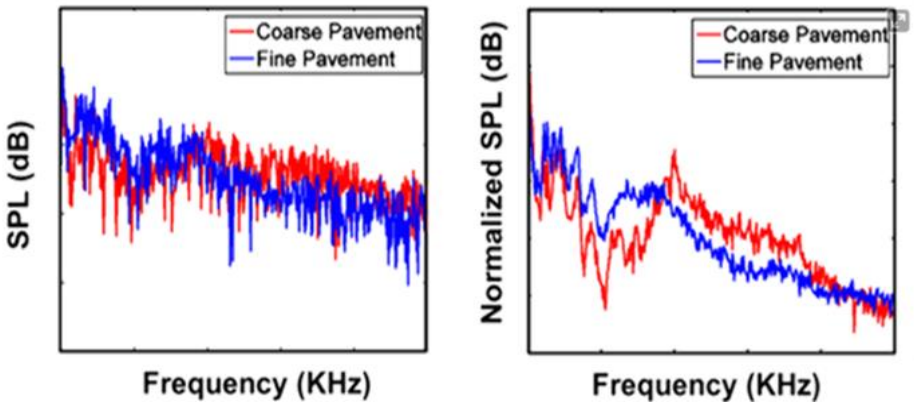
Lane-miles Covered	200 mi
Average Speed	18 mph
Total Driving Time	12 hours
Total Processing Time	15 hours
Total Time	27 hours

Information about location of the data and where they are representing are given by the GPS sensor mounted on top of the van.

Texture Ratio

Macrotexture is highly correlated to tire/road friction hence related to the severity of the sound generated by tire-pavement interaction. MTD shows severity of segregation and raveling, two dominant types of pavement distress.

Microphone Signal to differentiate course and fine pavements



PAVEMON Tour

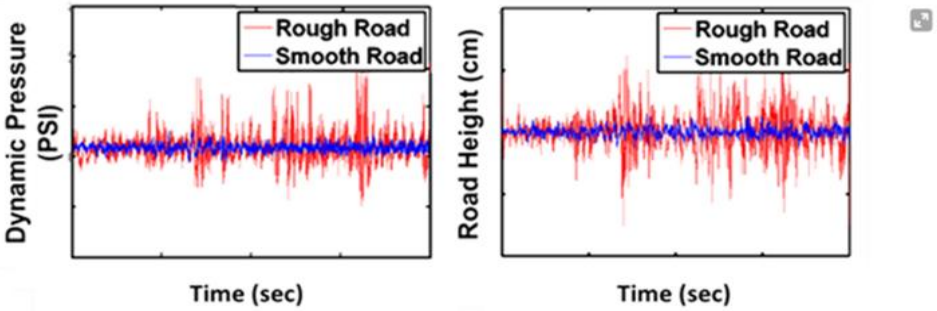
VOTERS PAVEMON

VOTERS Project

Equivalent International Roughness Index

Through VOTERS Dynamic Tire Pressure Sensor and an axle-accelerometer, International Roughness Index (IRI) has been quantified. IRI has been used worldwide for evaluating and managing highways since the early 1980s.IRI is highly related to the ride quality or comfort experienced by a driver.

DTPS Signal to differentiate rough and smooth pavements



Manholes, Road Profiles & Rutting Depth

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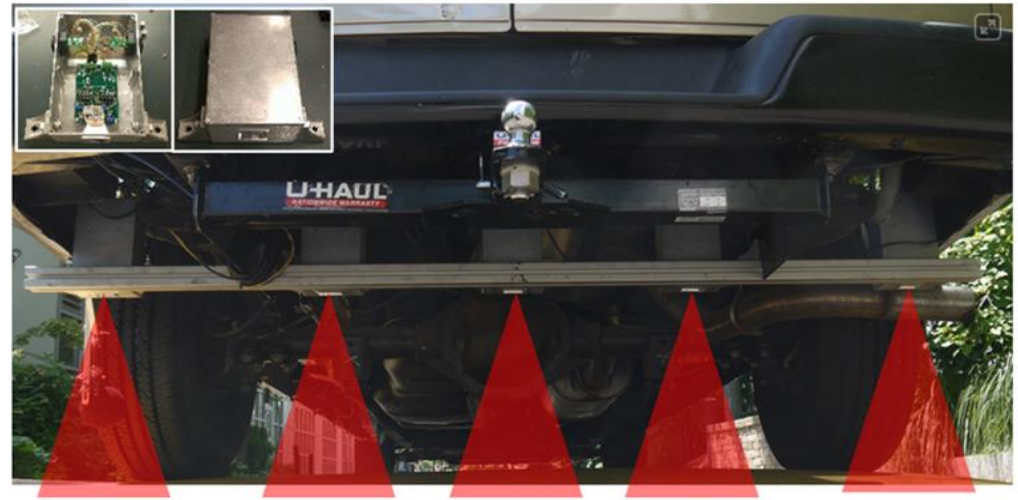
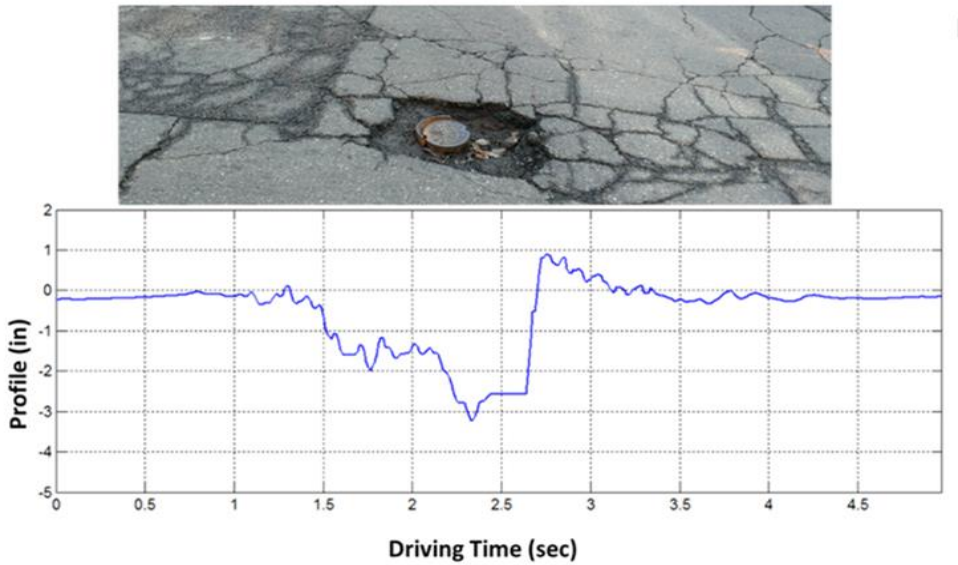


VOTERS millimeter-wave radar systems mounted underneath the van is capable of detecting metal objects on the road and is used to identify the manholes.

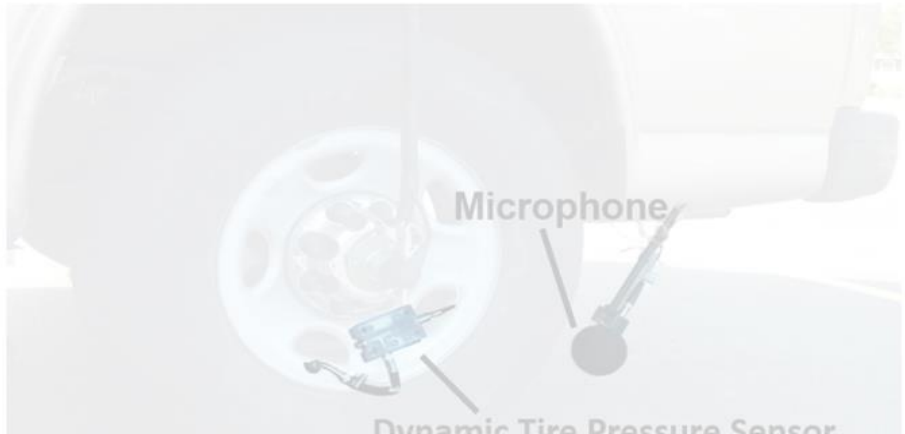
Road profile from mm-wave Radar signal



Crack Types and Density

VOTERS has created a color video acquisition and automated analysis system to verify the physical measurements of other sensors in addition to quantification and classification of pavement cracks. **Click on any point on the map to see the image of that location and the crack detection results.**

Ratings every twenty meters



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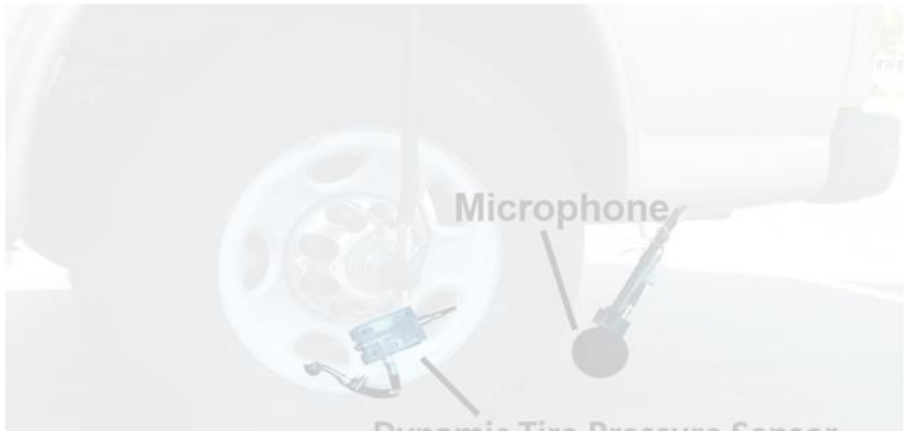

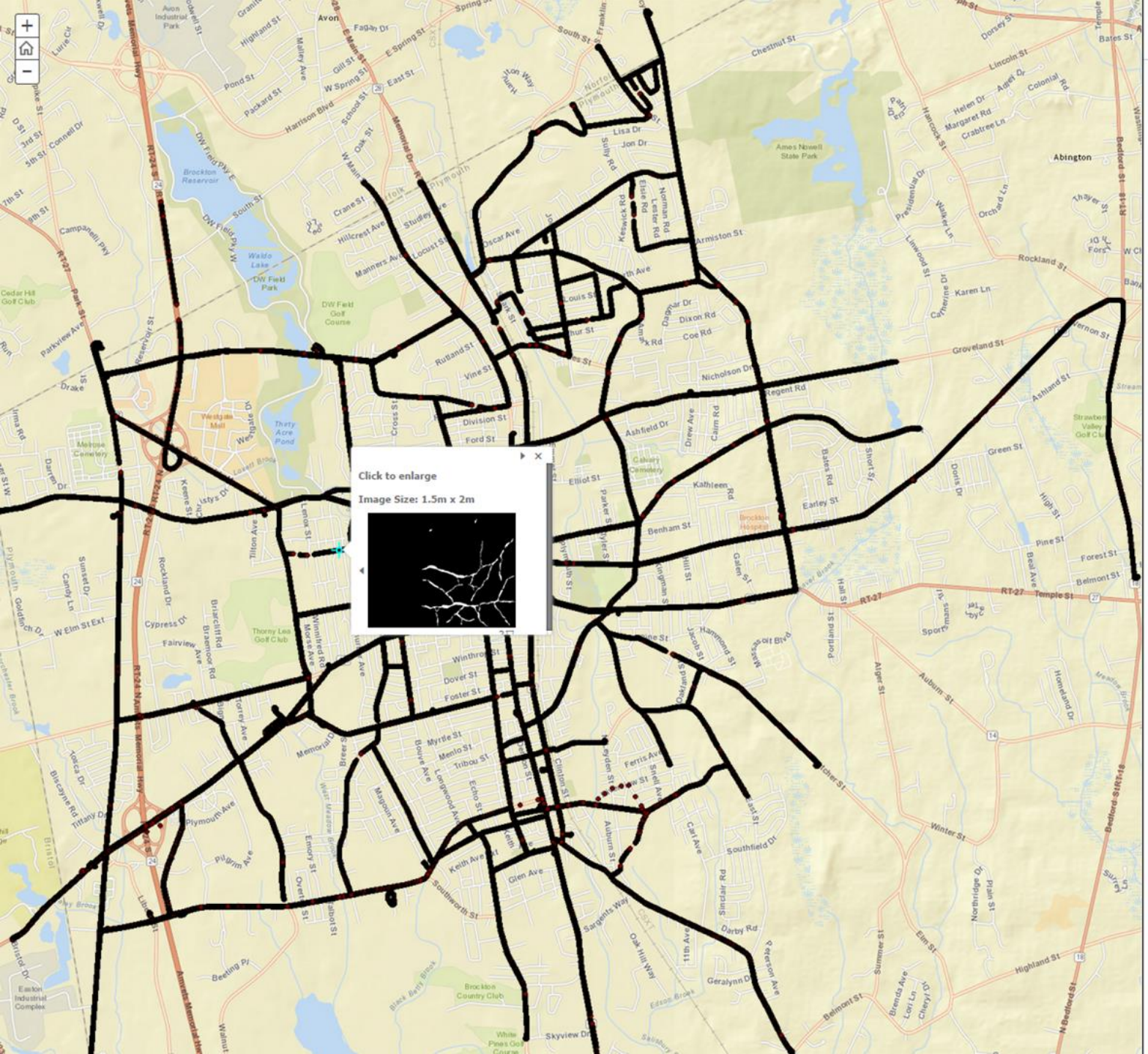

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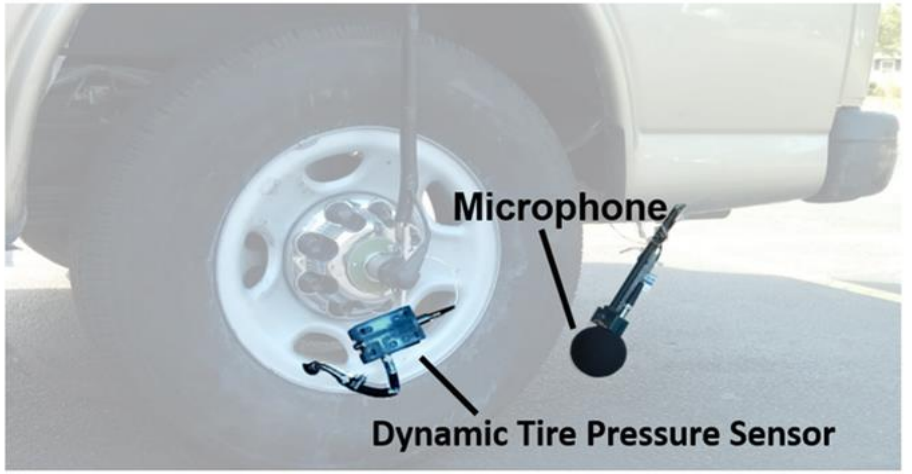
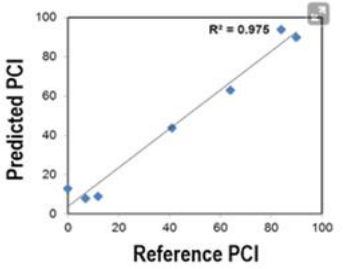


Through acoustic measurements of Microphone and Dynamic Tire Pressure Sensor, PCI has been estimated with a sensor fusion model. These measurements are

- Consistent in different runs
- Are validated with images
- Are calculated for every 20 meters of the road

Correlation with Reference PCI



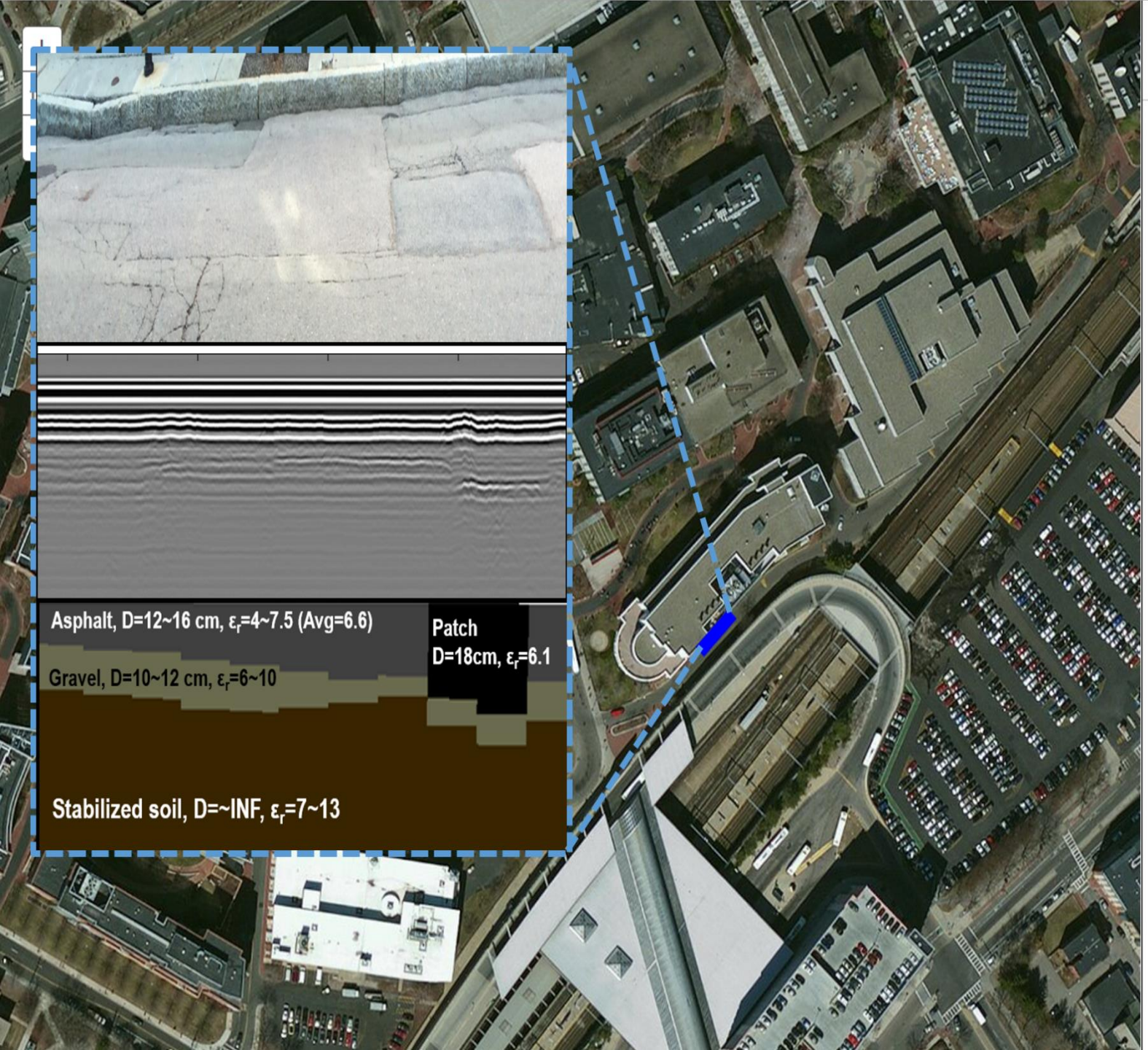
Overall Ratings of each road

Overall Ratings of each road

Pavement Condition Index (PCI) is the main measure used in the US to assess road conditions. PCI is between 0-100 (100 for a good condition and 0 for a failed condition).

VOTERS uses two independent algorithms for PCI and IRI calcualtions. According to literature review, these two should have a negative correlation. While VOTERS does not calculate PCI from IRI, it is impressive to see how well these parameters correlate. See the correlation **here**.

Subsurface Information



Subsurface Information

VOTERS can provide Pavement Layer profiling with air-coupled GPR in addition to dielectric constant, providing more insight into condition of pavements to help with a better maintenance planning.

Pavement Management Toolbox

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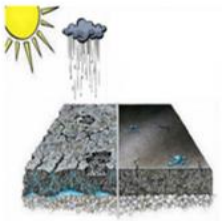
Pavement Management Toolbox

Maintenance Suggestions

Priority Assessments



Deterioration Model

Budget Planning

A data driven customizable pavement manaagement toolbox was developed to plan optimum maintenance and repair activities with respect to the priority policies to make practical and defensible decisions. This toolbox leverage information from VOTERS, LTPP, DOT and NOAA datasets.

Demo

PAVEMON

PAVEment MONitoring system

Exporting Practical Data and Statistics

- Statistics (overall and customizable)
- Exporting of data from Database
- Pop-up menus

Images of Camera

3D Viewer

Paveman Toolbox

- Condition Projection
- M&R Suggestions
- Prioritization based on budget
- Long-term Planner

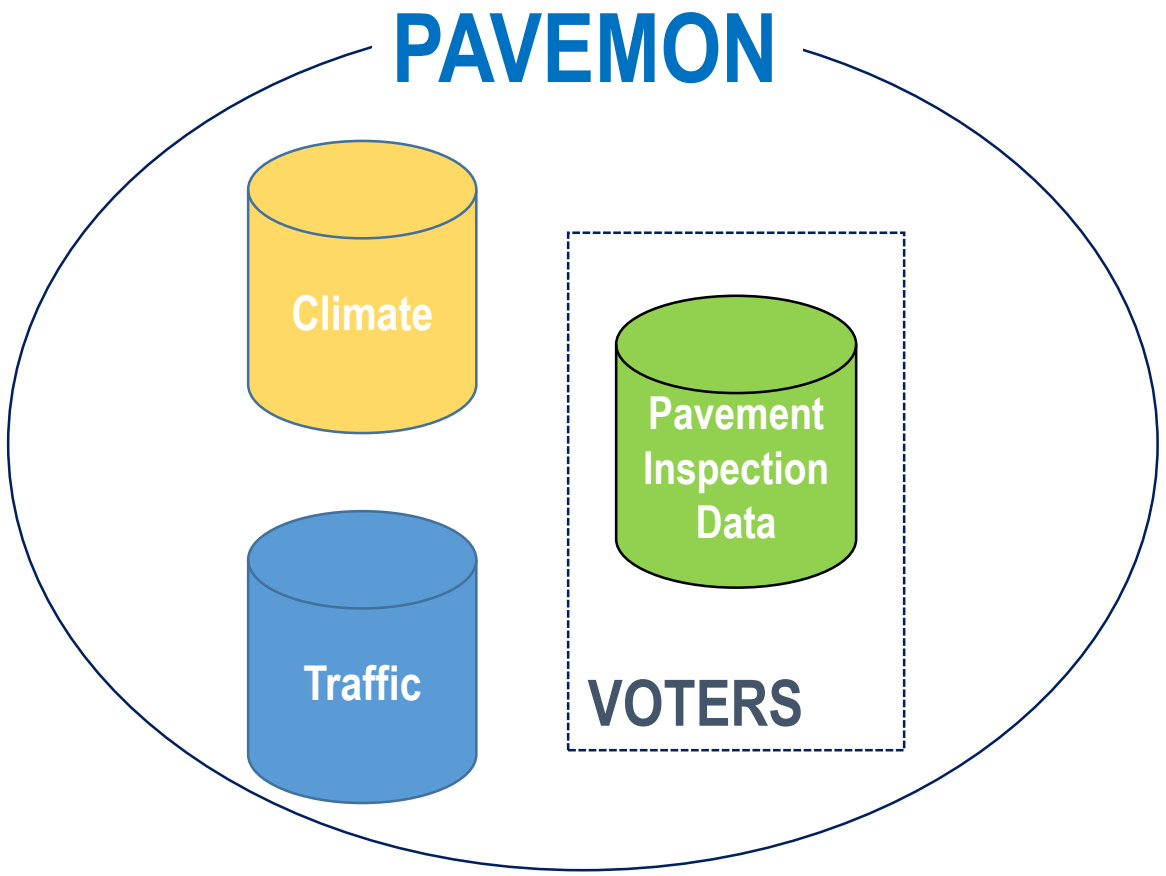
High resolution temporal data analysis

Summary of PAVEMON Features

- Monitoring 400,000+ images, 1TB+ of VOTERS data and GB of third party data
- Query raw or processed sensors' data
- Export road locations and characteristics
- Navigate through time and observe changes
- Examine quality of data through provided current pavement images
- Study relationship between pavement parameters
- PAVEM**A**N: A data driven customizable Pavement Management Toolbox developed for decision making
- Extract actionable information and features for doing the Right Repair, at the Right Place, in the Right Time

Outlook

- PAVEMON to integrate VOTERS and third-party data for the most effective decision makings **across different organizations** and leverage a city/state's data investment



Users: Pavement Engineers

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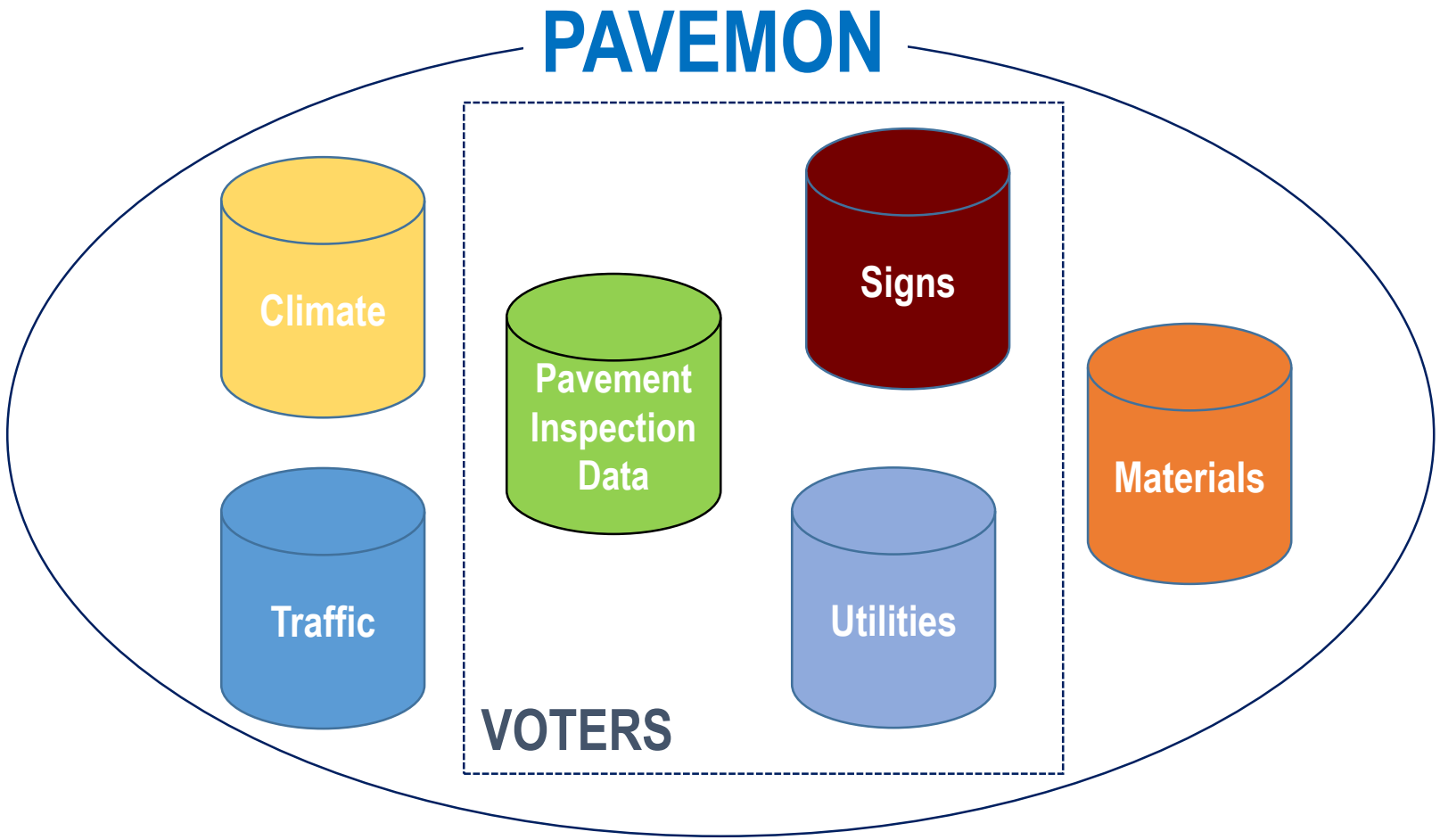

Users: Pavement Engineers, Asset Engineers, Traffic Engineers, Materials Engineers, Utility Engineers

Thank you !

Salar Shahini Shamsabadi: shahini.s@husky.neu.edu

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Supporting Organizations