Machine Learning Applications in Design and Analysis of Transportation Infrastructures

"In God, we trust. All others must bring data."- W. Edwards Deming

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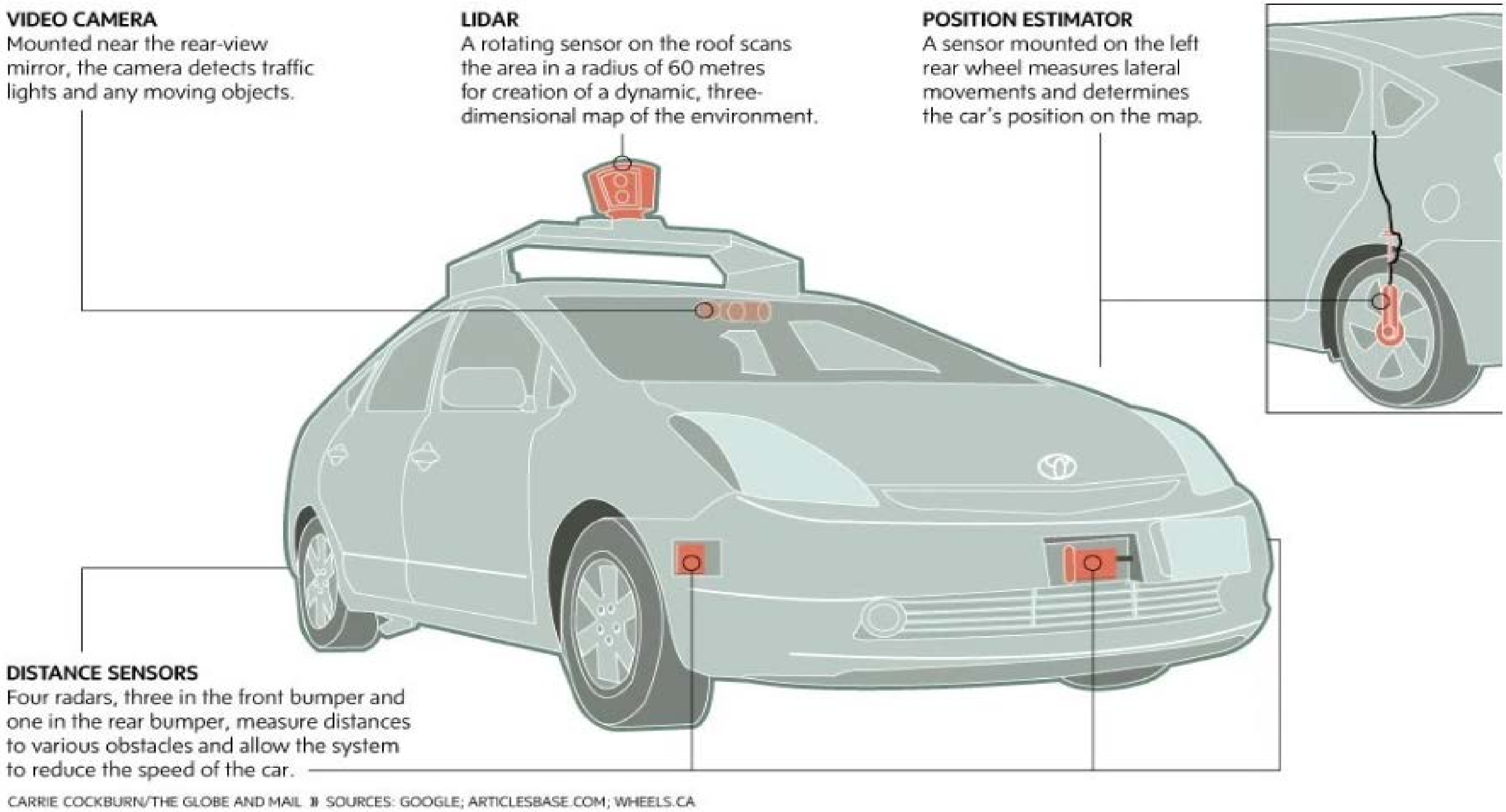
Challenges for DOTs

- In 2013, 38.2 millions tons of freight moved everyday (FHWA, 2015).
- By 2040, It will increased to 51.5 millions tons per day (FHWA, 2015).
- Between 2008 and 2012, number of permits increased by 50% (FHWA, 2015).

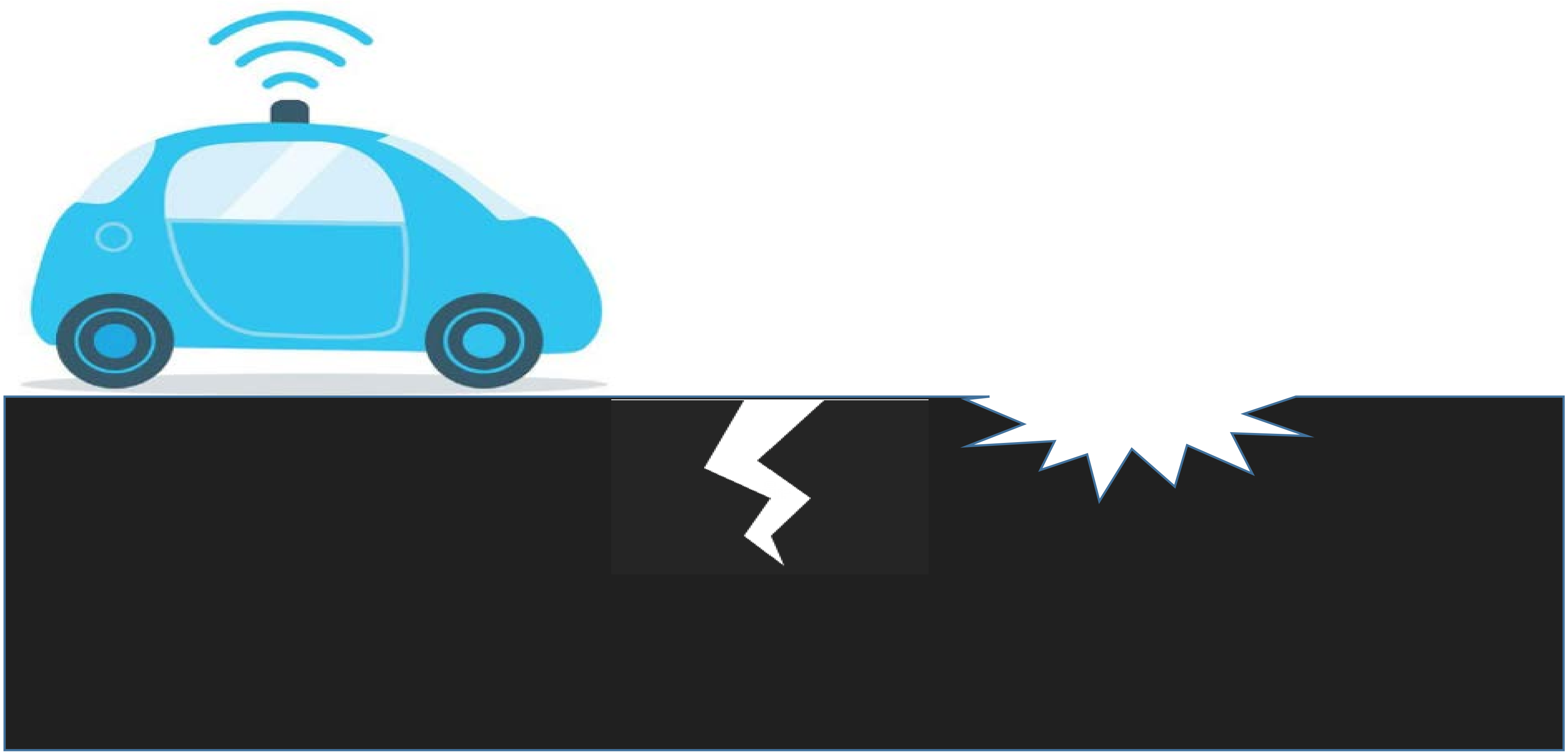
- 24% of the bridges in US are functionally obsolete (ASCE, 2013).
- Dwelling maintenance and rehabilitation budgets.
- To provide well maintained and functional infrastructures for safer mobility!

New challenge: Autonomous and Connected Vehicles!

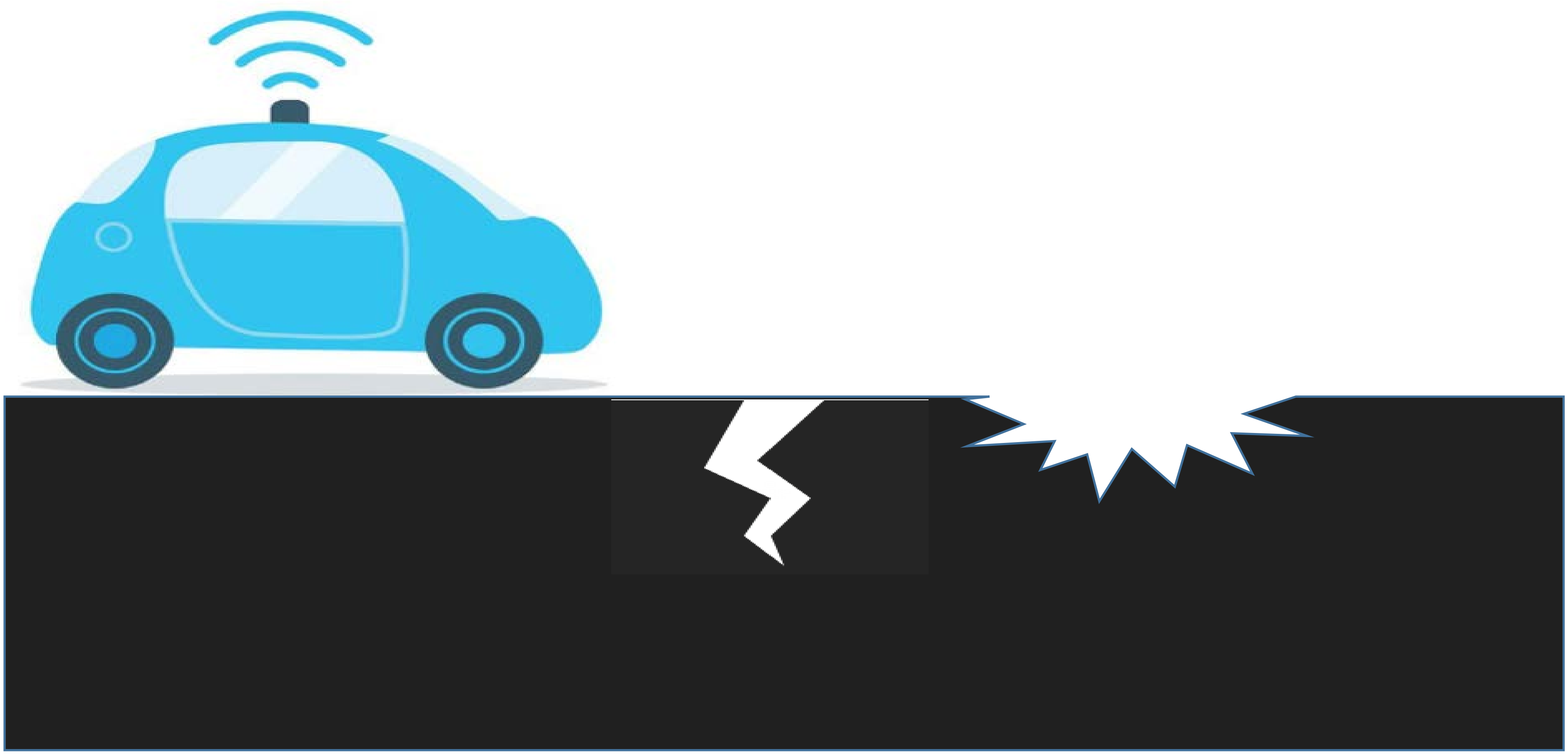
High Tech Autonomous Vehicles…



Same Infrastructures…

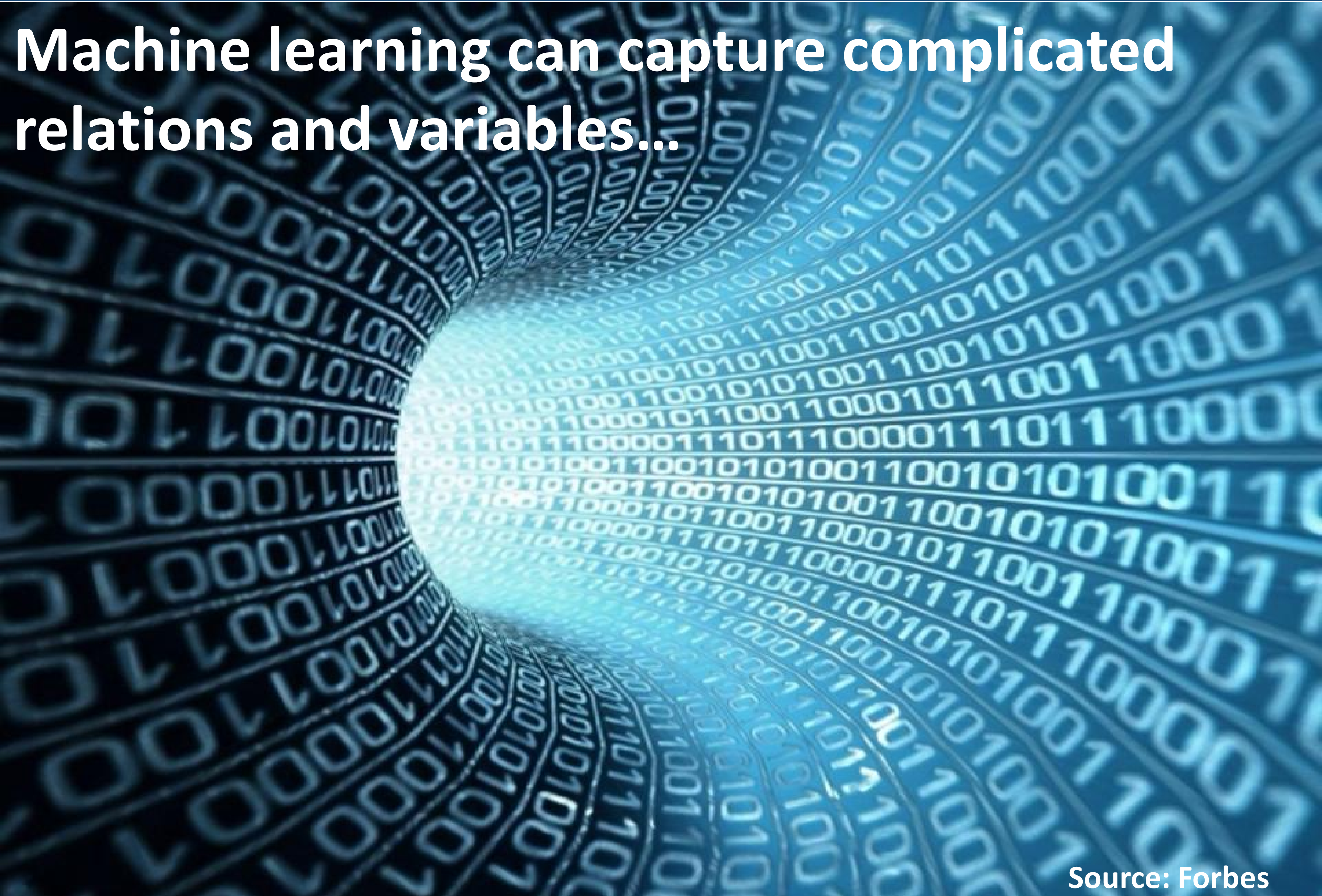


Same Infrastructures…



Same Infrastructures…

Machine learning can capture complicated relations and variables…



Source: Forbes

Oversize and Overweight Vehicle Permit Fee

$$W = 500\left(\frac{LN}{N-1} + 12N + 36\right)$$

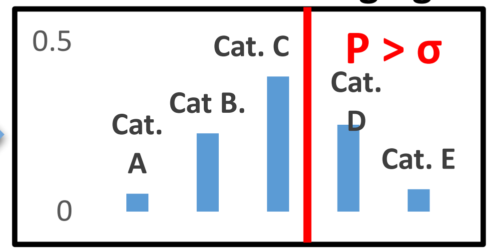
Source: http://www.heavyhaul.net

Overweight Vehicle Fee for Bridges

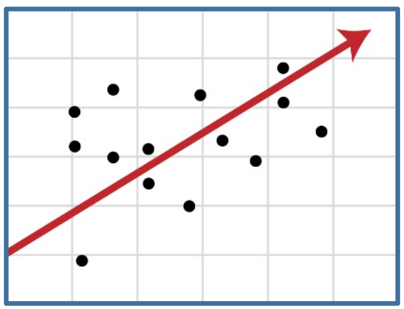
National Bridge Inventory

Bridge Conditions and Characteristics

Scenario 1: With Damaging Trucks



Service Life (SL) Predictor



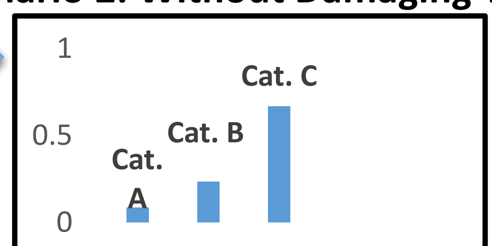
- SL 1 (e.g. 48 Years)
- SL 2 (e.g. 40 Years)

BLCCA

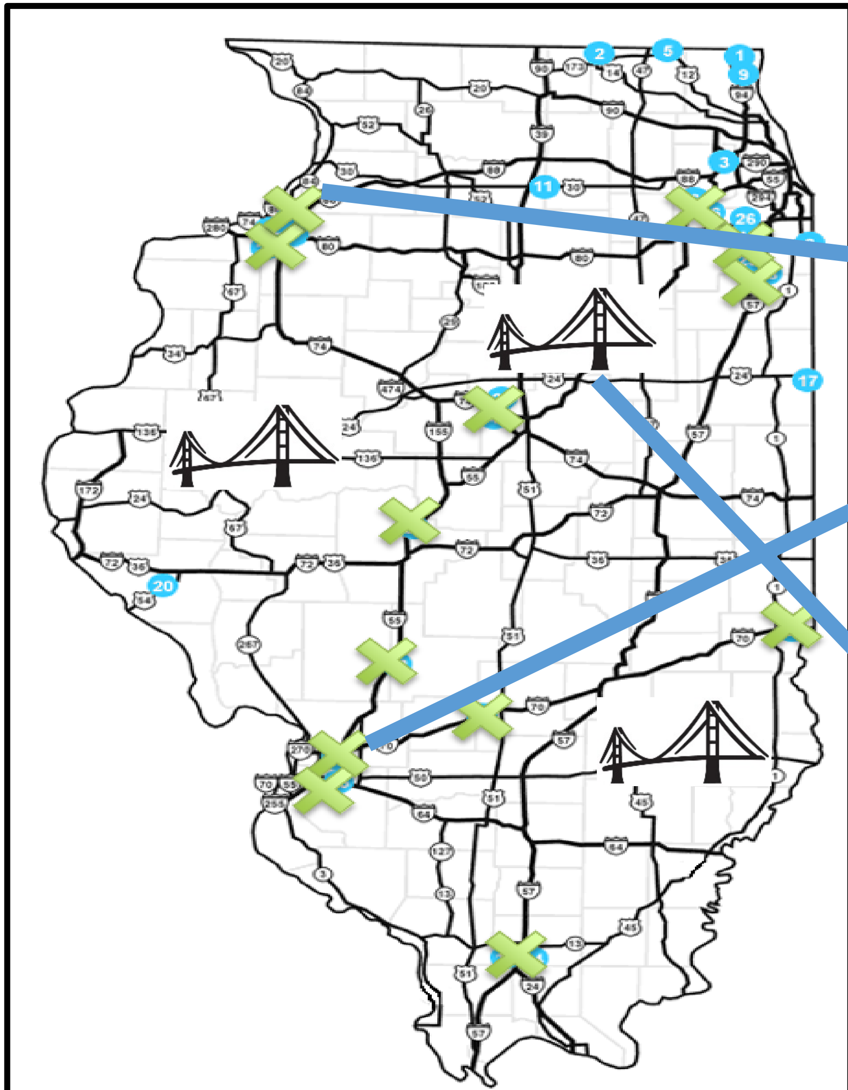
Weigh-In-Motion Data

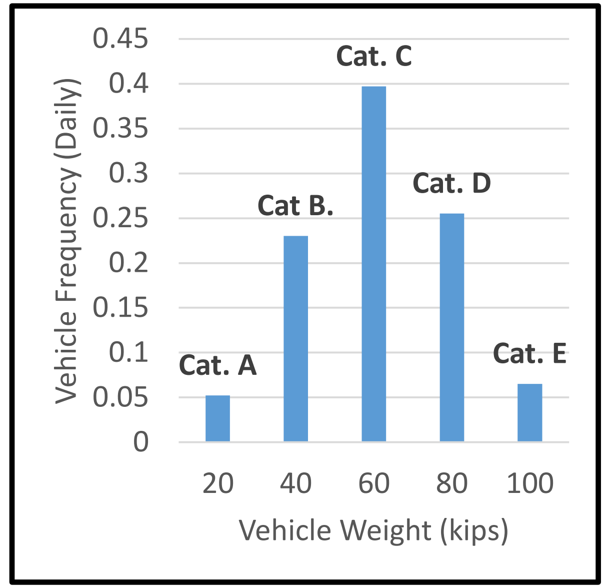
Vehicle Weight Distribution

Scenario 2: Without Damaging Trucks



Vehicle Weight Distribution Estimation Over Entire Network



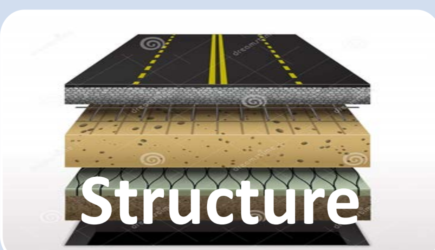


Gaussian Mixture Models+
Elastic-Net (LASSO and Ridge Regression)

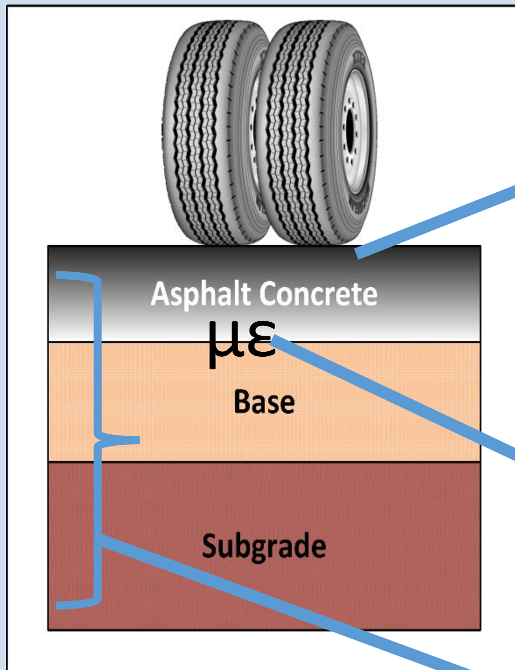
Predicting structural responses within an airfield pavement

Mechanistic Empirical Pavement Design Approach

Inputs



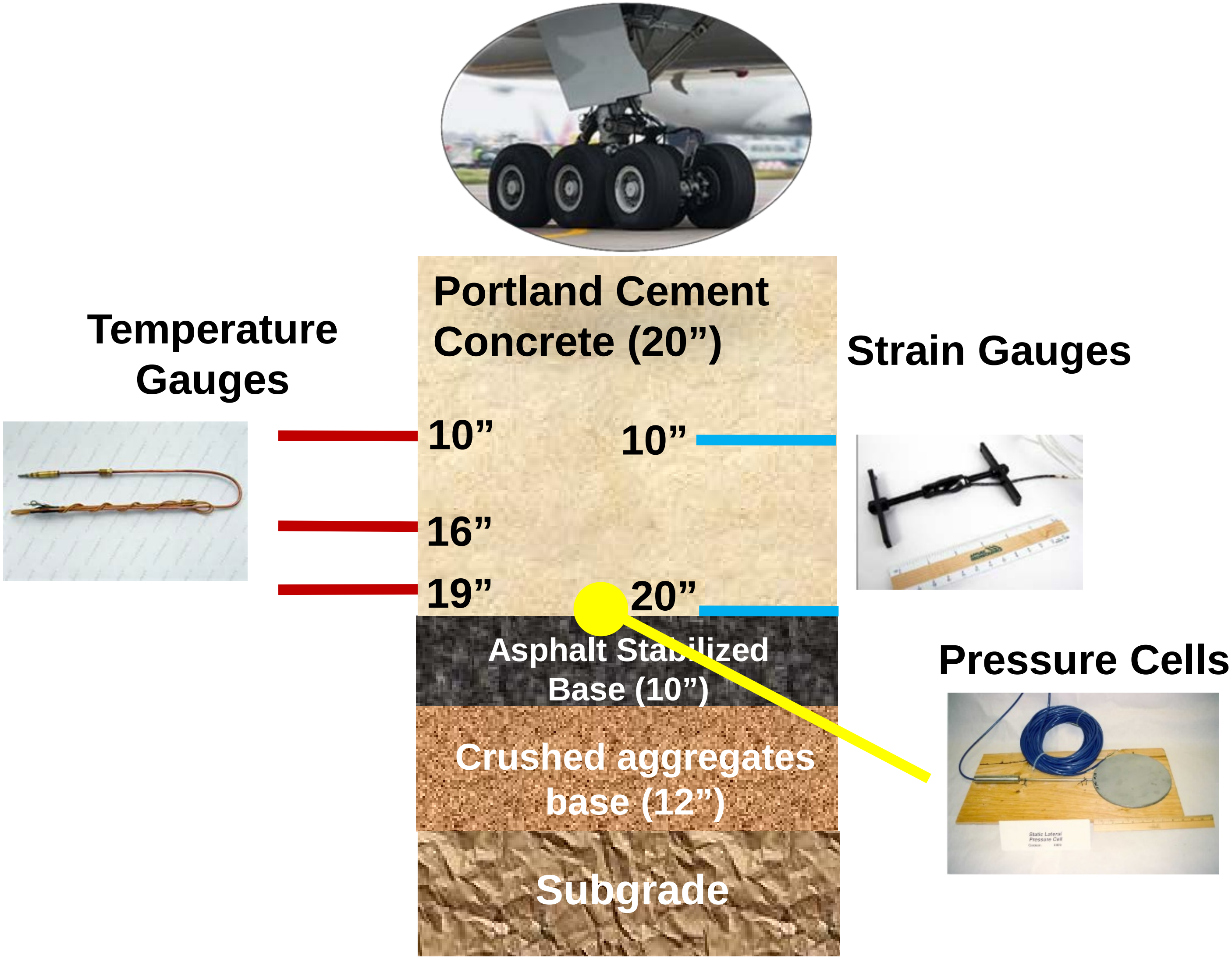
Mechanistic



Calculate Pavement Responses (Critical Strains)

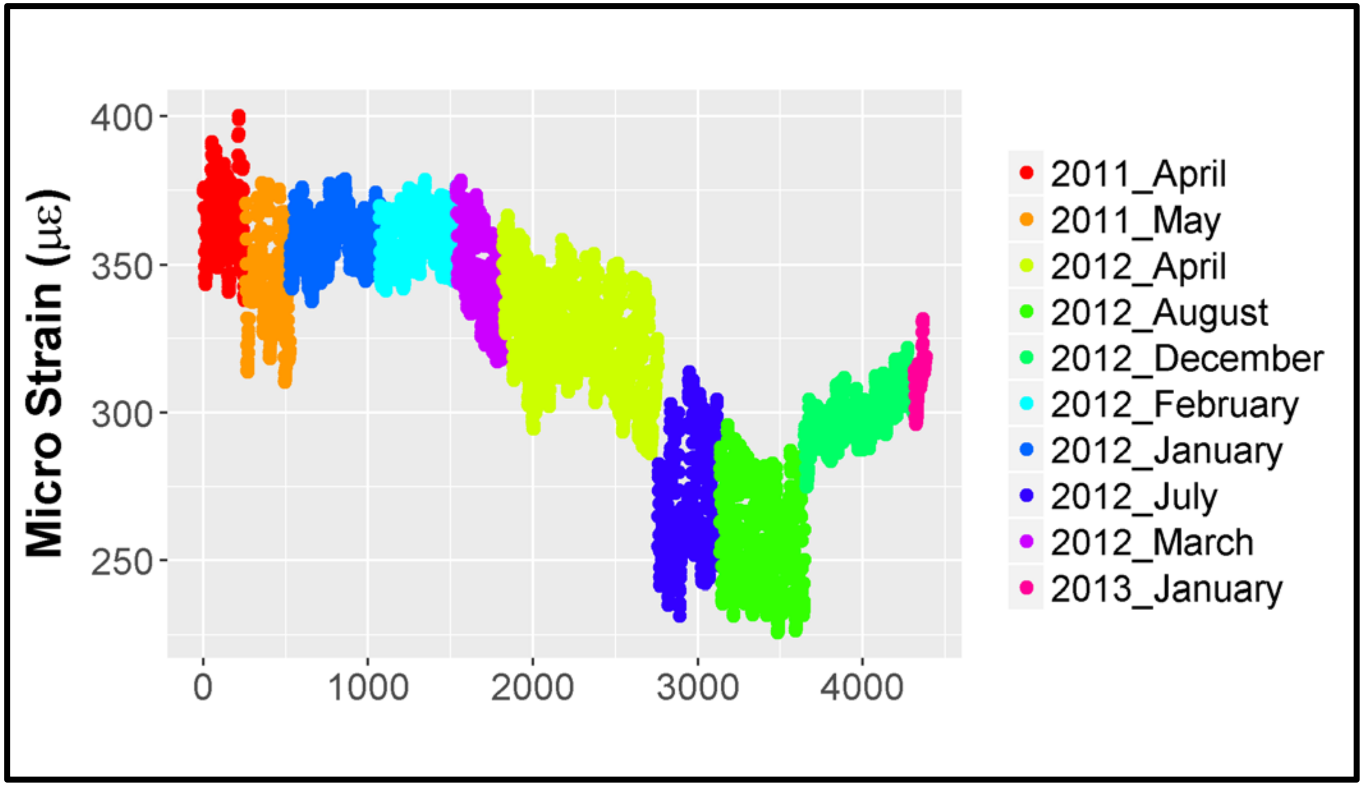
Empirical

JFK Airport Instrumentation

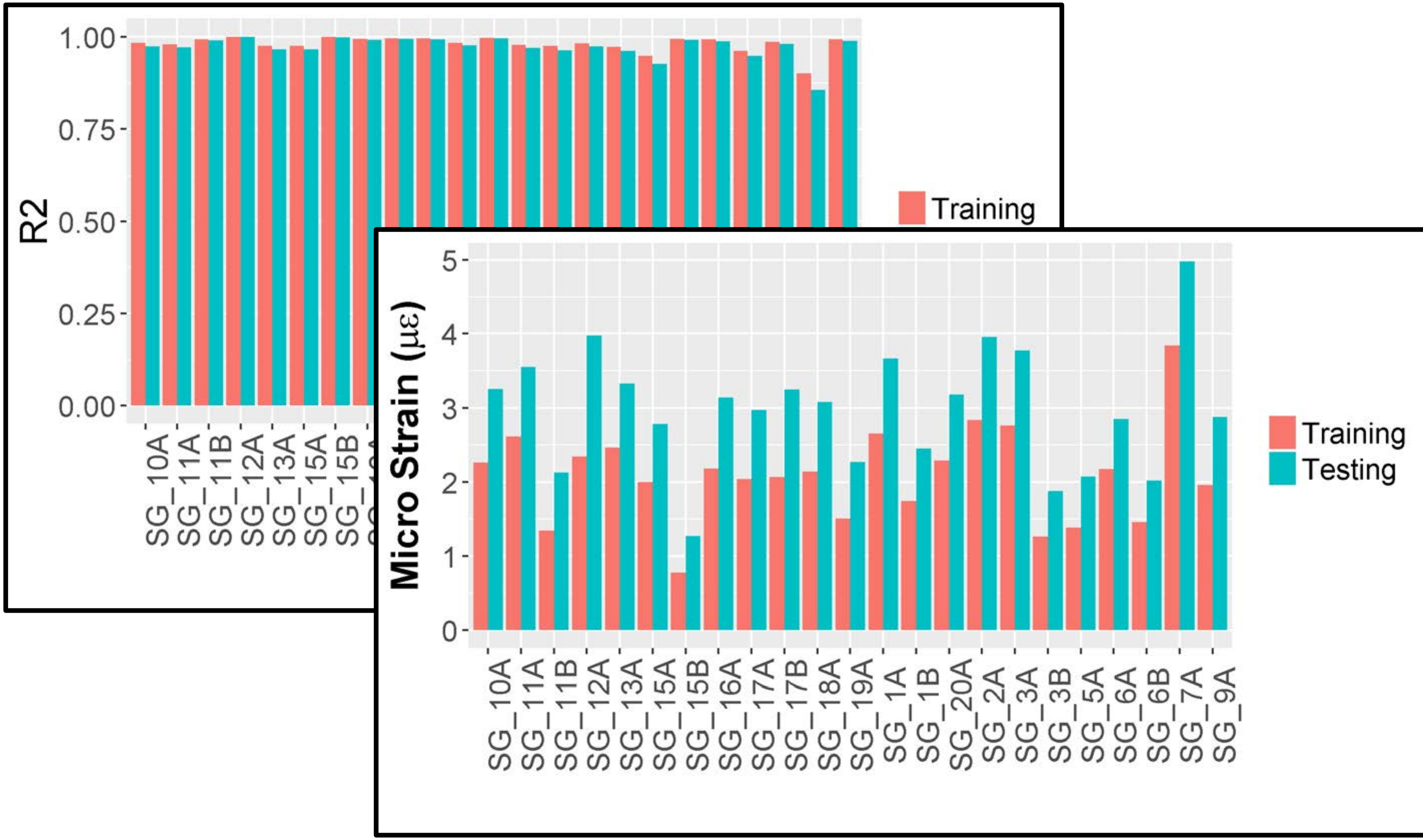


Response Prediction

- **Objective:** **Predict the response within pavement at various depths using pavement temperature data and climatic data.**



Results


R2
1.00
0.75
0.50
0.25
0.00
SG_10A
SG_11A
SG_11B
SG_12A
SG_13A
SG_15A
SG_15B
Training
Micro Strain (με)
5
4
3
2
1
0
SG_10A
SG_11A
SG_11B
SG_12A
SG_13A
SG_15A
SG_15B
SG_16A
SG_17A
SG_17B
SG_18A
SG_19A
SG_1A
SG_1B
SG_20A
SG_2A
SG_3A
SG_3B
SG_5A
SG_6A
SG_6B
SG_7A
SG_9A
Training
Testing

Summary

- We have proved the power of ML for addressing the problems in transportation infrastructure management.
- Use ML based models for new challenges:
  - Quantify the effects on CAVs on infrastructures
  - Use CAVs to improve transportation infrastructure management
- The ultimate goal: Help accelerating the adaption of CAVs

Questions?