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TRANSPORTATION RESEARCH BOARD

Understanding Pavements – Long-Term Pavement Performance Program Updates

February 4, 2021

@NASEMTRB
#TRBwebinar

PDH Certification Information:

- 1.5 Professional Development Hour (PDH) – see follow-up email for instructions
- You must attend the entire webinar to be eligible to receive PDH credits
- Questions? Contact Reggie Gillum at RGillum@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

RCEP

REGISTERED CONTINUING EDUCATION PROGRAM

#TRBwebinar

Learning Objectives

1. Identify current and ongoing LTPP program activities
2. Discuss how the LTPP program supports state transportation agencies
3. Identify how to get involved and who to contact at the program level

All photos source: FHWA.

OFFICE OF RESEARCH, DEVELOPMENT, AND TECHNOLOGY

UNDERSTANDING PAVEMENTS— LONG-TERM PAVEMENT PERFORMANCE (LTPP) PROGRAM UPDATES

Transportation Research Board (TRB) Webinar

February 4, 2021

Larry Wiser
Federal Highway Administration (FHWA)
Highway Research Engineer
Long-Term Infrastructure Performance Team

Y. Jane Jiang
FHWA Highway Research Engineer
Long-Term Infrastructure Performance Team

Deborah Walker
FHWA Research Civil Engineer
Long-Term Infrastructure Performance Team

TURNER-FAIRBANK
Highway Research Center

LTPP PROGRAM UPDATES

- Overview of the LTPP InfoPave™ Web Portal
- Revamped LTPP Data Analysis Plan
- FHWA InfoMaterials™
- 2019–2020 LTPP Data Analysis Student Contest

OVERVIEW OF LTPP INFOPAVE

LTPP InfoPave

- VISUALIZATION: LTPP Section Mapping[1]
- DATA: Data Selection and Download[2]
- ANALYSIS: Data Availability Chart[3]
- TOOLS: LTPP Climate Tool[4]
- OPERATONS: Materials Reference Library[5]
- NON-LTPP: MnROAD Test Track Data[6]

[1]FHWA. "LTPP InfoPave: Visualization." (Web page) Washington, D.C. Available online: https://infopave.fhwa.dot.gov/Media/LTPPSectionMapping, last accessed January 11, 2021.
[2]FHWA. "LTPP InfoPave: Data." (Web page) Washington, D.C. Available online: https://infopave.fhwa.dot.gov/Data/VisualDataSelection, last accessed January 11, 2021.
[3]FHWA. "LTPP InfoPave: Analysis." (Web page) Washington, D.C. Available online: https://infopave.fhwa.dot.gov/Analysis/DataAvailability, last accessed January 11, 2021.
[4]FHWA. "LTPP InfoPave: Tools." (Web page) Washington, D.C. Available online: https://infopave.fhwa.dot.gov/Data/ClimateTool, last accessed January 11, 2021.
[5]FHWA. "LTPP InfoPave: Operations." (Web page) Washington, D.C. Available online: https://infopave.fhwa.dot.gov/MRL/Library, last accessed January 11, 2021.
[6]FHWA. "LTPP InfoPave: Non-LTPP." (Web page) Washington, D.C. Available online: https://infopave.fhwa.dot.gov/Mnroad/index, last accessed January 11, 2021.

REVAMPED LTPP DATA ANALYSIS PLAN

LTPP DATA ANALYSIS PLAN

- LTPP Data Analysis Plan[1]
- Expanded Data Analysis Plan[2]
- Analysis Plan on LTPP InfoPave[3]
- Revised LTPP Data Analysis Objectives and Outcomes

[1]TRB LTPP Committee. (1999). *Strategic Plan for Long-Term Pavement Performance Data Analysis*. TRB, Washington, D.C.
[2]TRB. (2017). *Long-Term Pavement Performance Data Analysis Program*. TRB, Washington, D.C.
[3]FHWA. “LTPP InfoPave: Analysis.” (Web page) Washington, D.C. Available online: https://infopave.fhwa.dot.gov/Analysis/DataAvailability, last accessed January 11, 2021.

LTPP DATA ANALYSIS WORKSHOP

GOAL

Update the LTPP data analysis plan to reflect a strategic approach to using LTPP data to meet the highest priority needs of the pavement community.

PURPOSE

Receive input from pavement analysis subject matter experts to be considered by FHWA in revising the LTPP data analysis plan.

PRODUCTS

Assemble a set of proposed new and revised LTPP data analysis project descriptions that outline the required work.

REVISED LTPP DATA ANALYSIS PLAN

LTPP DATA ANALYSIS OBJECTIVES AND OUTCOMES					
OBJECTIVES	**1. Characterize loading, environment, and materials and impact on pavement performance (past Objectives 1, 2 and 3 on InfoPave™)**	**2. Determine the effects of design features on pavement performance (past Objective 7 on InfoPave™)**	**3. Improve selection and design methodologies for new and rehabilitated pavements (past Objectives 5 and 8 on InfoPave™)**	**4. Improved strategies for planning maintenance and preservation treatments (past Objective 6 on InfoPave™)**	**5. Improve pavement asset management practices (past Objectives 4 and 9 on InfoPave™)**
OUTCOMES	A. Characterization and impact of traffic loading on pavement performance	A. Quantify the impact of specific design features (e.g., subsurface drainage, base types, shoulder types, edge support, etc.) on performance	A. Enhanced pavement response and performance prediction models	A. Performance analysis ready maintenance and preservation data sets	A. Evaluation and use of pavement performance data in pavement management and performance reporting
	B. Characterization and impact of environmental effects on pavement layer characteristics and pavement	B. Impact of design features on measured pavement responses (deflections, load-transfer, strains, etc.)	B. Distress prediction based on commonly collected pavement data	B. Procedures for identifying maintenance and preservation needs	B. Data collection efficiency and quality management
	C. Impact of material characteristics and properties on pavement performance	C. Guidelines to select design features for improved pavement performance	C. LTPP data to support/improve mechanistic-empirical procedures	C. Performance prediction of maintenance and preservation treatments	C. Capstone analysis findings
	D. Relationship among individual performance indicators (e.g., roughness, deflection, etc.) and pavement performance	D. Capstone analysis findings	D. Capstone analysis findings	D. Capstone analysis findings	
	E. Capstone analysis findings				

Source: FHWA.

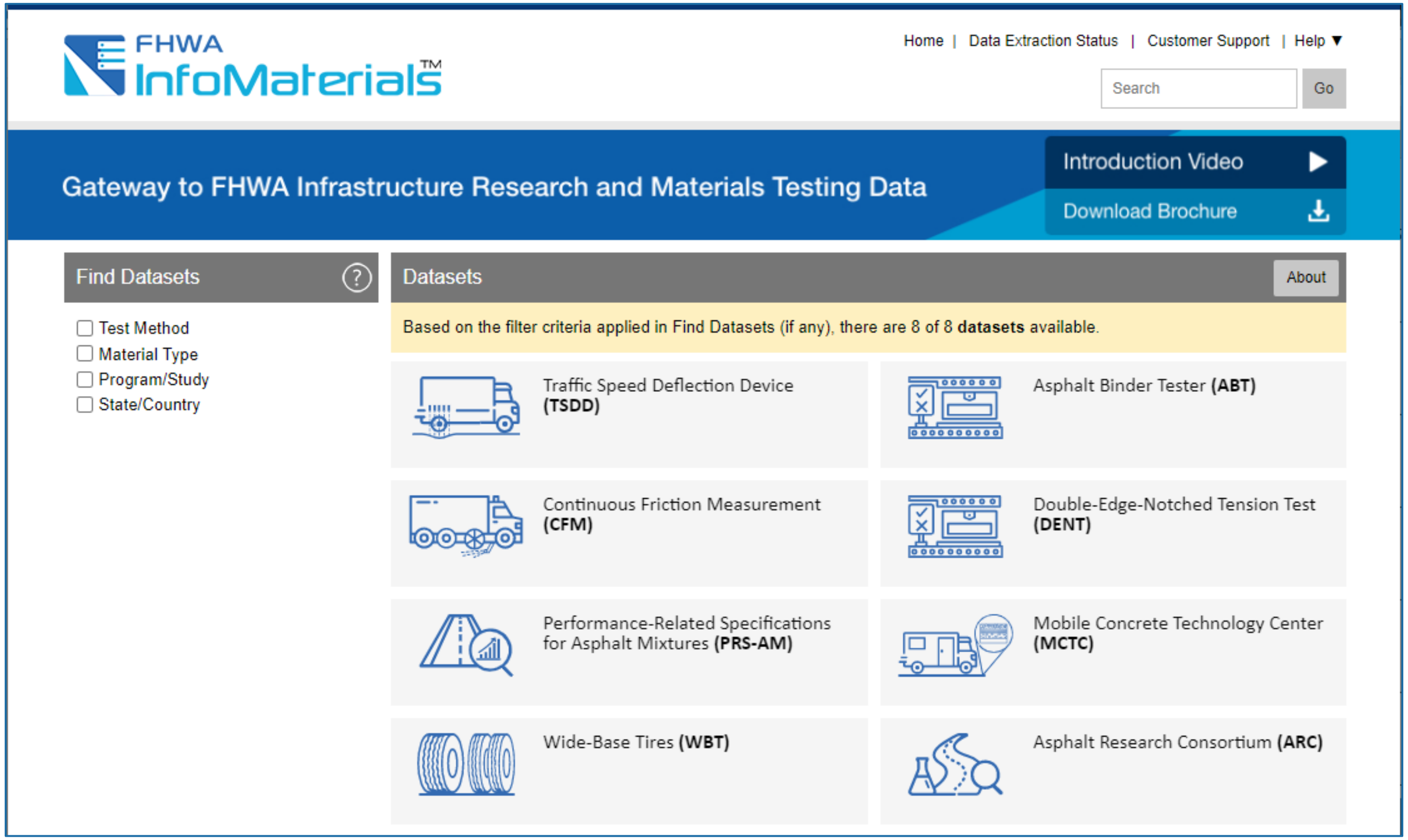
CLOSING COMMENTS

- Significant progress has been made
- Much remains to be done
- Coordination with other programs and transportation agencies is essential
- Thank you for your continued support and we welcome your feedback

FHWA INFOMATERIALS

WINDOW INTO INFRASTRUCTURE RESEARCH AND MATERIALS TESTING

INFOMATERIALS—GATEWAY TO FHWA'S INFRASTRUCTURE RESEARCH AND MATERIALS TESTING DATA



Source: FHWA.

https://infopave.fhwa.dot.gov/InfoMaterials*

*FHWA. "FHWA InfoMaterials." (website) Washington, D.C. Available online: https://infopave.fhwa.dot.gov/InfoMaterials, last accessed January 7, 2021.

BENEFITS OF FHWA INFOMATERIALS

- Accesses FHWA research and materials testing data
- Enhances organization and functionality
- Minimizes duplication of research and materials testing
- Facilitates data sharing and cooperation among research programs and agencies
- Complies with the Open, Public, Electronic, and Necessary (OPEN) Government Data Act

INFOMATERIALS' MAIN FUNCTIONALITY

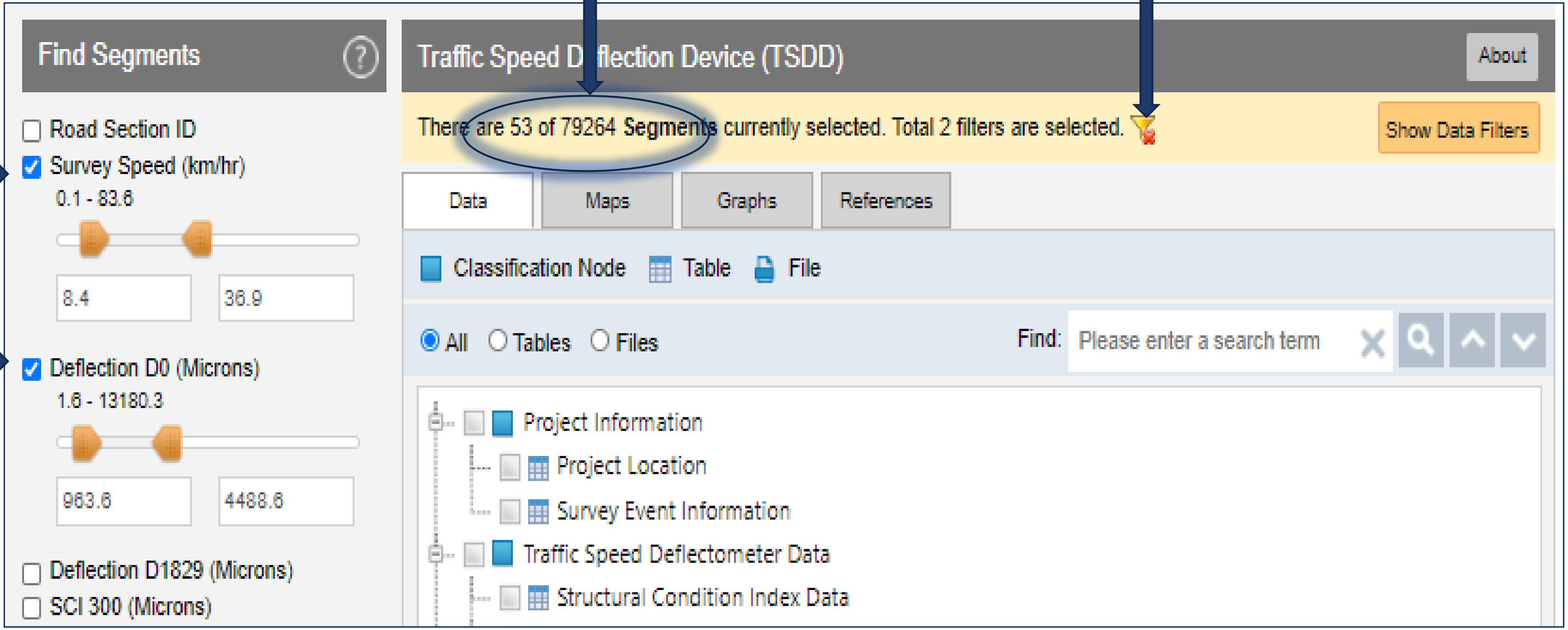
- Multiple Datasets from which to Choose
- For Each Dataset:
  - Filters to Find Data of Interest
  - Maps
  - Visualization and Graphs
  - Data Exploration and Download
  - References and/or Reports

DATA FILTERS—NARROW DOWN DATA

Select data specific filters

Filter applied

Remove filter

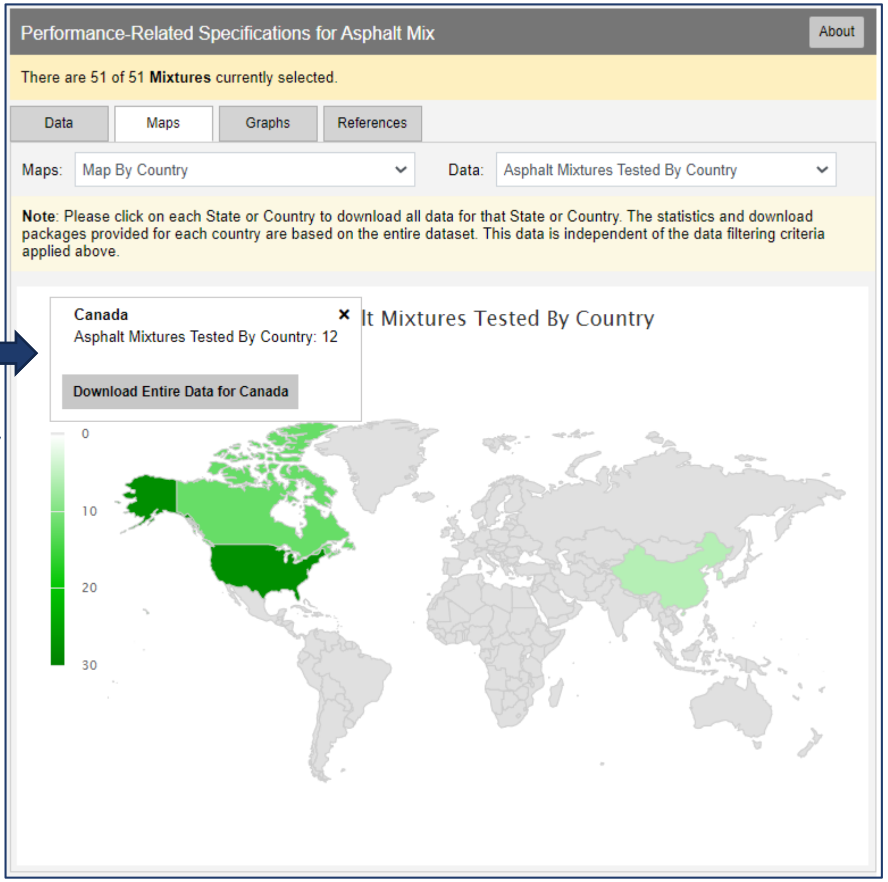


Source: FHWA.

MAPS

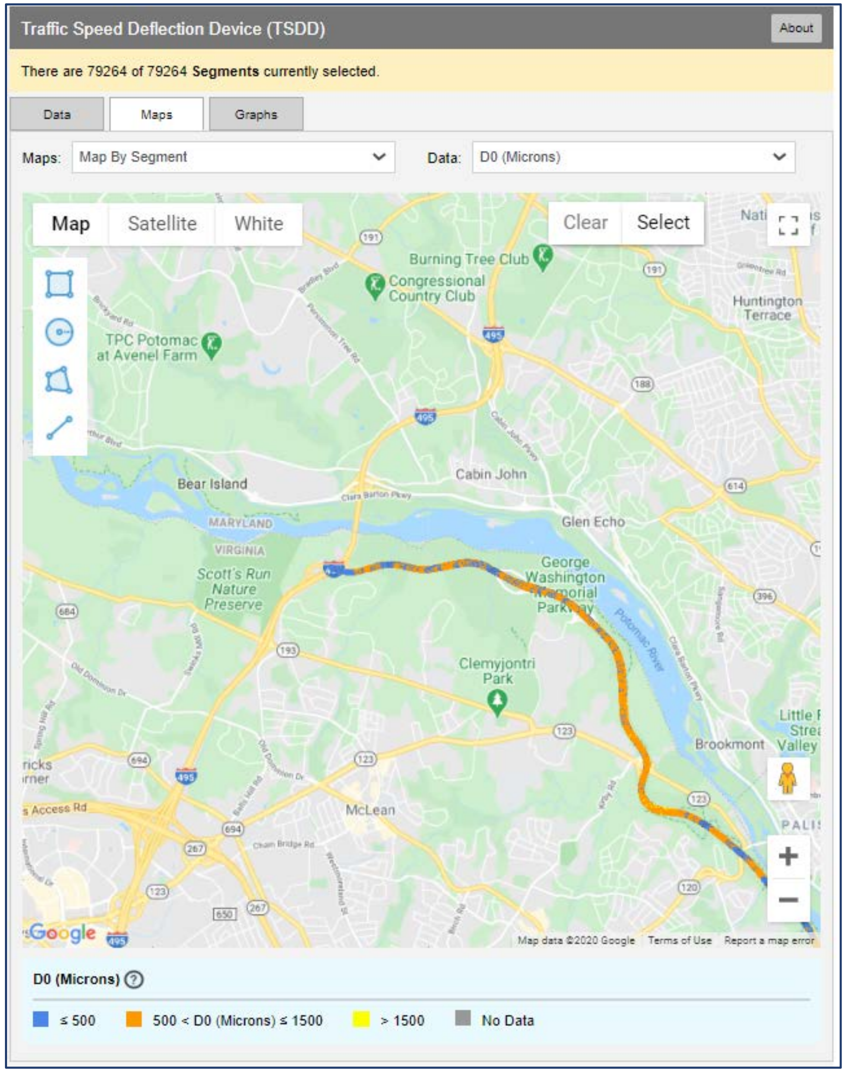
Map by States/country

Click on each country to display data availability and download its data



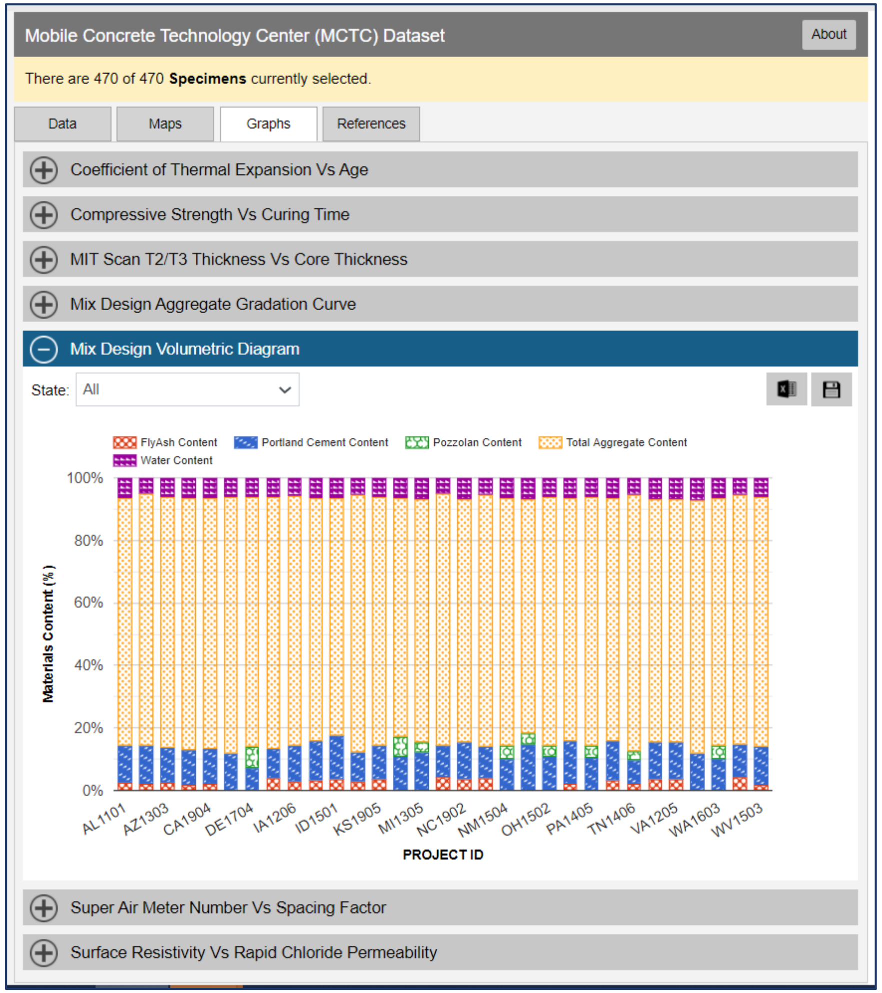
Source: FHWA.

Map by segment



Website Screenshot: FHWA. Original Map: © 2020 Google. Map Data: © 2020 Google. Modifications: FHWA.

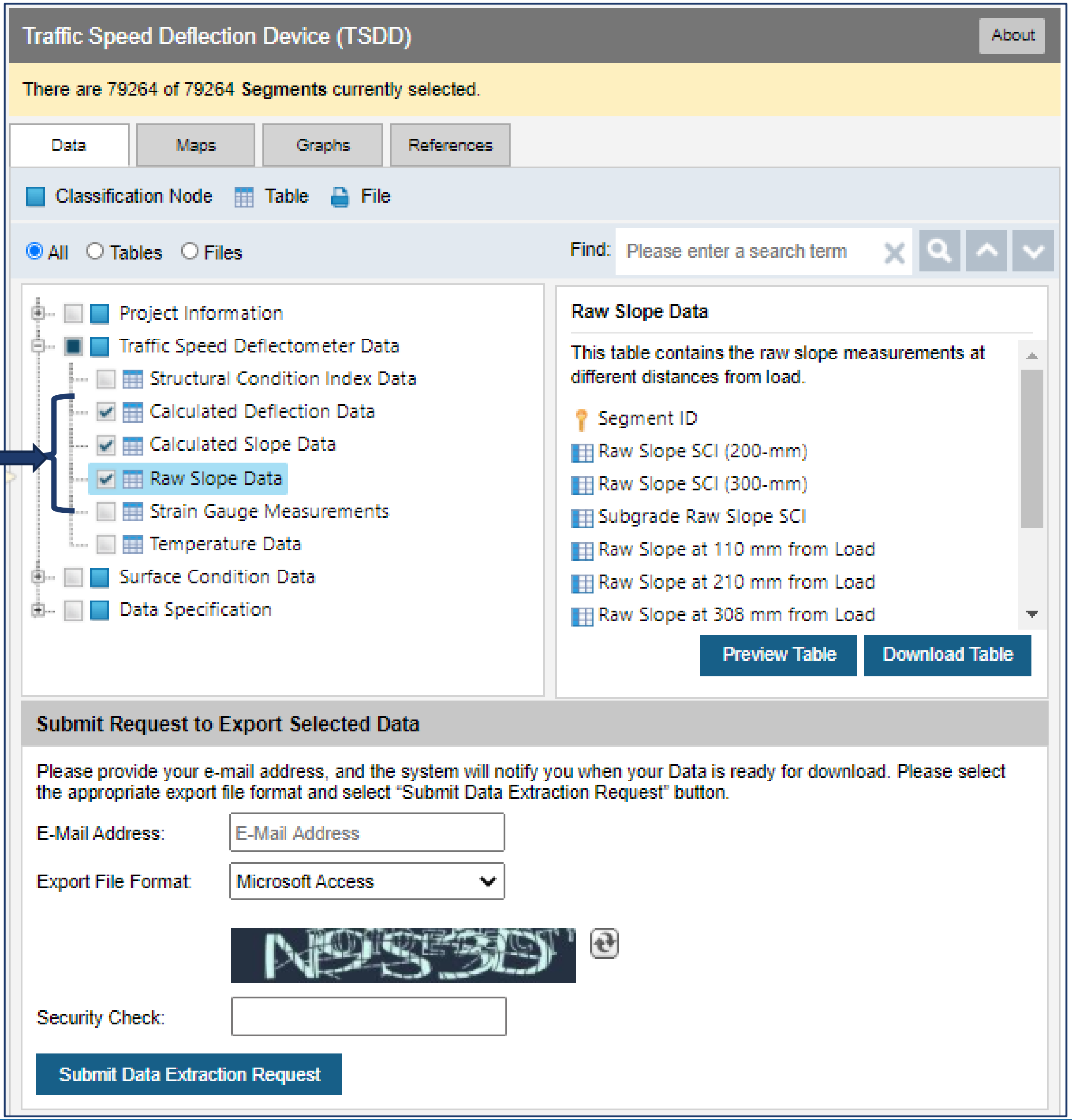
VISUALIZATION/GRAPHS



All photos source: FHWA.

DATA CLASSIFICATION AND DOWNLOAD

Selected Data



Source: FHWA.

FHWA INFOMATERIALS

https://infopave.fhwa.dot.gov/InfoMaterials

All photos source: FHWA.

2019–2020 LTPP DATA ANALYSIS STUDENT CONTEST WINNERS

ARAMIS LÓPEZ CHALLENGE CATEGORY

- **1st PLACE WINNER**

  Fengdi Guo, Massachusetts Institute of Technology

  Assessing the Influence of Overweight Vehicles on Pavement Performance

- **2nd PLACE WINNERS**

  Issa M. Issa and Dan G. Zollinger, Texas A&M

  A Framework for a Distress-Based Traffic Equivalency to Efficiently Evaluate the Effect of LTPP Traffic Loads on Pavement Performance

  Muhamad Munum Masud, Michigan State University

  Weigh-in-Motion Accuracy Prediction Using Axle Load Spectra and Effect of Overloading Vehicles on Pavement Performance

GRADUATE CATEGORY

- **1st PLACE WINNER**

  Hamad Bin Muslim, Michigan State University

  Effects of Seasonal and Diurnal FWD Measurements on LTE of JPCP–LTPP SMP Data

- **2nd PLACE WINNER**

  Haoran Li and Katelyn Kosar, University of Pittsburgh

  Performance of Ohio SPS-2 Sections: Lessons Learned

FWD = falling weight deflectometer
JPCP = jointed plain concrete pavements
LTE = load transfer efficiency
SMP = seasonal monitoring program
SPS = Specific Pavement Studies

CONTACT

Larry Wiser
Highway Research Engineer
Larry.Wiser@dot.gov

Jane Jiang
Highway Research Engineer
jane.jiang@dot.gov

Deborah Walker
Research Civil Engineer
deborah.walker@dot.gov

Source: FHWA.

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Assessing the influence of overweight vehicles on pavement performance

Fengdi Guo (presenter), Jeremy Gregory, Randolph Kirchain

Concrete Sustainability Hub, Massachusetts Institute of Technology

Evaluation and prediction for the influence of traffic weights on pavement performance

Explore which performance metrics are sensitive to traffic weights

Qualitative Analysis

RNN models are developed for prediction

Deterioration Prediction

Quantitative Analysis

Predict pavement performance evolutions under different traffic weights

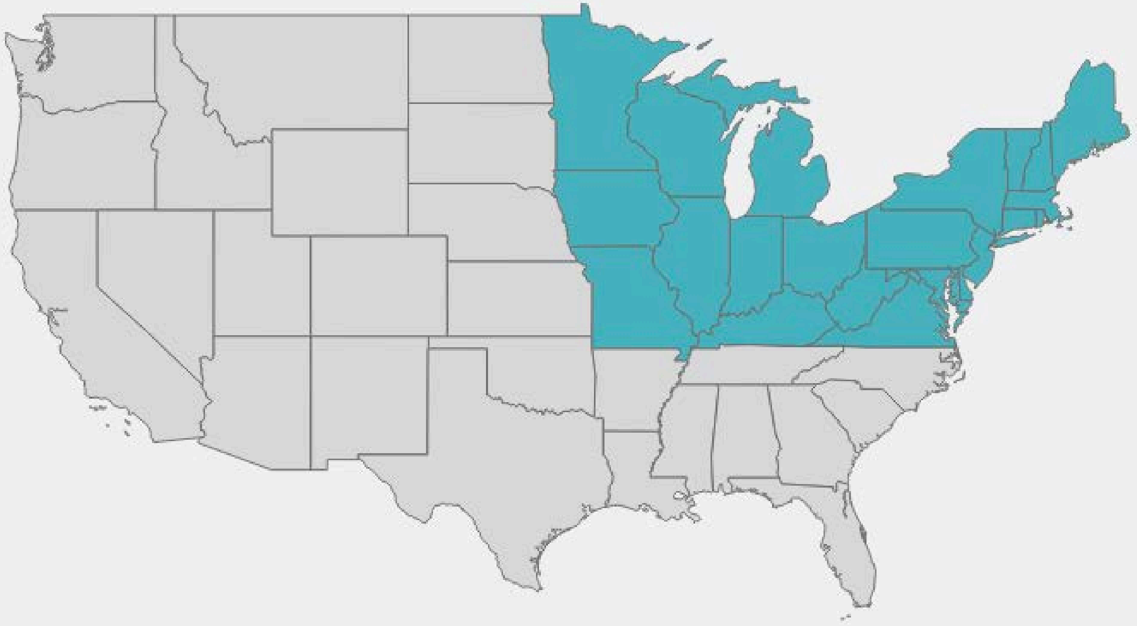
Life-cycle Cost Analysis

Evaluate the economic loss caused by growth of traffic weights based on life-cycle cost analysis

1

Qualitative Analysis

Pavement segment selection in LTPP database



Segment selection

LTPP database

LTPP is a large research program that aims at improving pavement engineering through the tracking of pavement performance.

Wet-Freeze climate zone

- AADTT reflects truck traffic volume
- ESAL reflects truck traffic weight
- Only most segments in the Wet-Freeze climate zone have the ESAL information

*AADTT: average annual daily truck traffic
ESAL: Equivalent Single Axle Load

Traffic weight metric

Traffic weight

Average Annual Cumulative Traffic Weight (AACTW)

- Expected Equivalent Single Axle Load ($ESAL_e$):

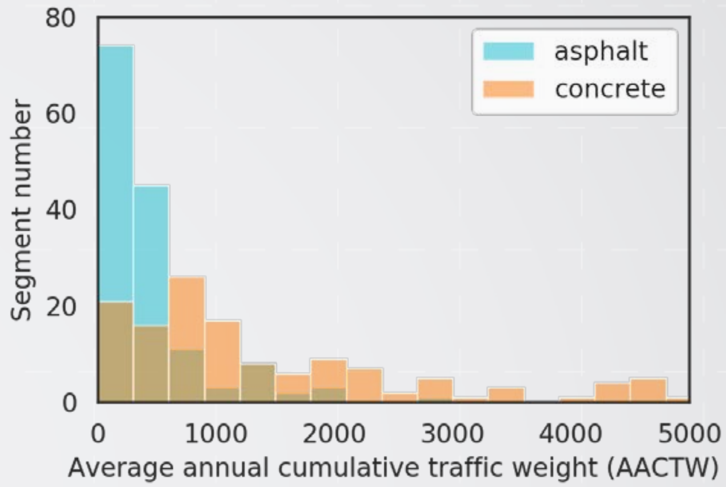
$$ESAL_e = \sum_{i=4}^{13} ESAL_i \cdot C_i$$

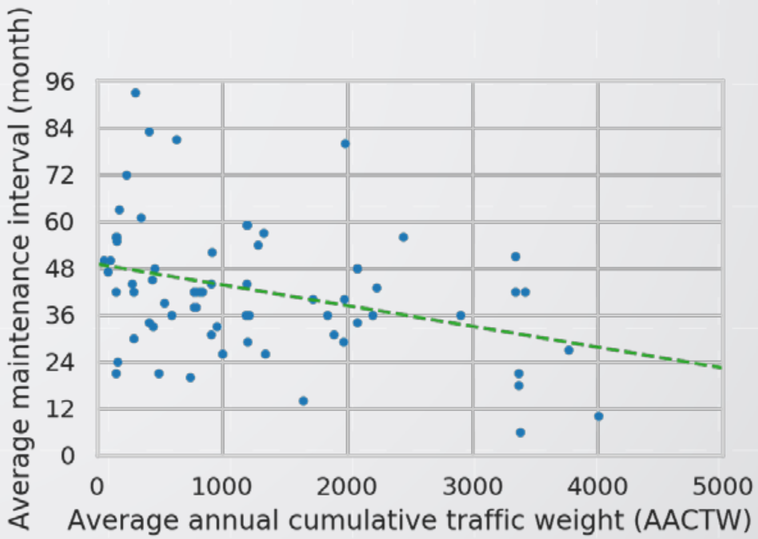
- AACTW:

$$AACTW = ESAL_e \cdot AADTT$$

AACTW statistics

- AACTW for asphalt pavements is smaller than concrete pavements
- On average, when AACTW increases by 1,000, the maintenance time interval decreases by about 5 months.



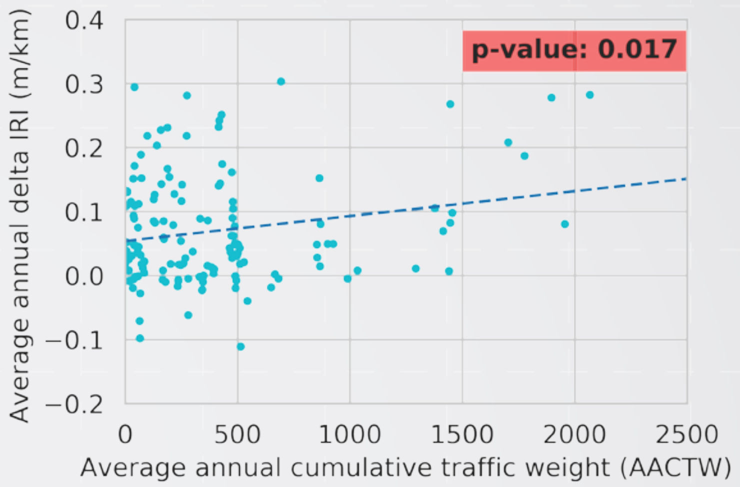


* AADTT: average annual daily truck traffic

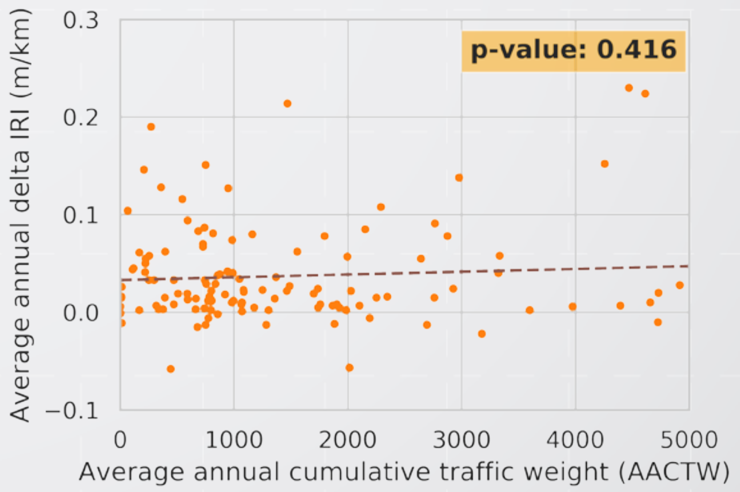
Evaluation of traffic weights on various performance metrics

Linear regression analysis

- For each performance metrics, build a linear regression model between the metric and traffic weight (AACTW).
- If the p-value for the coefficient of AACTW is less than 0.05, then traffic weight is considered as significant for the deterioration of this metric.



IRI for asphalt pavements



IRI for concrete pavements

Evaluation of traffic weights on various performance metrics

What we learned

- For asphalt pavements, IRI, rut and alligator crack are sensitive to traffic weights. It is difficult to draw a firm conclusion for longitudinal crack, longitudinal wheel path crack and transverse crack due to insufficient data.
- For concrete pavements, all performance metrics are insensitive to traffic weights.

	IRI	rut	edge fault	wheel fault
Asphalt pavements	✓	✓	—	—
Concrete pavements	✗	—	✗	✗

	alligator crack	longitudinal crack	longitudinal wheel path crack	transverse crack
Asphalt pavements	✓	?	?	?
Concrete pavements	—	✗	—	✗

2

Deterioration Prediction

Recurrent neural network model

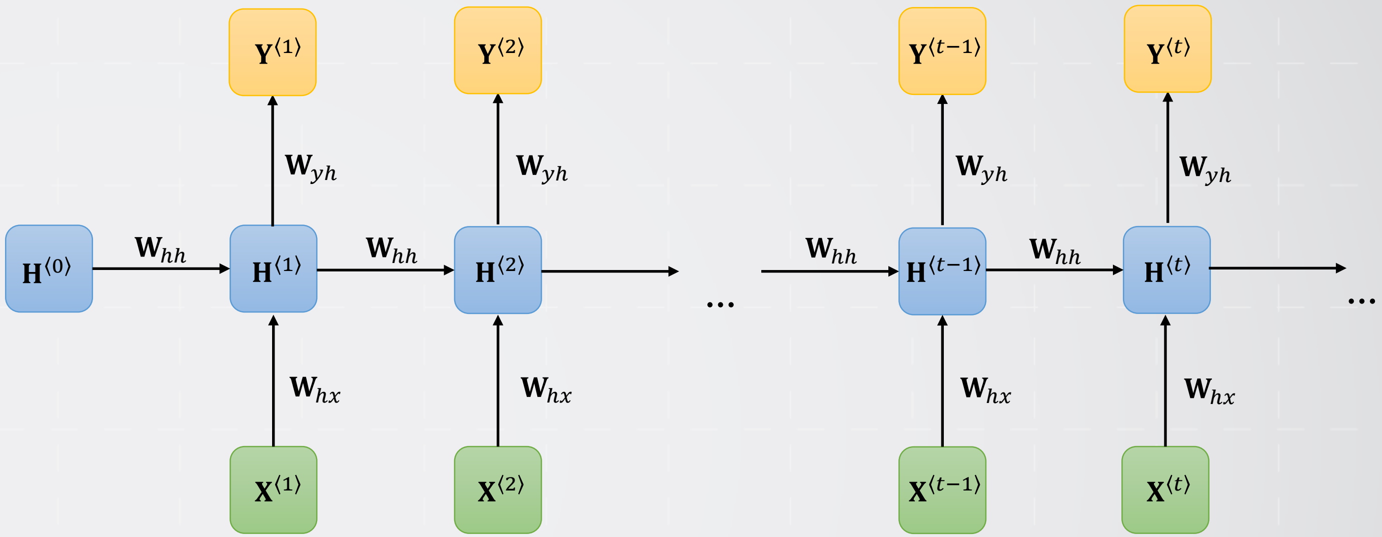
RNN models

Incorporate temporal behavior

- Historical information is stored in the hidden layer.

Applications

- It has been widely used for both time-series analysis and natural language processing.
- Even though pavement distress data in most dataset are in the temporal form, it has seldomly been applied for pavement distress prediction in the literature to date.



$$H^{\langle t\rangle} = \sigma_1\left(W_{hh}H^{\langle t-1\rangle} + W_{hx}X^{\langle t\rangle} + b_h\right)$$

$$Y^{\langle t\rangle} = \sigma_2\left(W_{yh}H^{\langle t\rangle} + b_y\right)$$

Generate parameters to reflect treatment history

Treatment history

LAYR	SURTYP	SURTHK	BASTYP	BASTHK	SUBBASTYP	SUBBASTHK
1952	AC	4.8 inch	TB	4.3 inch	GS	3.0 inch
1998	AC	5.5 inch	-	-	-	-

Newly generated parameters

PMISYR	CONYR	RESYR	PAVTYP	SURTHK	SUBTHK	RESNUM
1952~1998	1952	-	AC	4.8 inch	0	0
>=1998	1952	1998	AC	5.5 inch	4.8 inch	1

Two types of ages

Two types of thicknesses

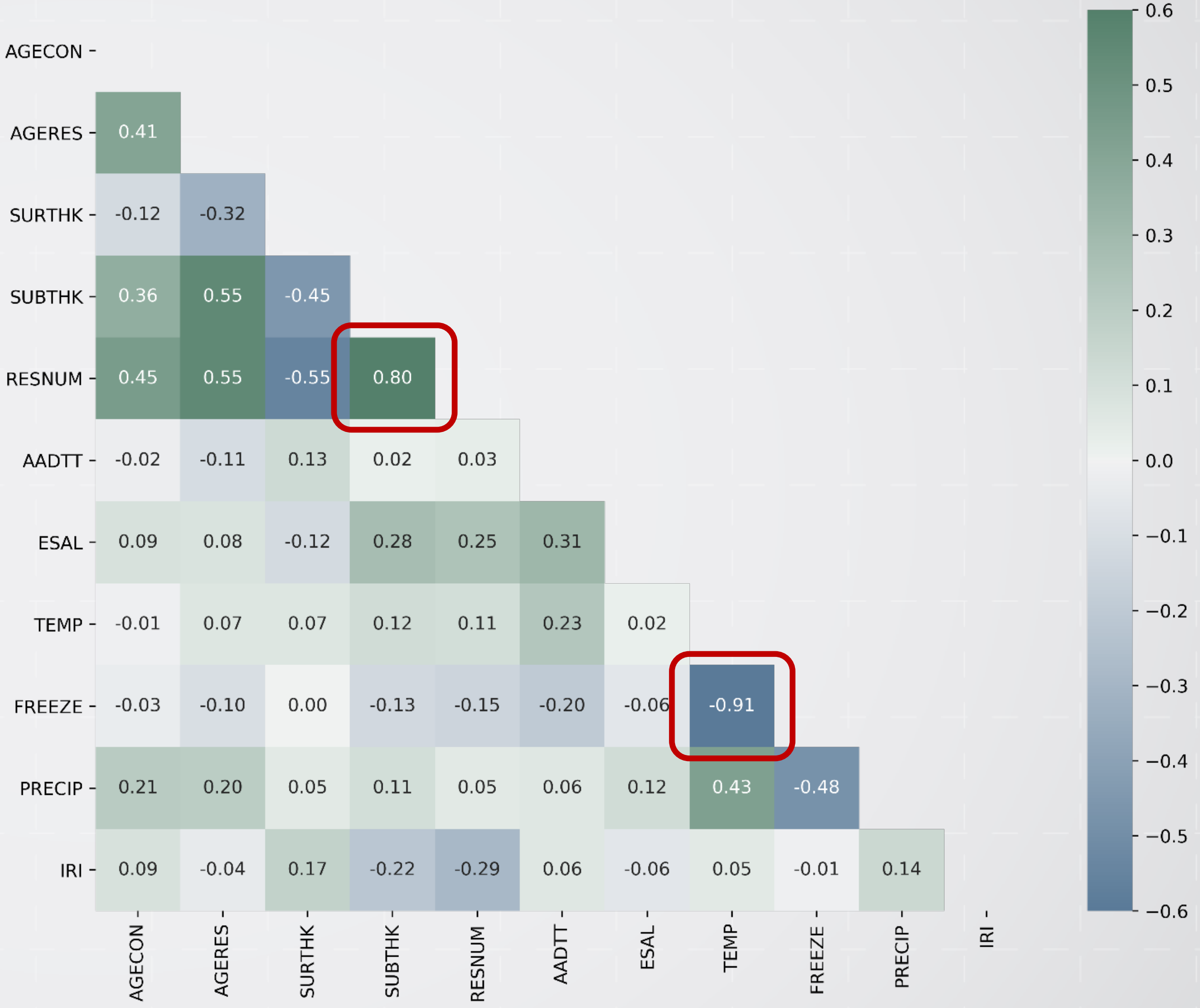
$$AGECON = PMSYR - CONYR$$

$$AGERES = PMSYR - RESYR$$

Select parameters based on correlation analysis

Parameter selection

- TEMP is strongly correlated with FREEZE. The variation for the TEMP is very small compared to FREEZE and thus is omitted from the analysis.
- RESNUM is strongly correlated with SUBTHK, because the number of overlays is mostly one for segments with overlays in the dataset. Here, RESNUM is also omitted.



Model training for RNN

Model parameters

- Neuron number in the hidden layer
- Epoch number
- Learning rate

10-fold cross validation

- Training data accounts for 80%, and validation data accounts for 20%.
- Due to the limitation of data, the test data is ignored to ensure models can be fully trained.
- Grid search is applied to find the optimal combination of model parameters.

Model performance

	Neuron	Epoch	Learning Rate	RMSE
IRI	7	65	0.001	0.114
RUT	7	40	0.001	1.278
ACRACK	7	55	0.001	43.0

* RMSE: root mean squared error

3 Quantitative Analysis

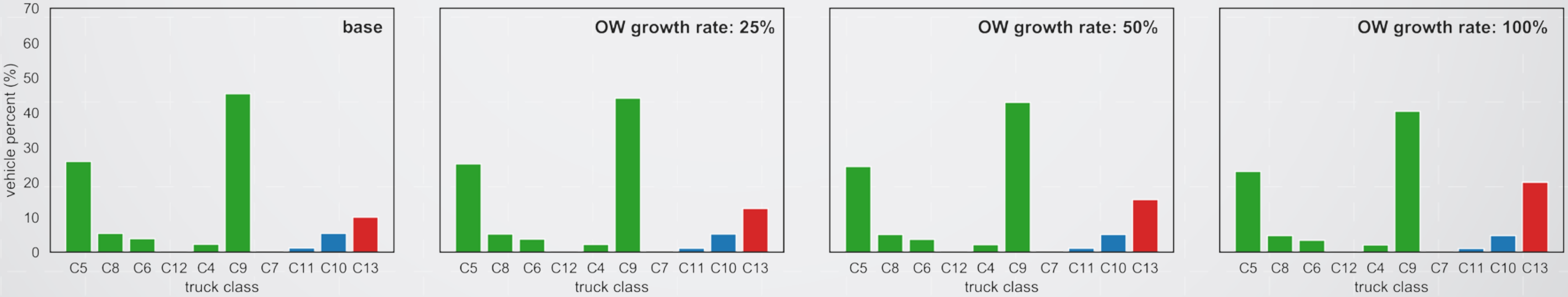
Prediction of performance metrics under different traffic weights

Pavement segment information

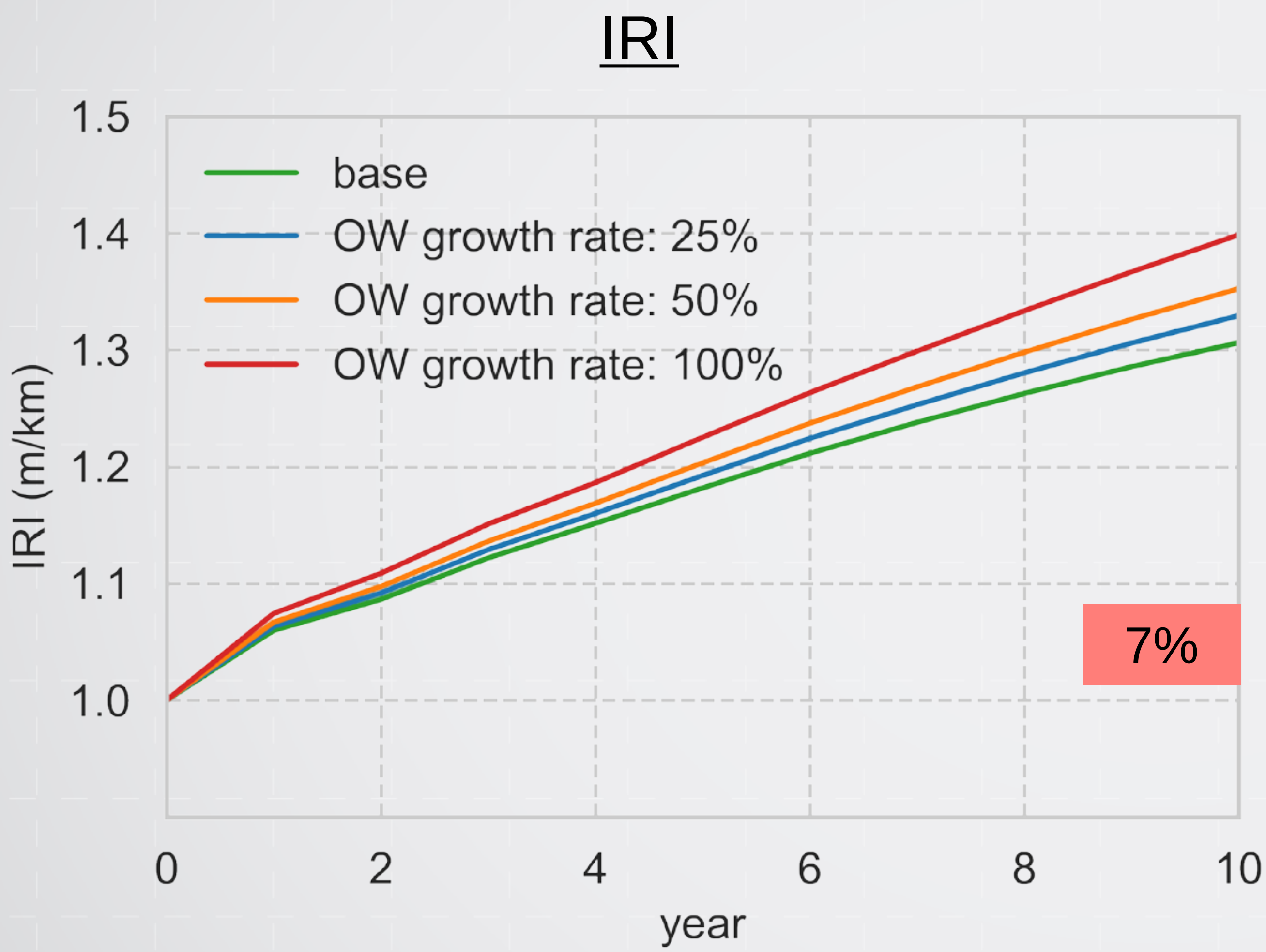
AGECON	AGERES	SURTHK	HMATHK	AADTT	FREEZE	PRECIP	IRI	RUT	ACRACK
5	0	9	0	212	543	957	1.0	2	2

Scenarios for overweight vehicles

The ESAL for overweight truck C13 is 5.65.
The ratios for overweight truck are 10% for the baseline scenario, and 12.5%, 15%, and 20% for proposed scenarios.



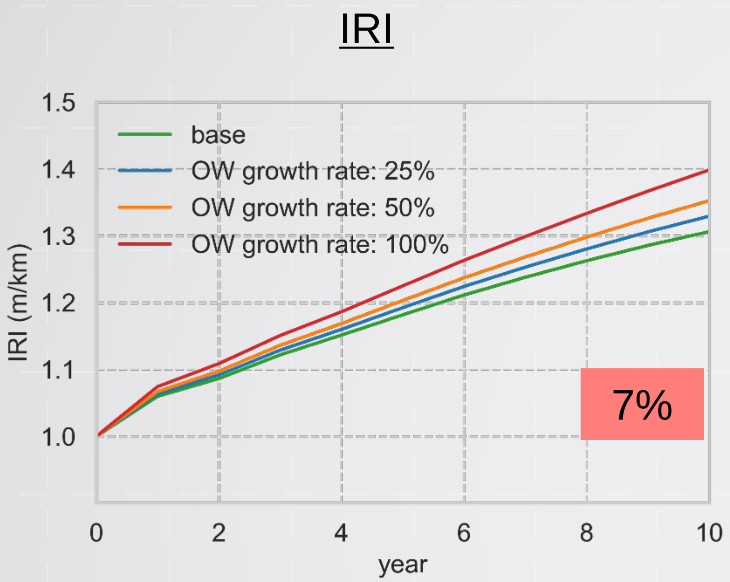
Traffic weights accelerate pavement deterioration rates

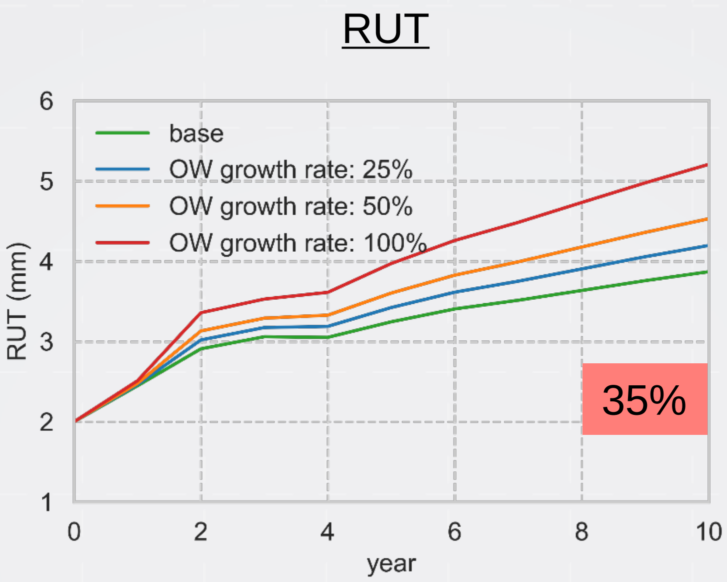


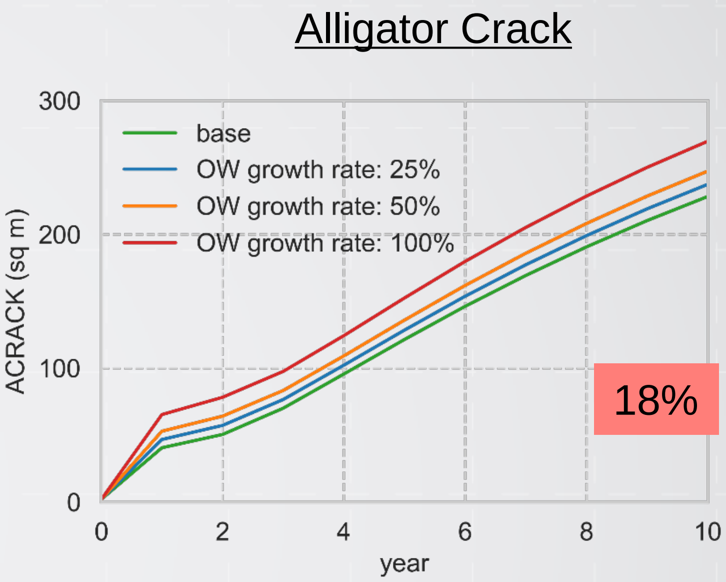
IRI deterioration rates

- With the increase of overweight vehicle ratio, IRI deterioration rates increases.
- When the overweight vehicle ratio doubles, the IRI deterioration rate increases by 7%.

Traffic weights accelerate pavement deterioration rates







Impacts of traffic weights

- With the increase of traffic weight, the deterioration rates for three condition metrics increase. Rut has the largest increase rate.
- The difference between rate 50% and base is smaller than the one between rate 50% and rate 100%, implying that the increase of traffic weight could accelerate deterioration rates.

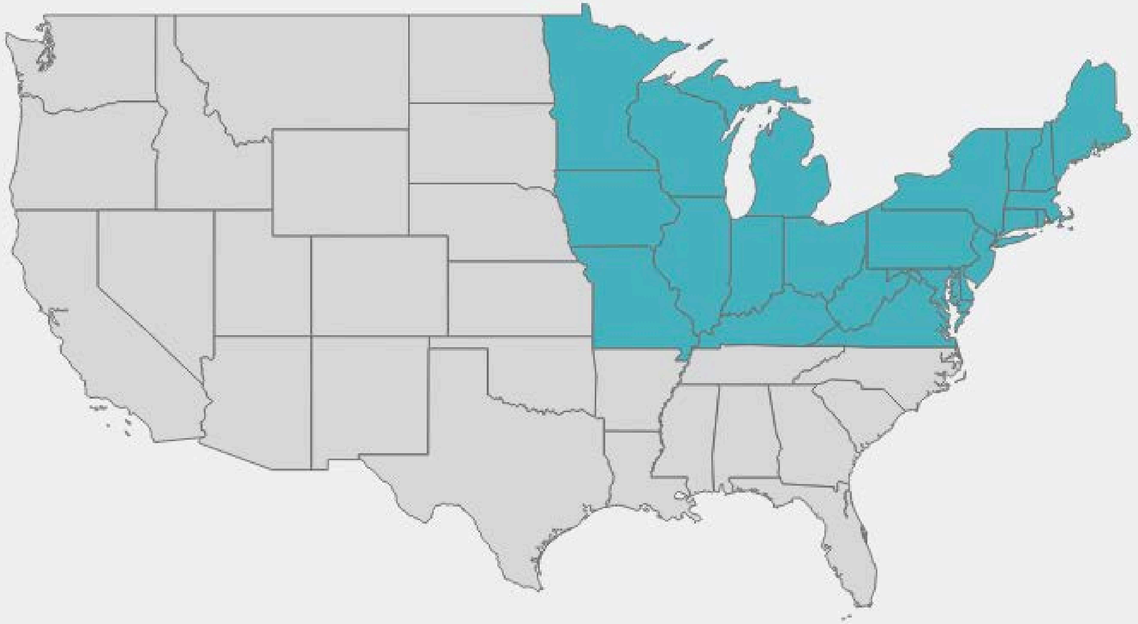
4

Life-cycle Cost Analysis

What’s additional cost caused by overweight vehicles?

Research question:

With the increase of transported traffic weights and overweight vehicles, how much additional life-cycle cost they would bring to current pavement networks?



Wet-Freeze climate zone

Asphalt pavements

- Account for 38% of asphalt pavements in US.
- Account for 34% of all pavements in US.

Pavement performance: IRI

- The sampling for pavement segments is based on FHWA road statistics, which only provides the roughness infomation.

Life-cycle cost analysis

Data preparation → **MRR cost** + **gasoline cost** + **diesel cost** → **Life-cycle cost**

Segment sampling

- FHWA road statistics
- LTPP database

MRR action cost

- Oman data
- Cost projection model

MRR decision

The selection of maintenance is determined by a maintenance decision tree based on IRI.

Fuel cost

- Excess fuel consumption cost is caused by roughness-induced and deflection-induced PVI.
- The growth of EVs is also incorporated.

Equivalent uniform annual cost (EUAC)

EUAC is the annual cost of the project or system equivalent to the discounted total cost or net present cost (NPC).

*PVI: pavement vehicle interaction

Traffic weight scenarios

Growth for overweight vehicle ratio

- The truck class distributions for the baseline scenario are sampled from LTPP database.
- The growth rate for overweight vehicle ratio increases by 25%, 50%, and 100%.

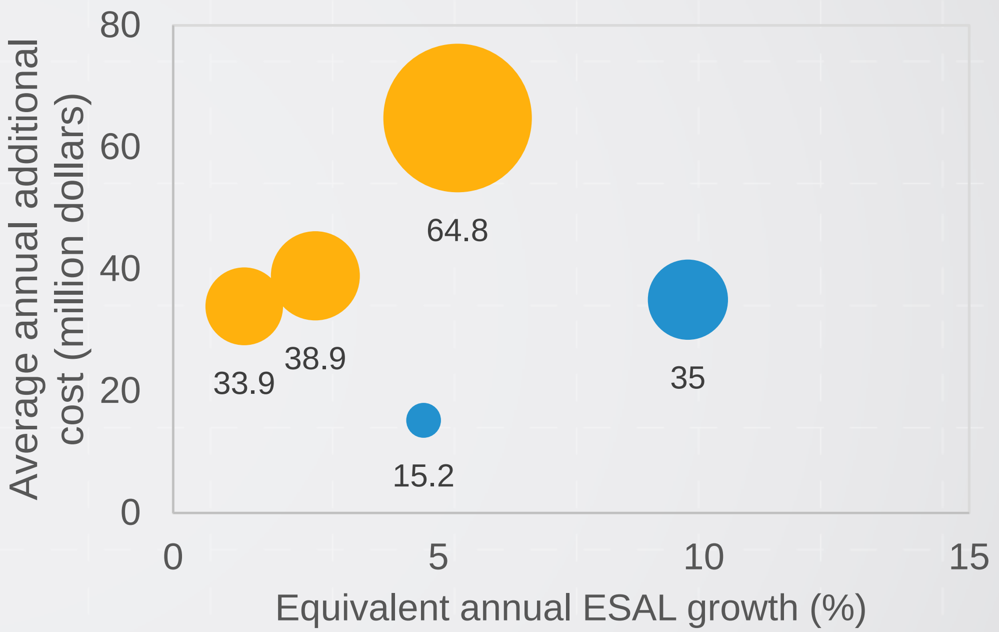
Growth for transported weights by truck

- The ratio for each type of trucks stays the same.
- The weight for each type of trucks increases by 1% and 2% annually.

Additional cost caused by increased traffic weights

Average annual additional cost for all states in Wet-Freeze climate zone (in millions/year)

Growth for overweight vehicle ratio			
scenario	**25%**	**50%**	**100%**
Equivalent ESAL	+1.34%	+2.68%	+5.36%
Growth for transported weight			
scenario	**1%**	**2%**	
Equivalent ESAL	+4.72%	+9.70%	



What we learned

- The growth of traffic weights leads to the increase of life-cycle cost for pavements.
- On average, one more overweight vehicle can bring an additional annual cost of $107.
- The growth of overweight vehicles has a larger impact compared to the growth of transported weights.

THANK YOU

guofd@mit.edu

Today's Panelists

- Larry Wiser, *FHWA*
- Jane Jiang, *FHWA*
- Deborah Walker, *FHWA*
- Fengdi Guo, *Massachusetts Institute of Technology*

#TRBWebinar

Moderator: Bouzid Choubane, *Florida Department of Transportation*

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