Improving pavement sustainability through integrated design, construction, management, LCA and LCCA

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ILLINOIS CENTER FOR TRANSPORTATION

Kent Lecture

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Outline

- A little about the University of California Pavement Research Center
- Changing system boundaries for pavement problems and solutions
- Vision for general approach to solve pavement problems
  - Review of approach and applications
- Examples of some recent applications
  - Calibration of mechanistic-empirical design with pavement management system models
  - Long life asphalt pavement using mechanistic-empirical design with performance related specifications
  - Assessment of change in pavement damage from electric vehicle implementation
  - Prioritization of policies for reducing greenhouse gas emissions
- The forgotten pavements
- Summary

Who and What is the University of California Pavement Research Center?

- Mission
  - *Research, development and implementation of economically and environmentally sustainable, equitably distributed, multi-functional pavement systems*
- Who we are
  - 2 campuses (Davis, Berkeley), materials laboratories, 2 Heavy Vehicle Simulators
  - 8 Professional Researchers
  - 8 Research and development engineers
  - 13 graduate students
  - 6 Technical and admin support staff
  - Partner research organizations
- 3 to 5-year contracts with Caltrans since 1995
  - Full arc: conceptual studies, basic research, development, support and evaluation of implementation, continuous improvement
  - Partnered Pavement Research Center

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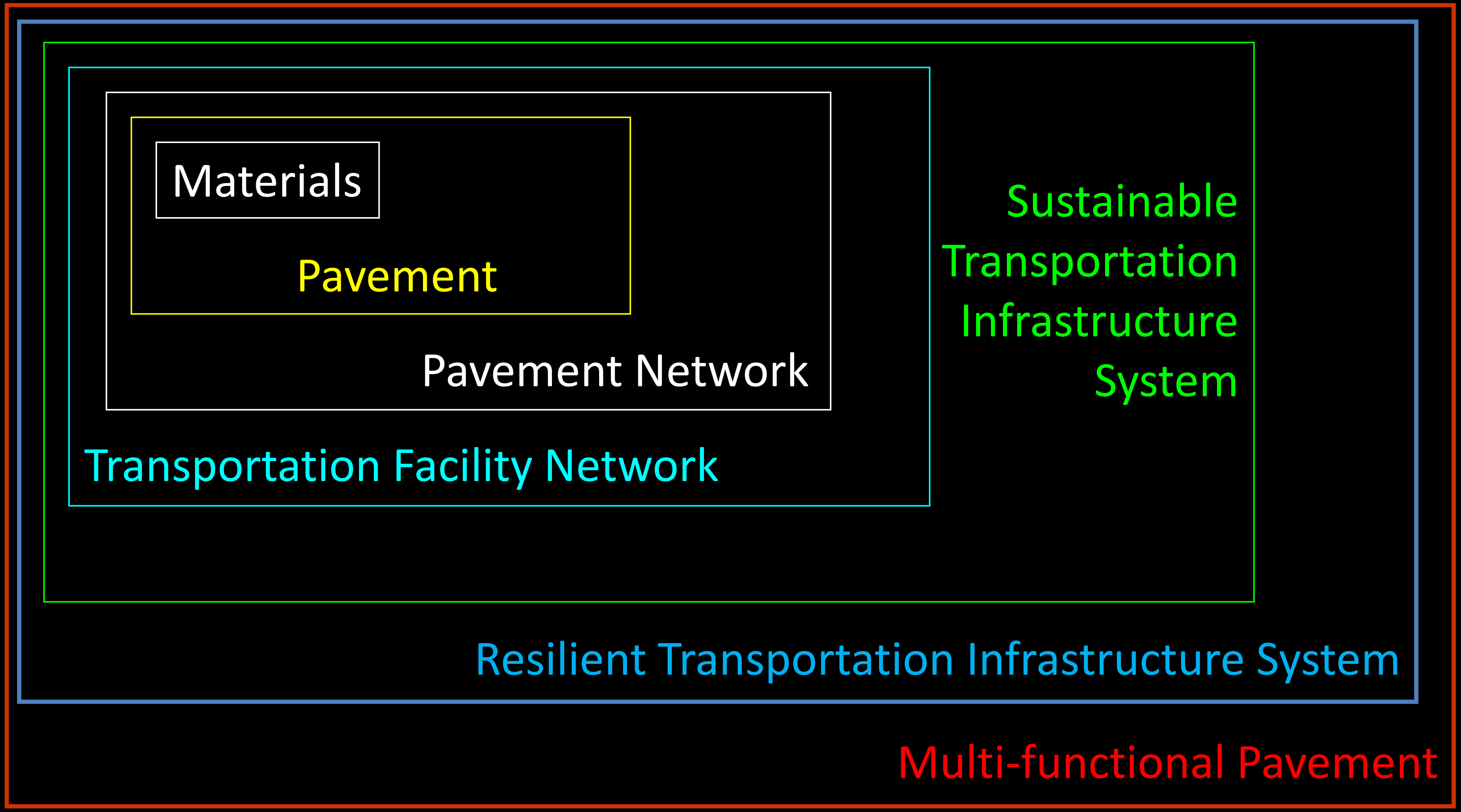
Some Current and Recent UCPRC Areas of Work

- Caltrans (90% of our work) and other work
  - Pavement management
  - Life Cycle Cost Analysis (LCCA)
  - Mechanistic-Empirical design methods
    - Long life rehabilitation, concrete and asphalt
  - Environmental Life Cycle Assessment (LCA)
  - New materials
  - Performance related specifications and construction quality
  - Rehabilitation construction productivity and work zone traffic
  - Recycling (asphalt, concrete, asphalt rubber, in-place recycling)
    - Existing pavement materials, other waste, forest and agriculture biomass feedstocks
  - Multi-functional pavement and quality of life
    - Permeable for stormwater quality, flood control
    - Pavement for thermal conditions (heat island, human thermal comfort) and noise
- Other partners
  - FHWA, Calrecycle, National Center for Sustainable Transportation, FAA, Air Resources Board, state and national pavement industries, legislature, agencies, universities, NGOs

Changing System Boundaries for Pavement Thinking over Last 80 Years



Period Start	Infrastructure Focus	Research	Implementation Examples
1948-1985	Deployment	Materials, empirical and then mechanistic-empirical structural design	AASHTO design methods (1965-1993)
1960s-ongoing	Deployment, rehabilitation	Integration of materials, mechanics, performance	Shell, Asphalt Institute PCA methods (1970-80s), MEPDG (2006), CalME (aimed at rehabilitation 2010)
1975-ongoing	Network asset management	Condition assessment, resource allocation, scheduling of M&R	Pavement management system (California 1978), automated condition assessment 2000-2010
1978-ongoing	Materials recycling, use of alternative materials	Materials properties and energy considerations	Use of Reclaimed Asphalt Pavement (RAP), tire rubber recycling, supplementary cementitious materials (SCM)
1995-ongoing	Reconstruction under traffic	Integration of traffic handling, construction productivity, fast materials, materials handling, demand reduction	Northridge earthquake (1994), southern California freeways (2000s), Utah Olympics (2002), Chicago Tollways (2010s)
1970s on	Life cycle cost efficiency	Application of economics to pavement type selection (Life Cycle Cost Analysis)	RealCost (1998)
1995 - ongoing	Global warming, environmental sustainability	Life Cycle Assessment for pavement, urban metabolism	Palate (1998), Tollway LCA tool (LCA and LCCA, 2017), eLCAP (2020), FHWA tool (2020), CA requirement for CAPs (2010)
2000 - ongoing	Climate resilience	Climate resilience of pavement systems (continuing, events)	Florida Energy and Climate Change Action Plan (2007), Infrastructure and Climate Network (2012)
2000 - ongoing	Multi-functional pavement	Permeable pavement, pavement for active transportation, stormwater quality, flood control, thermal comfort	NRMCA, NAPA, ICPI design guides (2010s), Caltrans permeable pavement design method for heavy vehicles (2016), ASCE standards (2018)

UCPRC Vision Document 2000

- Why written? After 15 years as a pavement researcher, and 5 years working with Caltrans, awareness that large important changes were needed in the Pavement Enterprise
  - History of repeated failures in getting to widespread implementation
  - Outside systems were going to require additional changes
- Prepared in response to question from graduating doctoral student:
  - “you talk about a lot of stuff, but I don’t see how it all fits together, why don’t you write it down?”
- Plan to try and not repeat mistakes of the past
  - Path forward to get research into practice
  - Create a system for continuous improvement

- Google: ucprc vision document
  - http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2000-10.pdf

J. Harvey, UC-Berkeley Pavement Research Center
December, 2000 v1.1.1

Vision for Caltrans/UC-Berkeley Partnered Pavement Research Center

The vision for the Caltrans/UCB Partnered Pavement Research Center is that Caltrans and other partners will have continuously improving state-of-the-art pavement technology to maximize the level of service to the users of Caltrans pavements, while optimizing expenditures on the pavement infrastructure.

Mission for Partnered Pavement Research Program

The mission of the Caltrans/UCB Partnered Pavement Research Center (PPRC) is to perform research, development, advising and training needed to provide Caltrans and other partners with state-of-the-art pavement technology. The technology may be developed by the PPRC, adapted from other sources and verified and calibrated for use in California, developed in partnership with other entities through leveraging with PPRC resources, or gathered directly from other sources, depending upon which method is most efficient.

Time Period and Scope of this Vision

The time period for this vision is approximately the next 10 to 15 years. An attempt has been made to incorporate longer-term trends wherever they can be identified, as well.

UCPRC Vision Document 2000
Observations

- Observations regarding the problem to be solved
  - Decision-making was not driven by data
  - Data were not collected, or were not organized and made available by the data owners
  - Tools to use the data were not available
  - Use of data was not integrated through the project delivery process of planning, design and life cycle cost analysis, construction and traffic management, asset management, and environmental assessment
  - Potential users were not trained in fundamentals to be able to use the tools
  - Researchers were not participating in development and implementation of data and tools, and technology transfer
- Observations regarding how to successfully move from concept to implementation
  - Policy makers, managers, and industry as well as “front line” staff needed to be trained at appropriate levels of detail
  - Support for implementation must be continuous for 5 to 15 years to complete the arc of implementation
  - Due to high turnover and changing responsibilities must communicate in a few minutes the research/development/implementation arc and where we are on it

Proposed Solution and Advice Received

- Proposed solution in the Vision Document 2000
  - A strategy and tactics for development of integrated Databases and Tools will need to be developed so that they are compatible with each other, and so that they can be upgraded periodically without losing their ability to interact.
  - Requires integration of software, specifications, work-flow processes, information flow, equipment and methods
- Advice
  - Jon Epps (successful academic implementer of research):
    - To be successful in moving from conceptual ideas to successful implementation for every $10 you have, spend $1 on research, $3 on development and $6 on implementation
  - Larry Orcutt (when Director of Caltrans Research):
    - This is more of an IT problem than a pavement problem, and state government is littered with IT failures because people with technical domain knowledge were in charge
    - You must understand how to solve an IT problem to successfully implement your research; data ownership is distributed within the organization

TECHNOLOGY

California is the world's tech capital, but state computers are failing residents

If California can't get government tech right, who can?

By DEBRA KAHN | 08/22/2020 11:08 AM EDT

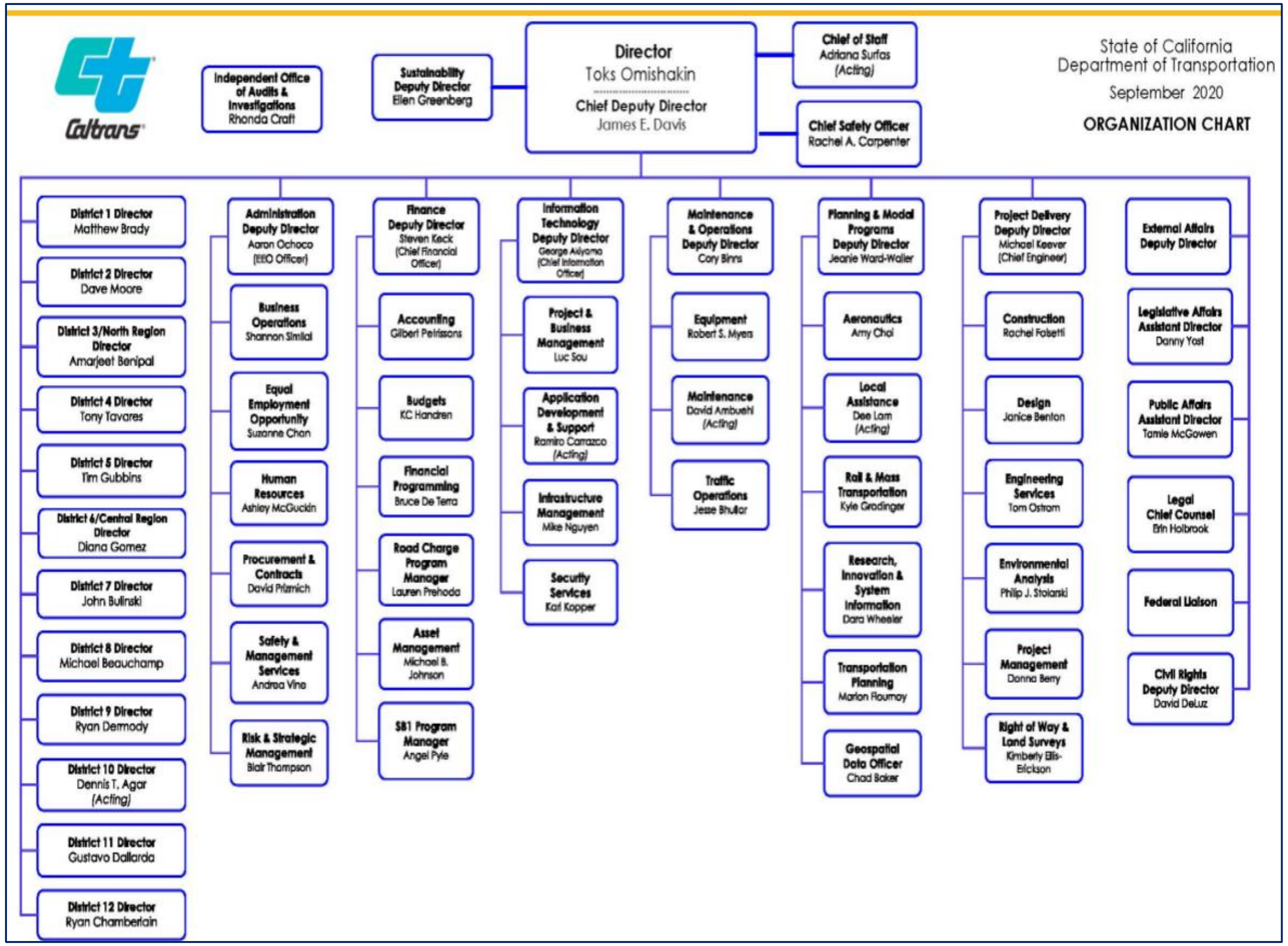
Share on Facebook Share on Twitter

SAN FRANCISCO — California is the preeminent incubator of technology, home to Silicon Valley tech giants and a robust startup culture that draws expertise and finance from all over the world.

https://www.politico.com/states/california/story/2020/08/22/california-is-the-worlds-tech-capital-but-state-computers-are-failing-residents-1309732

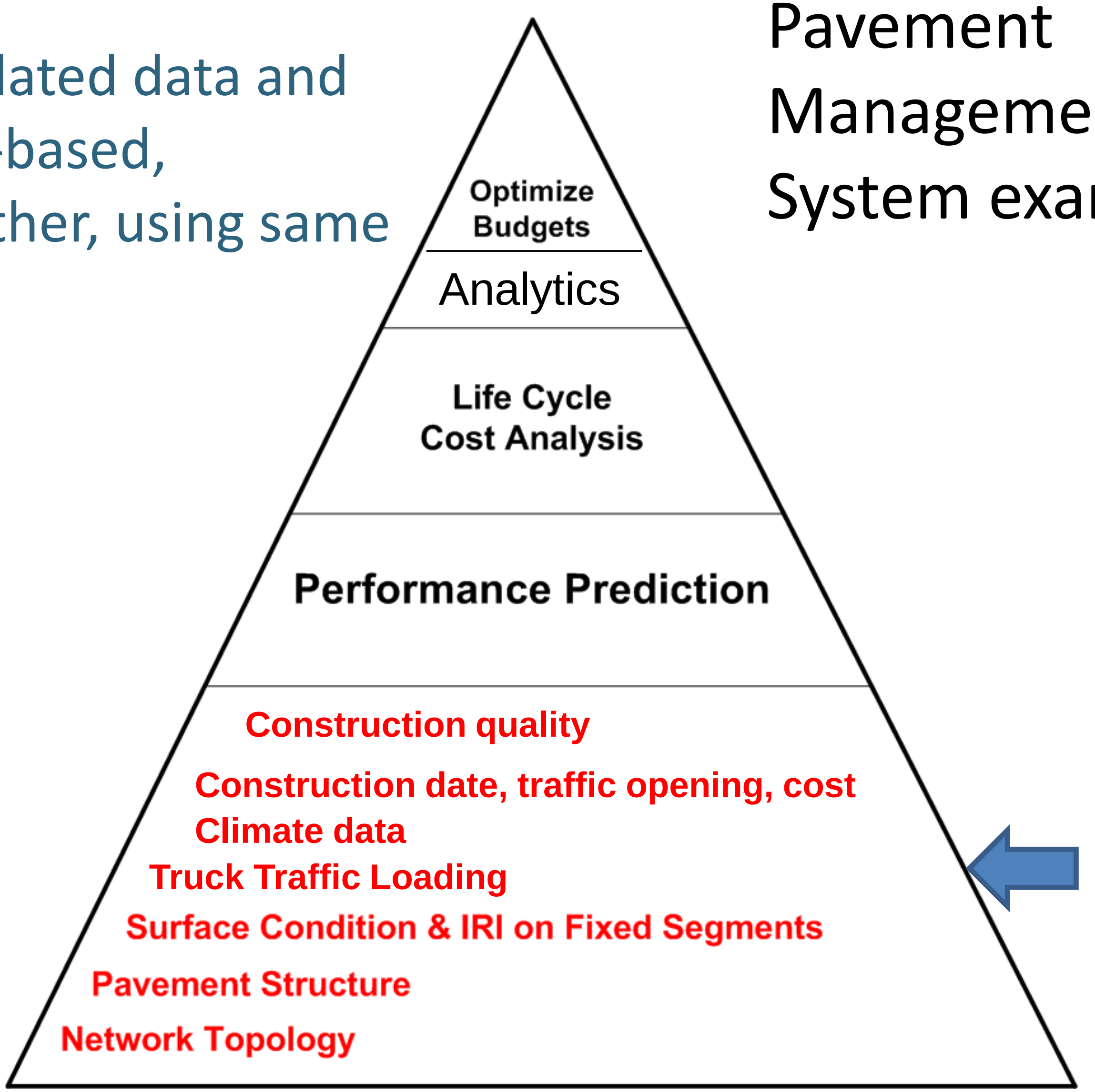
Questions Researchers Don't Like to Answer

- Researchers and champions must concisely answer these questions to middle and then upper management to move implementation forward:
  - Is this a solution for an agency problem, or a researcher's solution looking for a problem to solve?
  - How much will it save Caltrans?
    - Explain it on a life cycle basis
  - Quantify how much will this improve the environment (especially GHG)?
  - What is your confidence level that this will work?
  - Where are we in the process towards implementation?
  - What are the risks of implementation and how will they be addressed?



Information Technology and Pavement

- Pavement tools need updated data and models, make them web-based, and connected to each other, using same data
  - PMS
  - ME design systems
  - LCCA
  - LCA
- Update information routinely
- Databases first, software after data



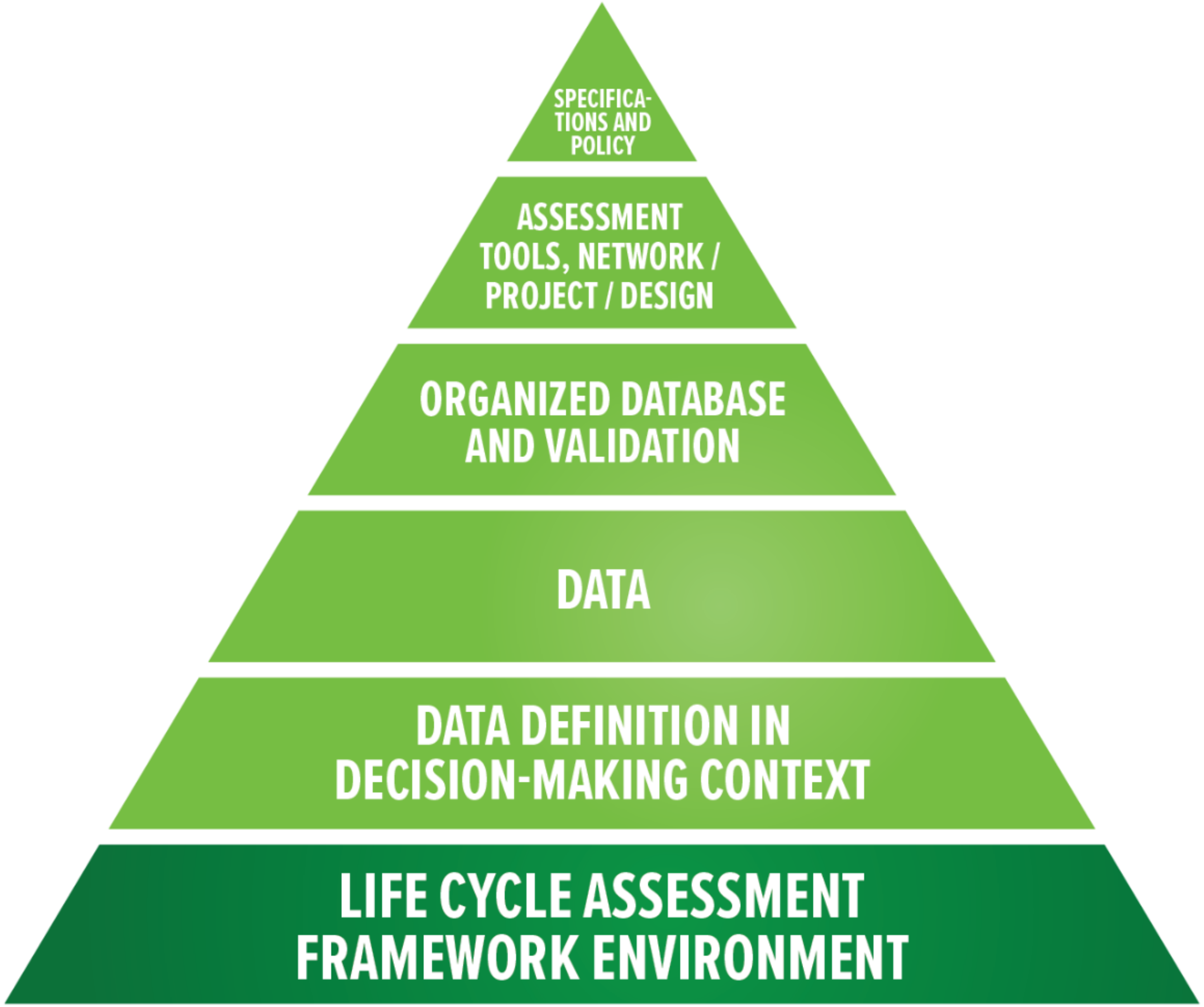
Pavement Management System example

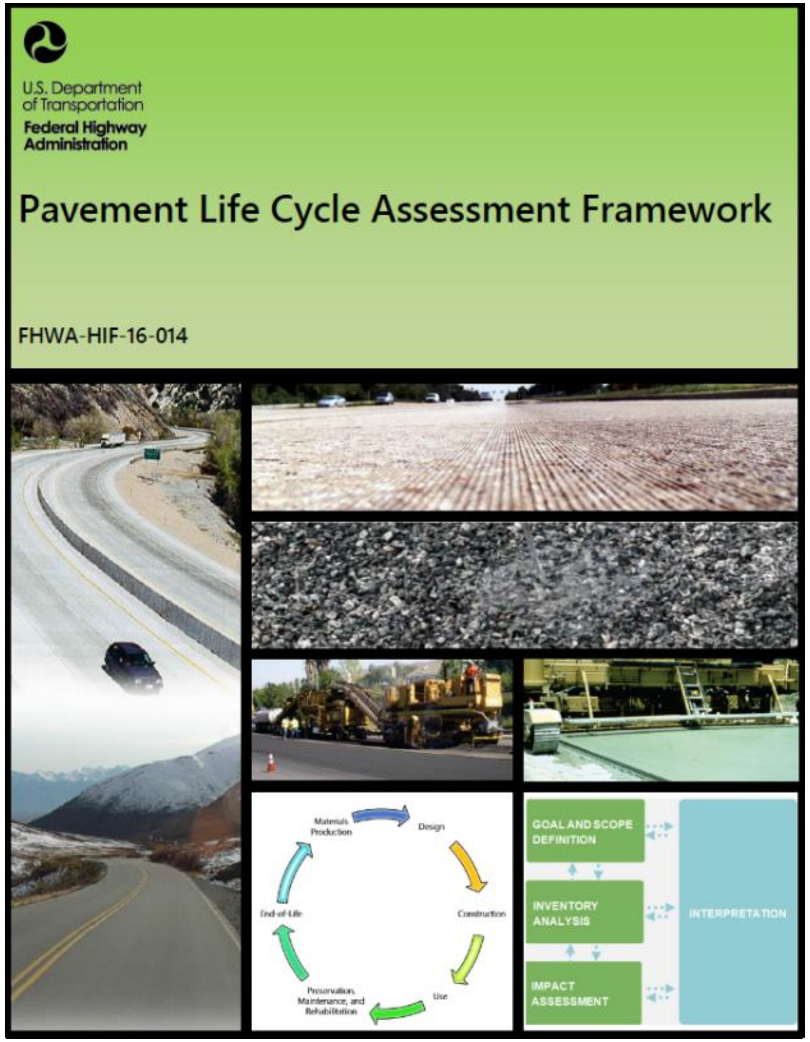
Data

Need strong foundation to perform desired operations

Information Technology and Pavement

- Life Cycle Assessment example
- Common background data definitions currently being developed by federal agency consortium
- Local example of full pyramid:
  - Chicago Tollway LCA





Integration of Data Definitions in Caltrans Pavement Tools

- Tools
  - Pavement asset management tool
  - Materials testing methods
  - Construction materials performance related specifications
  - Pavement design tools
    - Asphalt (Pavement ME)
    - Concrete (CalME)
  - Project life cycle cost analysis tool
  - Project environmental life cycle assessment tool

- Data definitions
  - Materials names and definitions
  - Treatment names and definitions
  - Mechanistic properties of materials
  - Pavement distress definitions
  - Truck type definitions
  - Traffic data definitions
  - Pavement failure definitions (distresses and smoothness) and M&R treatment trigger levels
  - Location reference system

Integration of Models in Caltrans Pavement Tools

- Tools
  - Pavement asset management tool
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  - Pavement design tools
    - Asphalt (Pavement ME)
    - Concrete (CalME)
  - Project life cycle cost analysis tool
  - Project environmental life cycle assessment tool

- Models
  - Empirical performance models (distress and IRI, not pavement condition index)
  - Traffic and truck growth models
  - Mechanistic-empirical damage models
  - Mechanistic-empirical distress models
  - Mechanistic-empirical design reliability approach
  - Cost models
  - Life cycle environmental impact models

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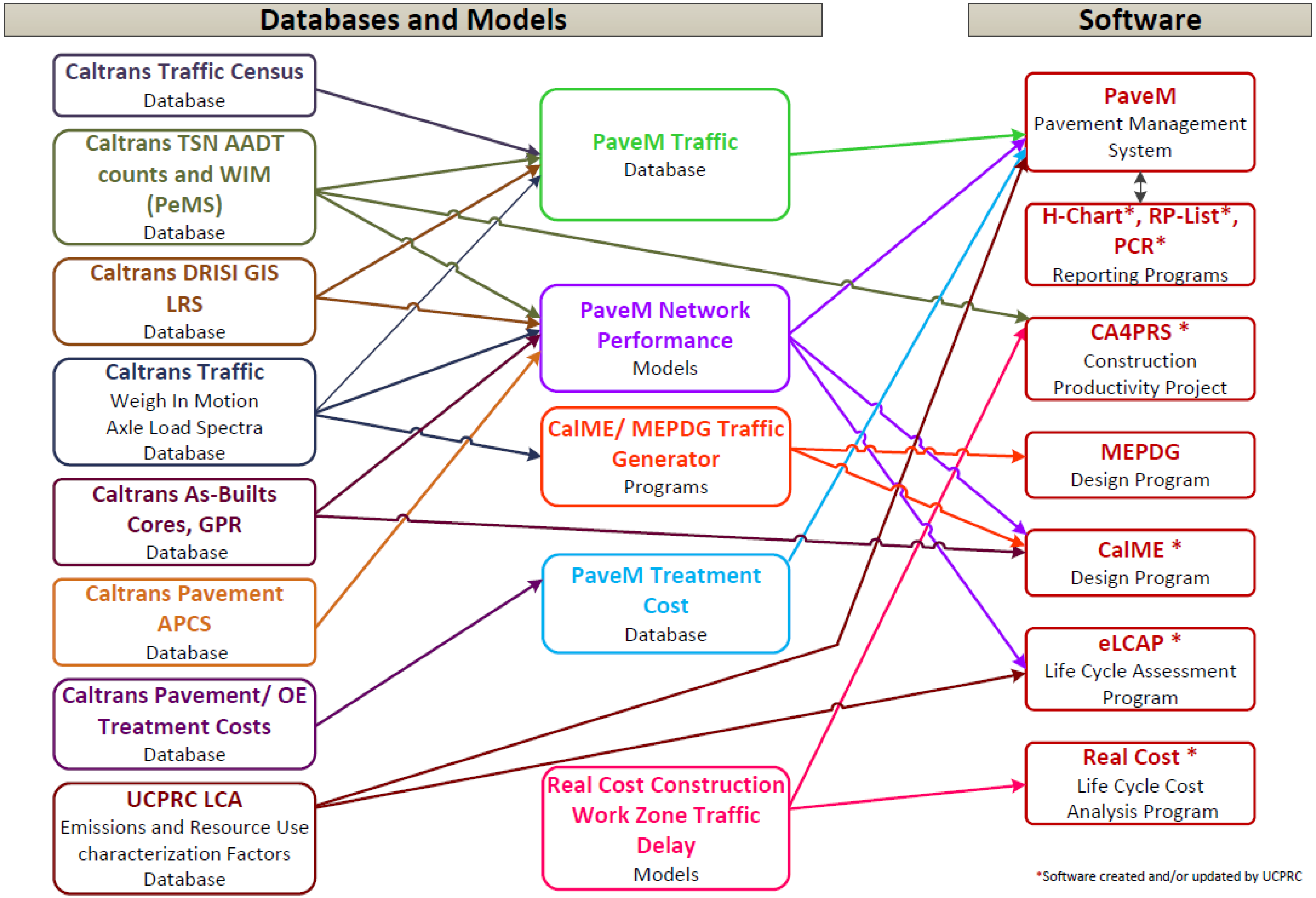
Caltrans Pavement Engineering and Database/Software Interactions

Note different data owners

Used to communicate with upper management and different data owners



*Software created and/or updated by UCPRC

Research arc in detailed road maps for each subject area

Pavement Research Roadmap

Active Transportation

VISION: Use pavement and street systems to help reduce environmental impacts and create economically and socially vibrant public places that promote personal mobility, healthy choices and safe communities

CONCEPT

SCOPE: Interaction of pavement design and street design on active transportation (non-motorized)

- Add literature and concepts developed by others using the Complete Streets (CS) study and other literature that are not covered in CS

RESEARCH

- 4.47/4.57 Surface treatments for bicycle ride quality
- NCST LCA framework for Complete Streets
- Case studies for Complete Streets
- Models for quantifying consequences of changes in street design on miles traveled, congestion, and motorized-vehicle emissions
- Further improvements of indicators (social, environmental, health, safety, economic)
- Expand the LCA framework for CS to nonmotorized oriented street design
- Incorporate improved models for CS and related street design strategies
- Improve design and selection of surfaces for Active Transportation
- Life cycle cost approach for Complete Streets
- Pavement performance models for Active Transportation
- New pavement types with reduced environmental impact, faster construction, improved performance, and lower life cycle cost

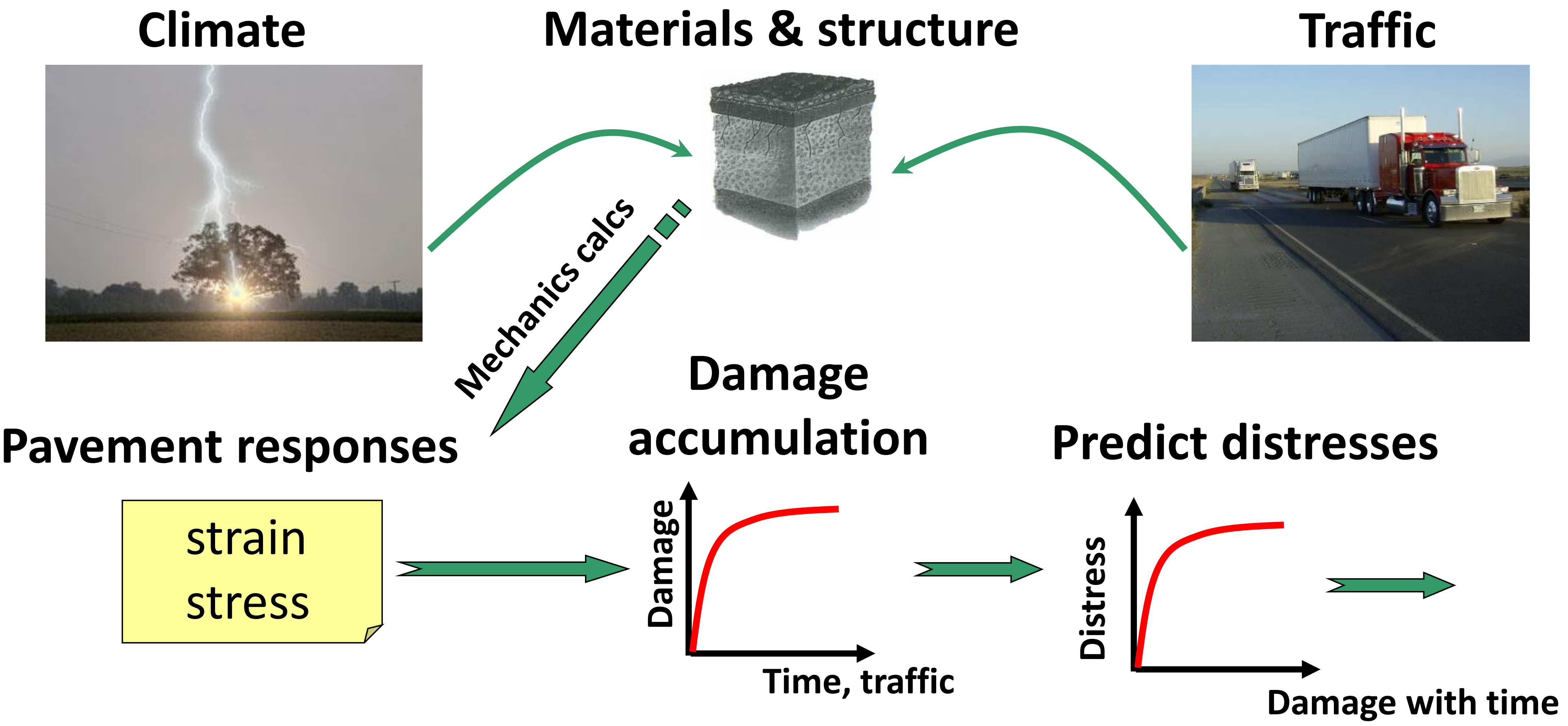
DEVELOPMENT

- Guidance and tools for LCA of Complete Streets
- Selection and design guidance and tools for Complete Streets for rural and urban functions and contexts
- Simple tests for lab and field for texture, albedo (thermal comfort), durability, friction, etc.
- Design and maintenance guidance to reduce costs, improve performance and reduce environmental impacts of active transportation routes

IMPLEMENTATION

- Training for selection and design of Complete Streets and nonvehicle oriented streets

ME Simulation Process

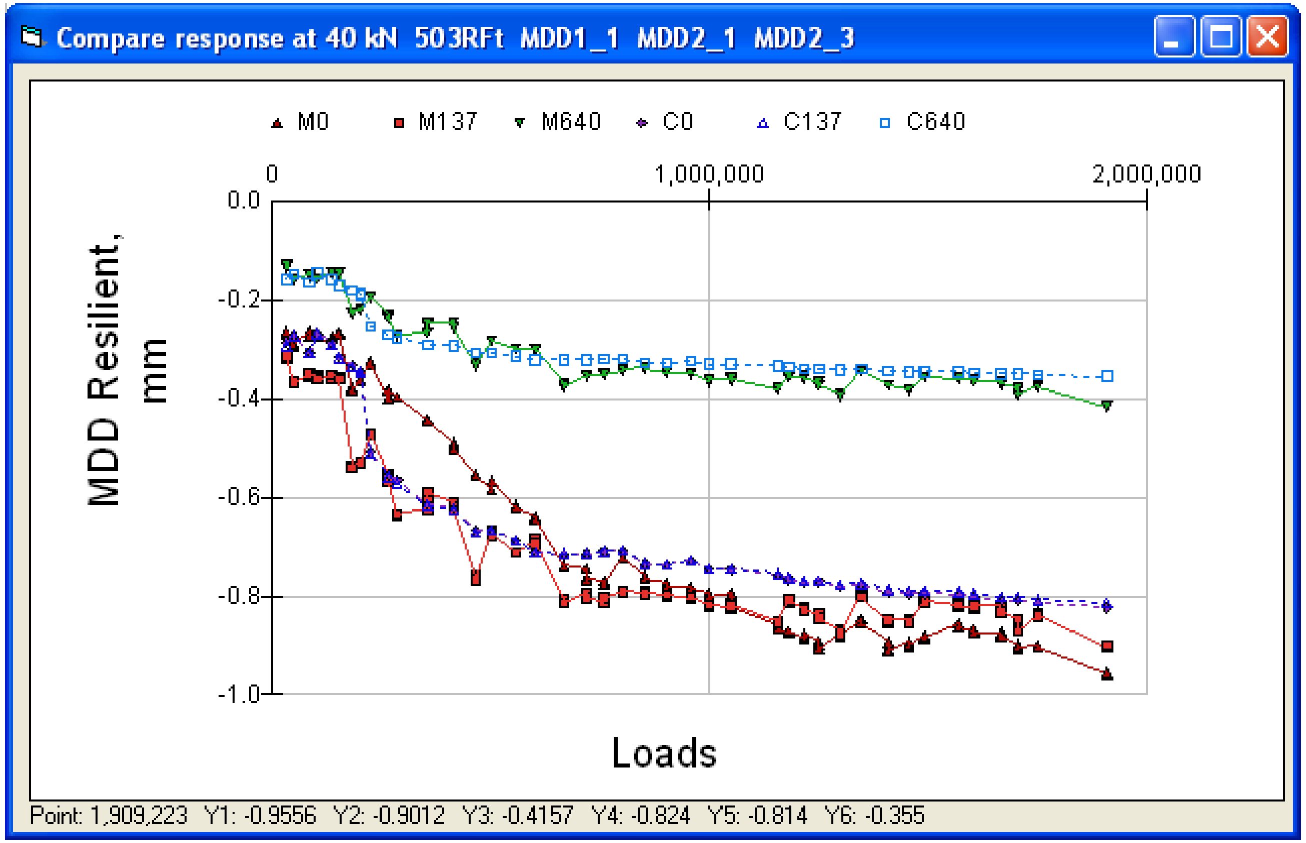


Simulated simultaneously for each distress

Adapted from Imad Basheer, Caltrans

CalME is an Incremental-Recursive Simulation Program

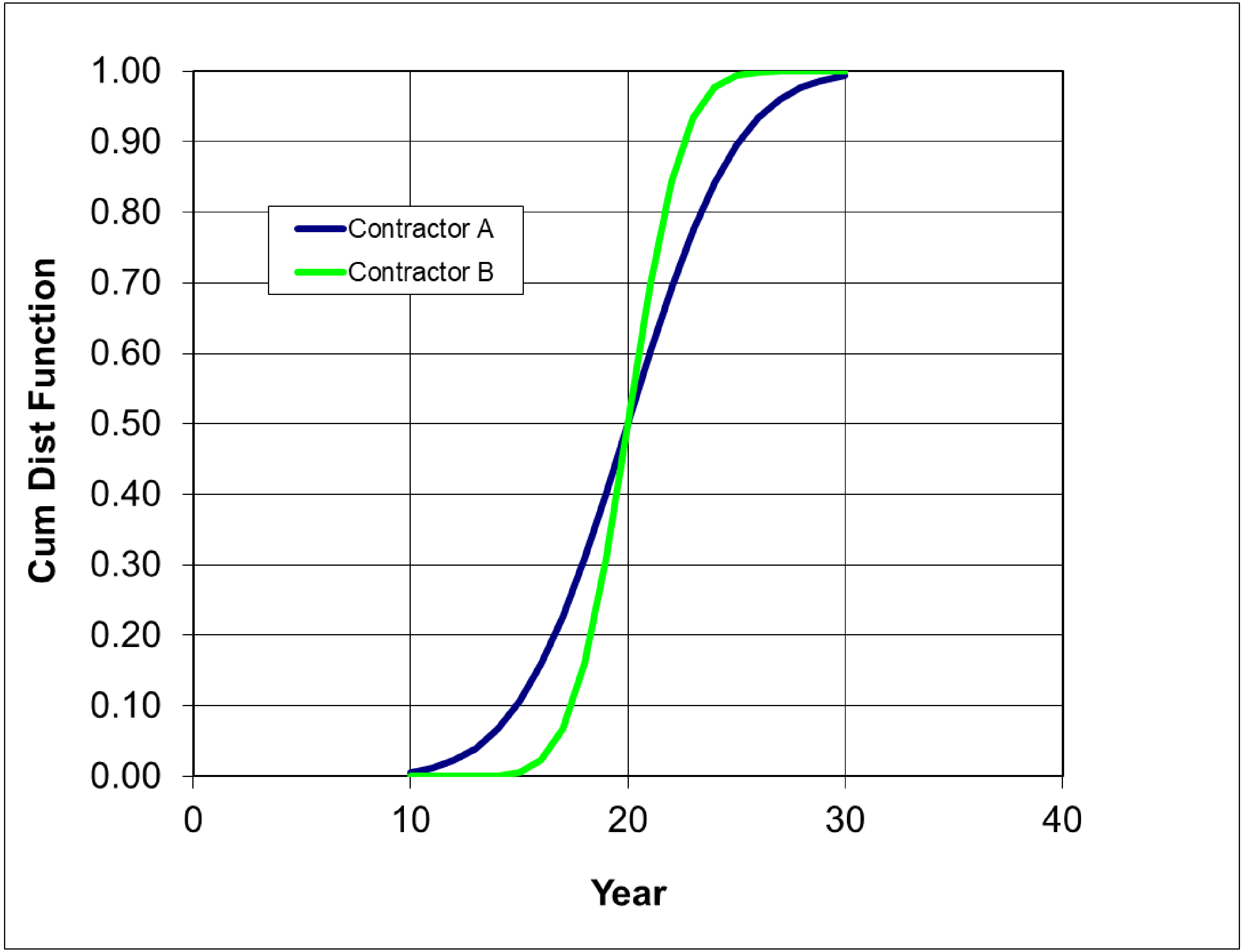
- Incremental-recursive
  - Characterize material damage process for different strain/stress levels
  - Simulate damage process in each time increment of entire life
    - Update stiffness after each increment
  - Correlation of damage to distress
  - Calibrate using data from entire damage process, not just the final “end point” of failure
  - Calibrate:
    1. Responses are calculated correctly through entire life considering damage process
    2. Damage from responses with distresses
  - Responses and damage initially calibrated using Heavy Vehicle Simulator sections
  - Damage vs cracking and rutting distresses calibrated using Westrack and other tracks



Goals of ME Calibration

- Data based design:
  - Simulations that match Caltrans pavement performance
  - Simulate the "truth" of pavement performance as best possible
- Data based reliability:
  - Probability that pavement won't fail before intended service life
  - Reliability based on observed variability on Caltrans network
  - Account for measured variability on the Caltrans network with appropriate reliability

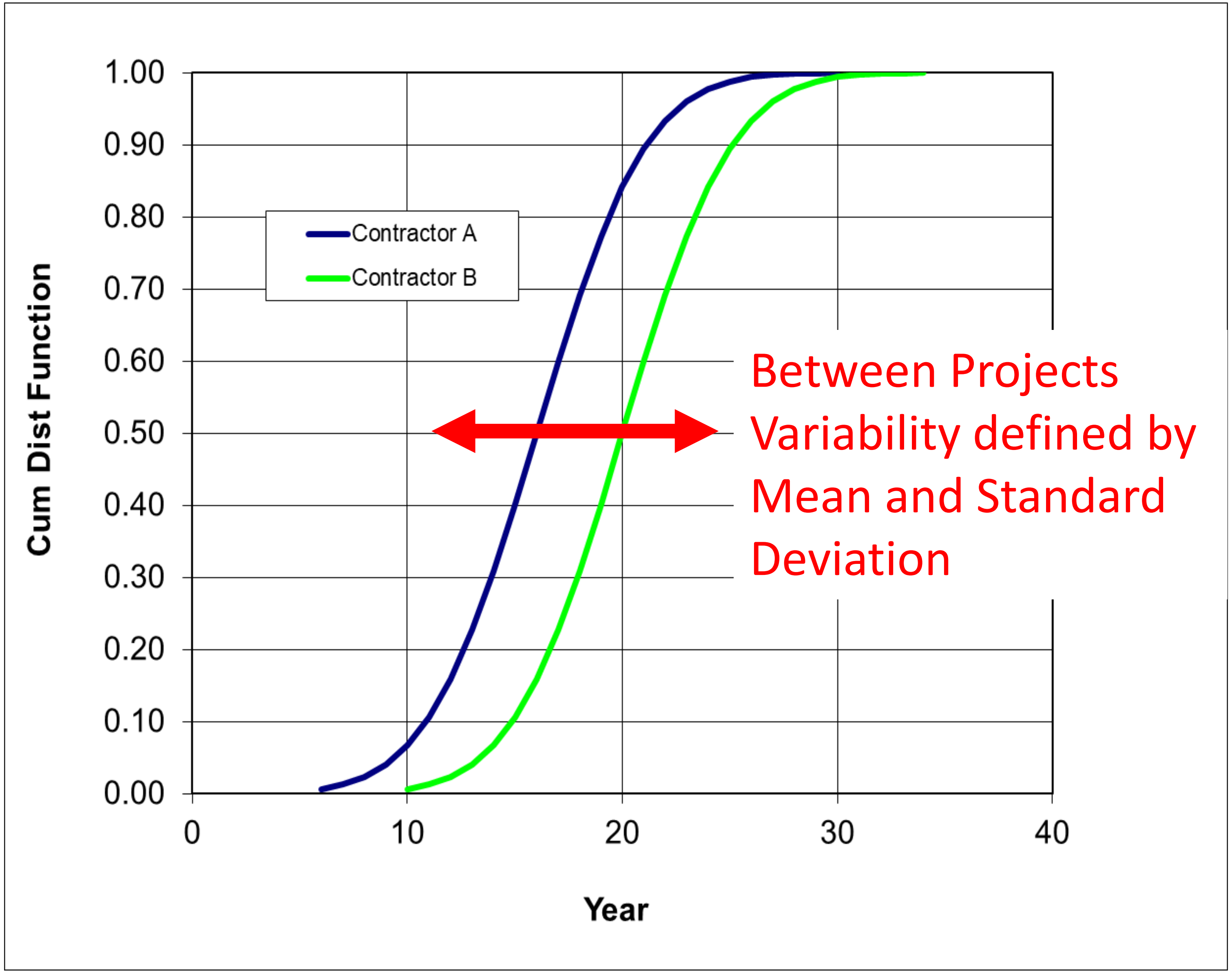
Within project variability



Within project variability = for a given contractor and material, the variability of the materials production and construction process within the project

- Calibrate CalME to match cracking within projects for same pavement structure, traffic, climate
- Within Projects Variability used with Monte Carlo Simulation to provide 95% Within Projects Reliability

Between Projects Variability



Between project variability = variability of low bid contractor material appearing on the job; designer does not know properties of material that will show up

- Calibrate CalME to match mean cracking between projects for same pavement structure, traffic, climate
- Variability of time/traffic to 50% cracking from PMS data used for 95% Between Projects Reliability shift factor

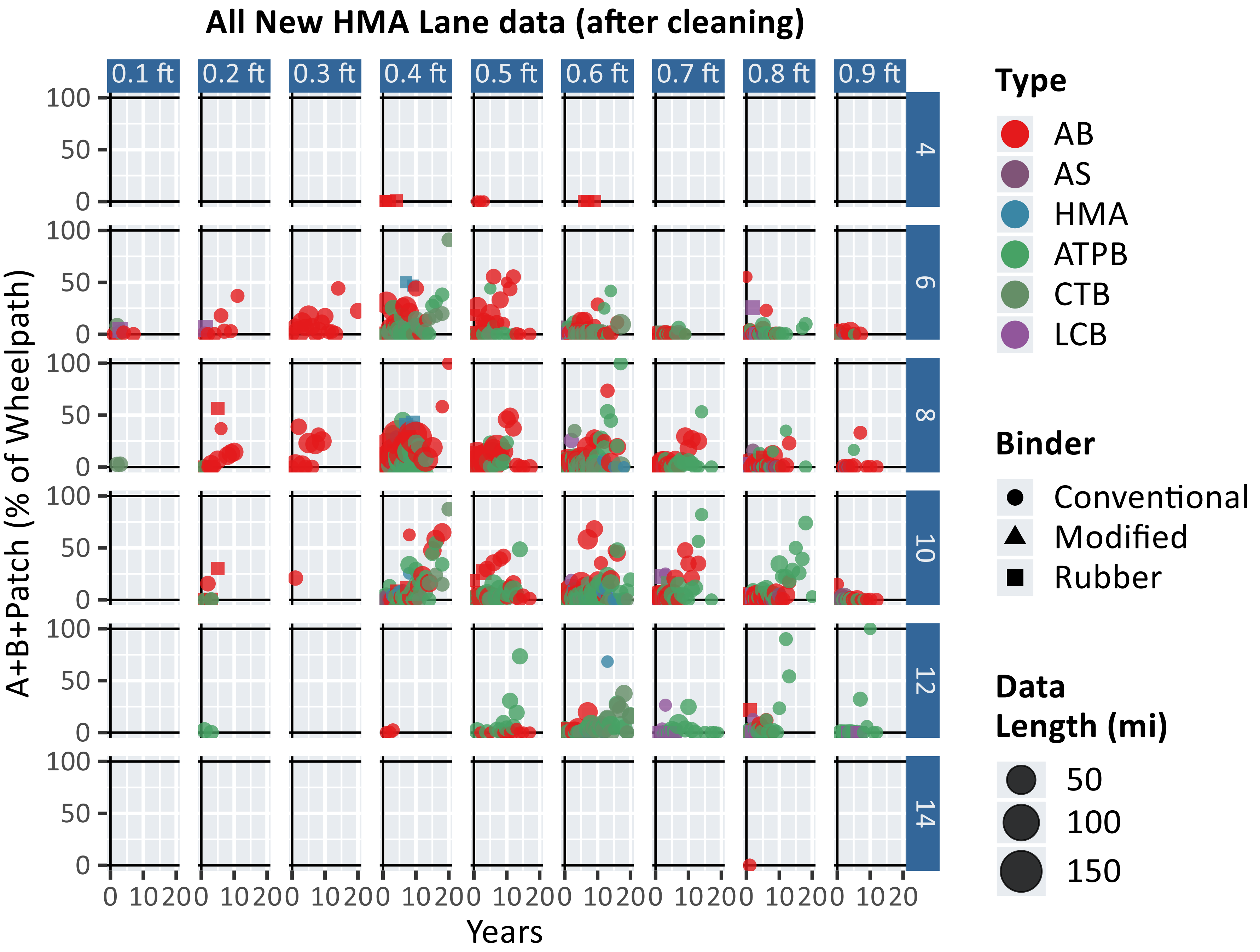
CalME v3 Calibration of Damage to Distress Transfer Functions with PMS Condition Survey Data

- Conventional approach to ME design calibration
  - Materials properties sampled on selected test sections, damage simulated for those sections, damage to distress transfer functions calibrated using PMS data for those sections
  - Typically uses about 50 to 200 miles of pavement for calibration
- CalME v3 calibration approach
  - Entire network in Caltrans complete pavement condition survey database since 1978 used for calibration
  - Calibrated for factors that low-bid project designer knows:
    - Traffic
    - Climate
    - Thicknesses
    - Material types
  - Used state-wide median values for factors that low-bid designer doesn't know:
    - ME material properties (stiffness, damage function) for material type
    - Within project variability of thicknesses, stiffnesses, damage functions
  - Same approach and reliability method used for calibration of Pavement ME concrete design method

Pavement management system performance data used for CalME v3 calibration

- Time periods for calibration PMS data:
  - 1978-2000 about 1/3 of observations
  - 2000-2018 about 2/3 of observations
- Used typical materials for these periods for calibration:
  - Hveem mix designs
  - Pre- and post-QC/QA air-voids
  - From UCPRC materials library

Pavement Type	Observations	Lane-miles
New asphalt pavement: aggregate base	8,530	1,021
New asphalt pavement: other base types	3,292	403
Asphalt overlays on asphalt	147,837	19,634
Asphalt overlays on concrete	9,331	1,594



Caltrans PMS fatigue cracking data for HMA thickness, TI traffic, base type, HMA type
Also considered climate region

Within Project HMA Layer Thickness Variability Check

- Pavement thicknesses from iGPR tool
  - 14 different projects from 2000 to 2010
  - 33 miles total length
- Conclusion:
  - Within project variability values in v2 for use in Monte Carlo are reasonable

Construction Variability Table

Layer	CoV Thick	Sdf Modulus	Sdf PdA	Sdf FtA	Sdf CrA
1	0.07	1.40	0.00	0.00	0.00
2	0.10	1.25	0.00	0.00	0.00
3	0.10	1.20	0.00	0.00	0.00
4	0.00	1.20	0.00	0.00	0.00

Project ID	Length (mi)	HMA Thickness			Project		Base Layer Thickness				Project	
		Average (mm)	Std	CoV (%)	Thickness (mm)	Comments	Material	Average (mm)	Std	CoV (%)	Thickness (mm)	Comments
CAL-4-E-33939-37433(2009)	2.2	198.6	22.7	11.4	152.4	-	-	-	-	-	-	-
CAL-26-E-42530-44344(2005)	1.1	141.5	30.8	21.8	152.4	-	-	-	-	-	-	-
KER-166-E-26443-27014(2010)	1.9	246.0	25.7	10.4	225.6	-	AB	301.3	127.1	42.2	466.3	AB-Class 2
ORA-55-N-20271-20839(2002)	0.3	366.3	12.3	3.3	374.9	(HMA+ATPB)	CTB	84.1	9.5	11.4	149.4	AB-Class 2
ORA-55-N-20839-21317(2002)	0.3	394.3	27.7	7.0	374.9	(HMA+ATPB)	AB	175.2	23.5	13.4	149.4	AB-Class 2
SCL-87-S-2169-6911(2007)	2.5	221.5	20.7	9.4	240.8	(HMA+ATPB)	CTB	186.7	15.5	8.3	137.2	CTB-Class A
SCL-680-S-14162-15884(2010)	1.1	235.6	32.9	13.9	289.6	(HMA+HMA)	CTB	105.3	15.2	14.5	152.4	LTB
SHA-44-E-29010-33326(2007)	2.7	155.5	16.5	10.6	149.4	-	AB	329.0	45.9	13.9	329.2	AB-Class 2
SHA-44-E-43410-45992(2005)	1.6	176.6	27.0	15.3	155.4	-	AB	364.0	39.4	10.8	353.6	AB-Class 2
SHA-89-N-47160-69757(2008)	14.2	136.4	13.3	9.8	152.4	-	AB	187.3	60.5	32.3	213.4	AB-Class 2
SON-12-W-32510-32768(2004)	0.2	170.3	14.9	8.7	249.9	-	CTB	181.6	18.4	10.1	106.7	AS-Class 4
SON-12-W-35343-36067(2010)	0.5	178.5	12.5	7.0	487.7	-	CTB	238.0	18.1	7.6	256.0	AS-Class 3
TRI-299-E-76589-78230(2003)	1.6	223.1	40.8	18.3	179.8	-	-	-	-	-	-	-
TUO-108-E-33648-38233(2007)	2.9	175.2	16.9	9.6	228.6	(HMA+ATPB)	-	-	-	-	-	-
Total length (mi)	**33.0**	**Median CoV (%)**		**10.1**				**Median CoV (%)**		**12.4**		

Within Project HMA Layer Variability Checks

- Similar checks for HMA Stiffness and Damage parameter variability performed using data from UCPRC Materials
  - 35 mixes, including HMA and RHMA-G
- Conclusion:
  - Values in CalME v2 reasonable
  - Some small changes

Mix	FMFC	FMLC	LMLC	FMPC	Total
RHMA-G	3	4	6	1	14
HMA	6	5	10	0	21

3.30.01-SB154-FMFC
3.30.01-SB154-FMPC
4.50-RAC-4.58RHMA
4.50-RAC-GR
4.50-RAC-SYAR
4.50-RAC-SB154
4.63-MER33-FMLC
4.63-INY395-FMLC
4.63-Lak20-FMLC
3.38-BUT162-FMFC
3.38-BUT162Y0-FMLC
CR-GG-Control
CR-GG-GRN10
IMP111-Y0-FMFC

3.30.01-FMFC-Y0-L2-SD76
3.32.02-FMFCb-Y0-NAPA29
3.30.01-SB154-FMLC-A
3.30.01-SB154-FMLC-B
3.30.01-SB154-LMLC-A
3.30.01-SB154-LMLC-B
3.30.01-SBd138-FMFC
3.32.02-FMFCa-Y0-NAPA29
3.32.02-FMFCy0L2-GLE5
3.33-TEH5-15%RAP-Y4
3.33-TEH5-SB-Y4-RB
3.41Aging-Napa290H-FMLC
4.61-MixA
4.61-MixD
4.61-MixJ
3.38-BUT162Y0-FMFC
CR-DG-Control
CR-DG-GRN15
CR-DG-GRN25
CR-DG-HWY15
CR-DG-HWY25

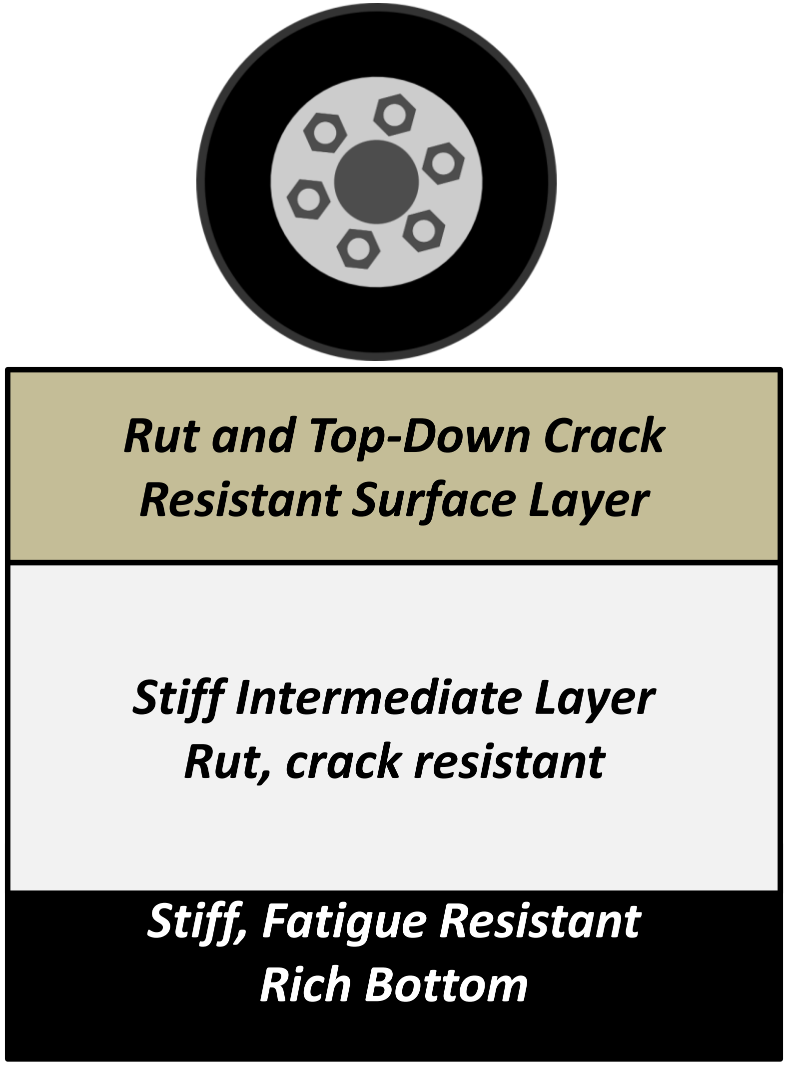
Long life asphalt pavement
mechanistic-empirical design with performance related specifications

- Pavement design goals:
  - 40-year design life for all structural layers
  - Periodic replacement of thin surface layer
- Integration of materials properties, design, construction quality assurance
  - Material properties from locally available materials are tested
  - Results are used to
    - Set performance related specifications (PRS) for use in procurement
    - Set surrogate test properties for construction quality assurance
  - Pavement is designed using CalME with the same properties (stiffness, fatigue, permanent deformation) used for the design
  - Winning low-bid contractor must prove that their job mix formula (JMF) will have the same properties
  - Surrogate tests (faster, cheaper, simpler than PRS tests) used during construction to identify whether mix has changed

Projects to date:
I-710 Long Beach (2002)
I-5 Red Bluff (2011)
I-5 Weed (2011)
I-80 Solano (2013)
I-5 Sacramento (2020)

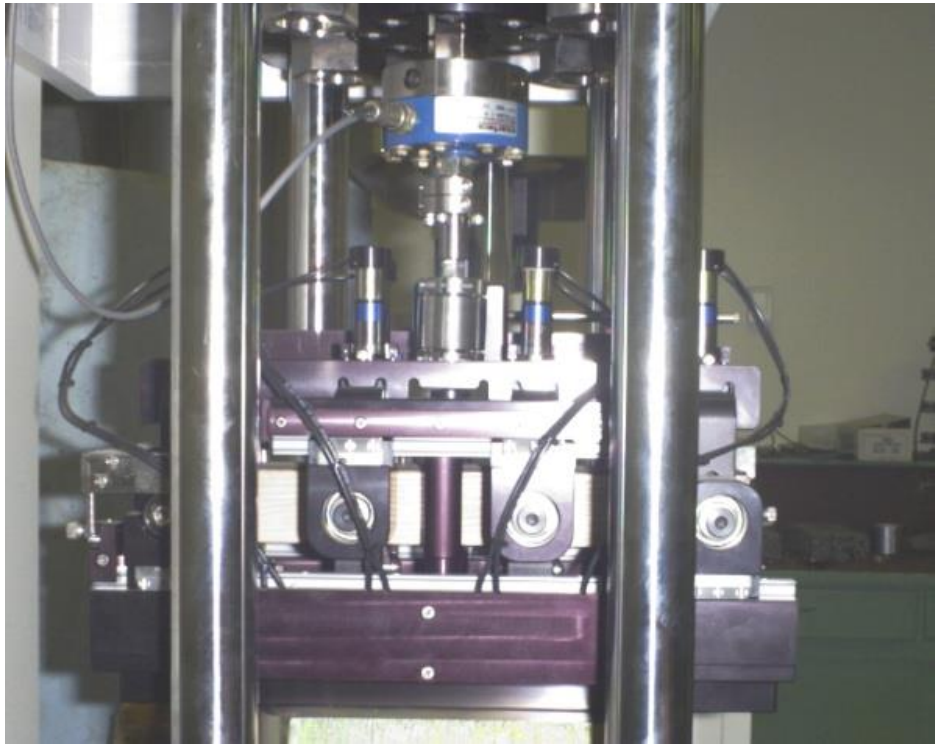
AC Long Life Structural Design

- **Surface Layer**
  - Polymer modified
  - 15% RAP max
  - 6% AV max in place
- **Intermediate Layer**
  - Max 25% RAP
  - 6% AV max in place
- **Rich Bottom Layer**
  - +X% Binder
  - Max 15% RAP
  - 3% AV in place max



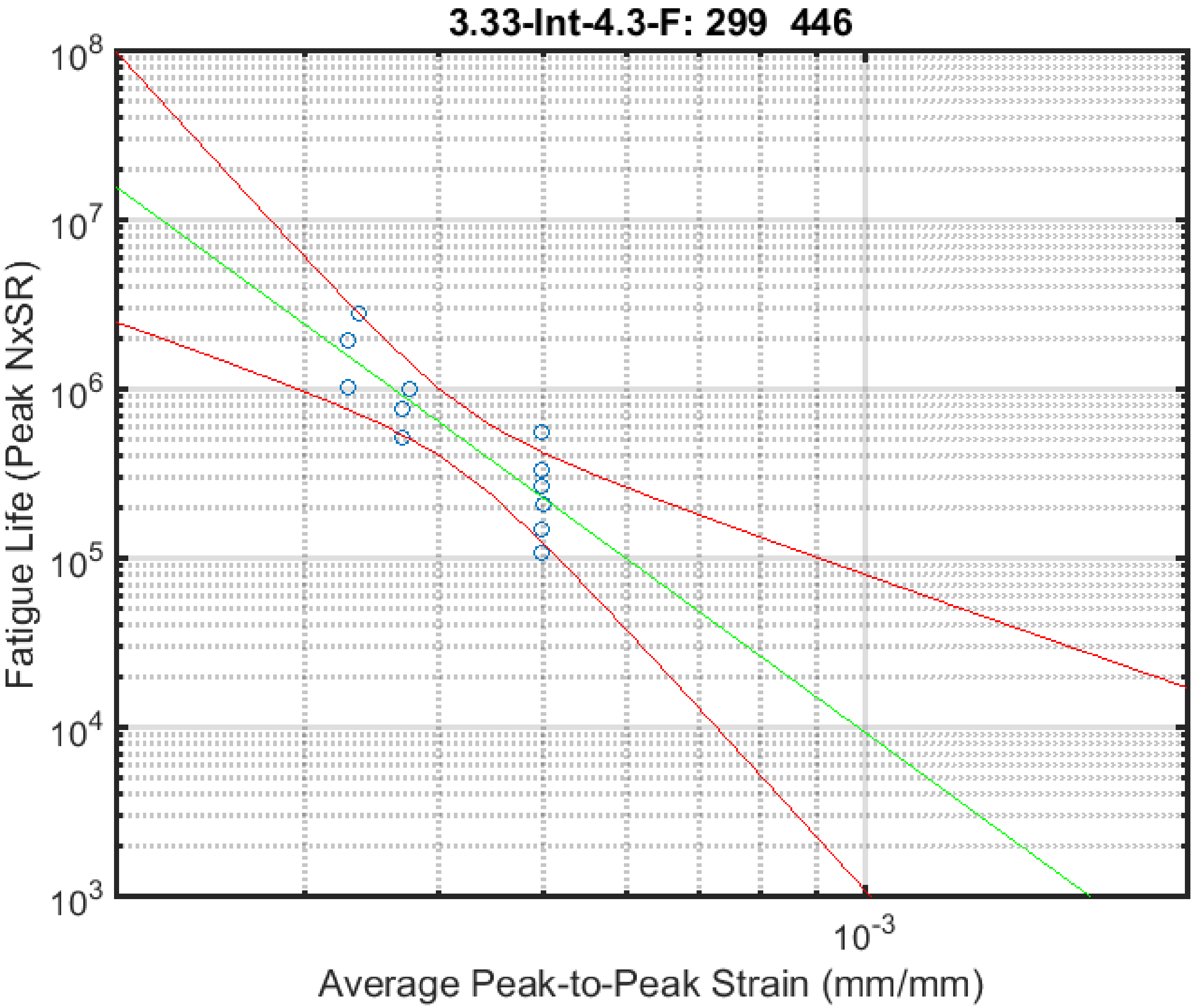
Performance Related Tests for Job Mix Formula

- **Fatigue/Stiffness** (for JMF approval only)
  - T 321, - Beam Flexural Fatigue test
- **Permanent Deformation** (New)
  - T 378, "Flow number test" using AMPT (asphalt mixture performance tester)
  - Using repetitions to permanent axial strain because Flow Number can be hard to pinpoint for California mixes
- **Fracture Energy Potential** (New)
  - TP 124, semi-circular beam (SCB) fracture test
- **Moisture Sensitivity**
  - T 324 Hamburg wheel tracking test (HWTT)
  - T 283 Tensile strength ratio (TSR)



Setting of Baseline Performance Requirements – Flexural Fatigue Life Example

- 95% confidence intervals determined from baseline mix tests
- Contractor average result needs to meet 5% confidence interval
- Intent: take most of testing risk off contractor
- 2-3 weeks to complete specimen preparation and testing
- Most standard volumetric mix design specifications waived to allow innovation

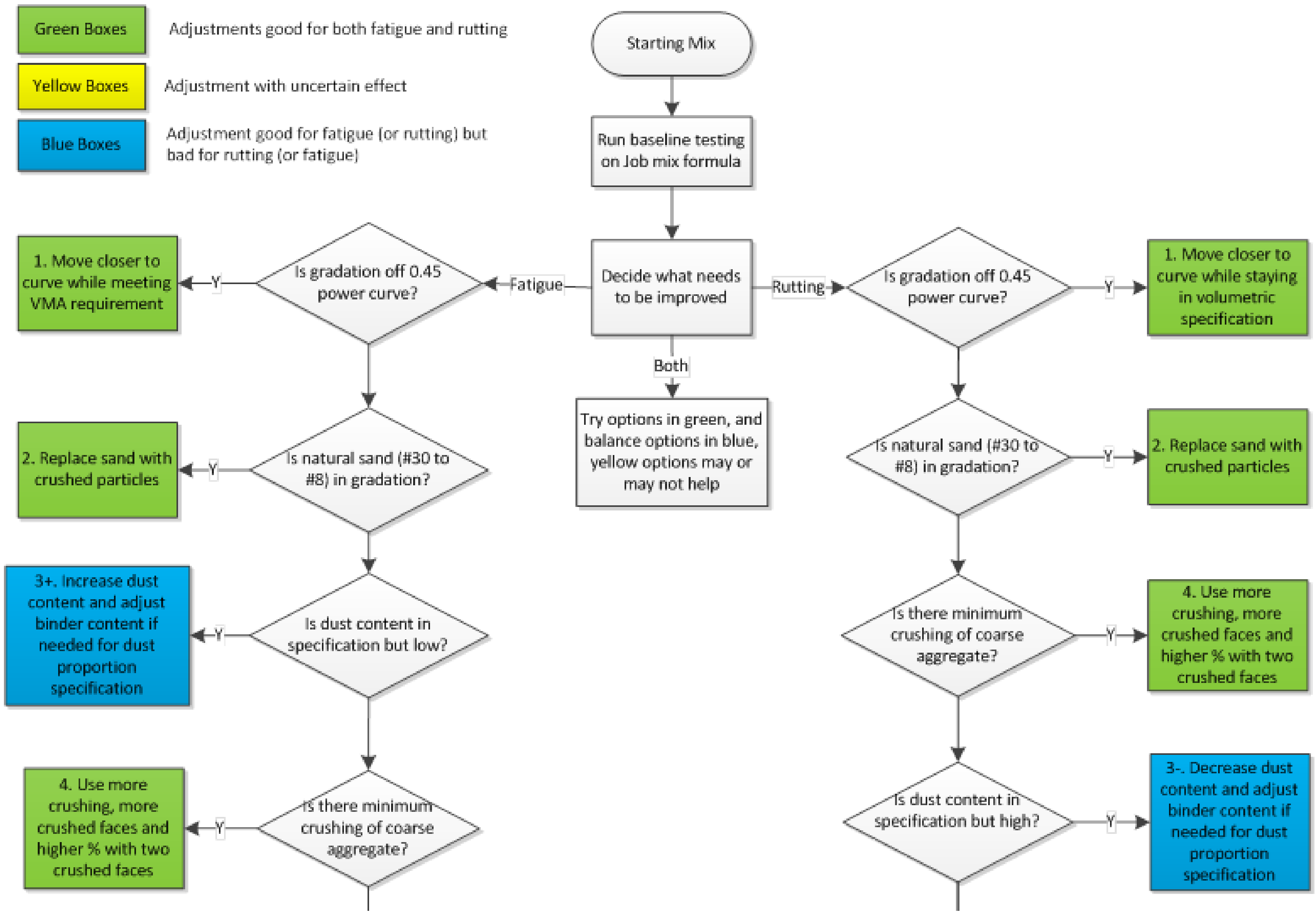


Performance Requirements JMF for Sac-5

HMA-LL Performance Requirements					
			Requirement		
Design parameters	Test method	Sample Air Voids	HMA-LL, Surface	HMA- LL, Intermediate	HMA-LL, Rich Bottom
Permanent deformation: [1,2] **Minimum number of cycles to 3% permanent axial strain**	AASHTO T 378[3]	Mix specific[4]	2,093	4,131	Not Required
Beam stiffness (psi): [2,5] **Minimum stiffness at the 50th cycle at the given testing strain level**	AASHTO T 321 Modified[3]	Mix specific[4]	214,000 at 952×10^{-6} in./in.	789,000 at 446×10^{-6} in./in.	756,000 at 441×10^{-6} in./in.
Beam fatigue: [2,5] **Minimum of 1,000,000 cycles to failure at this strain**	AASHTO T 321 Modified[3]	Mix specific[4]	617×10^{-6} in./in.	299×10^{-6} in./in.	306×10^{-6} in./in.
Minimum of 250,000 cycles to failure at this strain			952×10^{-6} in./in.	446×10^{-6} in./in.	441×10^{-6} in./in.

Mix Design Guidance for Contractors how to meet PRS

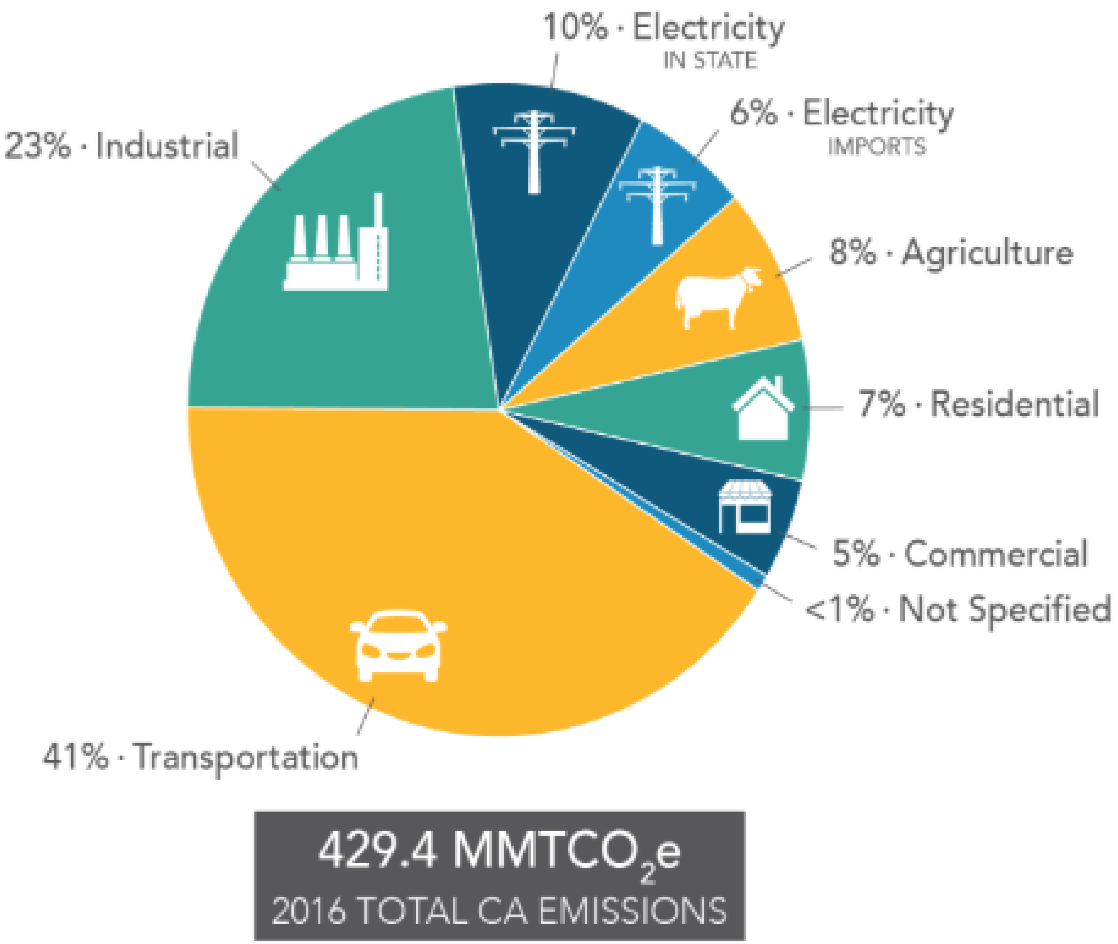
- Mix Design Guidance for Use with Asphalt Concrete Performance-Related Specifications
- http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2017-12.pdf
- Example mix design and guidance on how to improve meet PRS
  - Gradation
  - Aggregate texture
  - Binder content
  - Binder grade
  - Binder supplier



Estimated Potential Pavement-Related Reductions to 2016 California GHG Emissions

Possible Pavement Reductions	MMT/ year
Rolling resist to optimum	1.5 to 3.0
Reduce cement use 50%	0.2
Reduce virgin asphalt use 50%	0.7
Reduce hauling demolition, oil, stone haul 10%	0.6
TOTAL	**3.0 to 4.5**

0.7 to 1.0 % of 429 MMT state total
1.0 to 3.6 % of 126 MMT transportation total



http://www.arb.ca.gov/cc/inventory/data/data.htm

Assessment of change in pavement damage from electric vehicle implementation

- Study for the legislature to evaluate expected effects of conversion to alternative fuel trucks 2020-2050
- Question:
  - How much additional pavement cost and GHG emissions will heavier than ICE powertrains on alternative fuel trucks cause if axle load limits increase 0.1 tons?
  - How much is net +/– in GHG emissions?
- Scenarios:
  - Fast, medium, slow conversion to electric and fuel
  - State and local networks
  - Combined ME simulation of asphalt and concrete, cost analysis, life cycle assessment
- BTW California also has the worst air pollution in the country (even when we are not on fire), highest levels of asthmatic children

Capitol Alert

Gavin Newsom signs order banning sales of gas-powered cars in California by 2035

BY LARA KORTE AND SOPHIA BOLLAG

SEPTEMBER 23, 2020 10:32 AM , UPDATED SEPTEMBER 24, 2020 01:46 PM

California Governor Gavin Newsom issued an executive order on Sept. 23, 2020 requiring the sale of all new passenger vehicles to be zero-emission by 2035. BY CALIFORNIA GOVERNOR

Results
(under review)

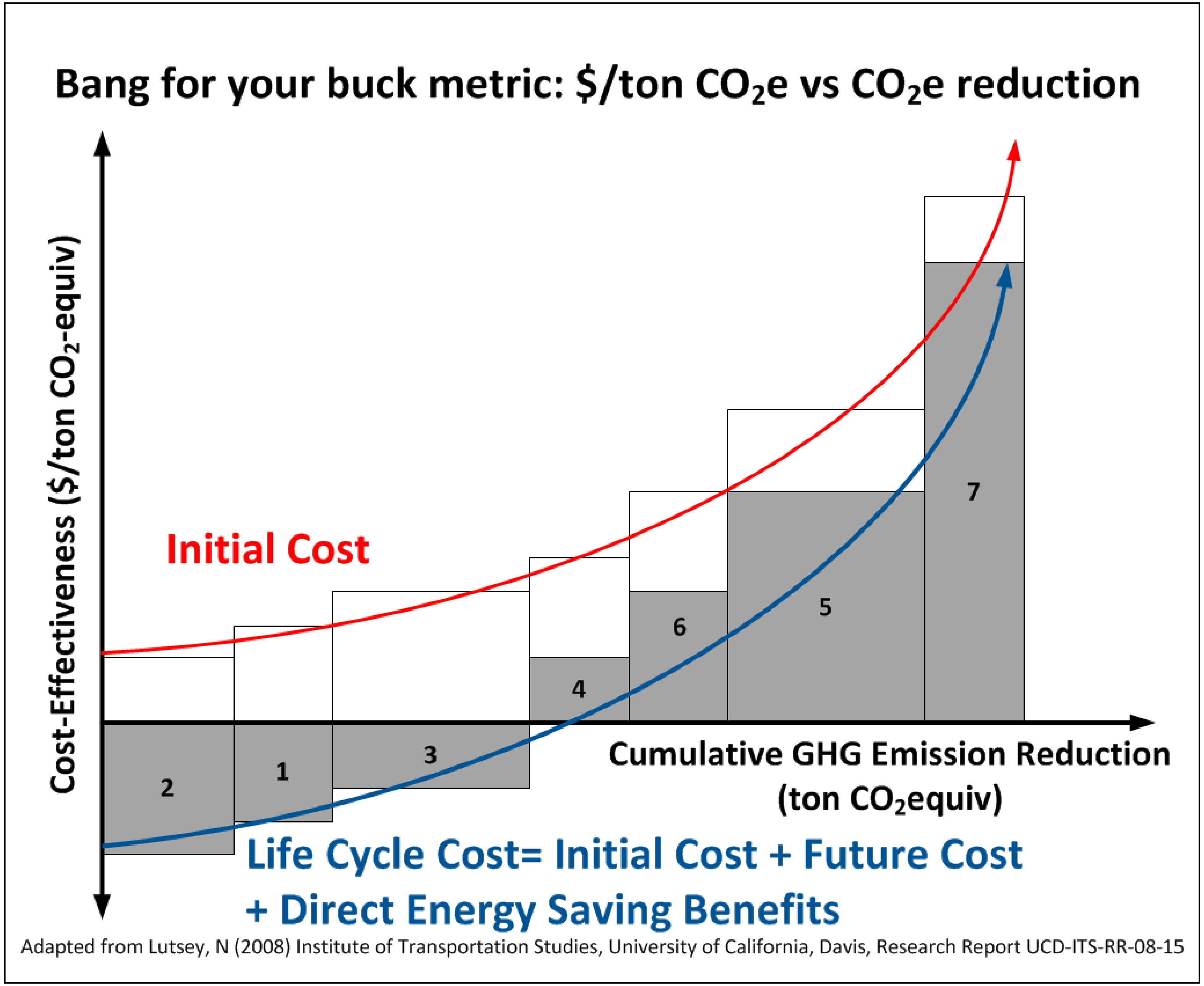
- Introducing heavier alternative fuel trucks, as allowed by AB 2061, is expected to result in only minimal additional damage to local- and state-government-owned pavements
- The cost of additional pavement damage from alternative fuel trucks will be negligible
  - The estimated annual cost increase for pavement damage is between zero and $21 million for the state highway network, and between zero and $33 million for the local roads network
- Projected greenhouse gas emissions reductions from alternative fuel truck adoption will far outweigh emissions from additional road maintenance
  - Study's least aggressive market penetration scenario yielded a net reduction in life-cycle, or well-to-wheel, annual truck emissions of about 6.3 million tons by 2050
  - Most aggressive scenario yielded a net annual reduction of 34 million tons—nearly 20 percent of California's entire transportation sector emissions in 2016

How Does State Government Currently Select More Sustainable Practices?

- Goals set by legislation and regulation
- Agencies develop strategies based on information from:
  - Lobbyists
  - Consultants
  - Universities
- Additional state legislation proposed for specifics of different industries, new technologies
  - Sometimes good science, sometimes not so good
  - Often driven by non-governmental organizations (NGO)
  - Industry tries to shape to capability and interests
- How to prioritize many ideas is a major problem for California legislature, California Air Resources Board, Caltrans and local agencies

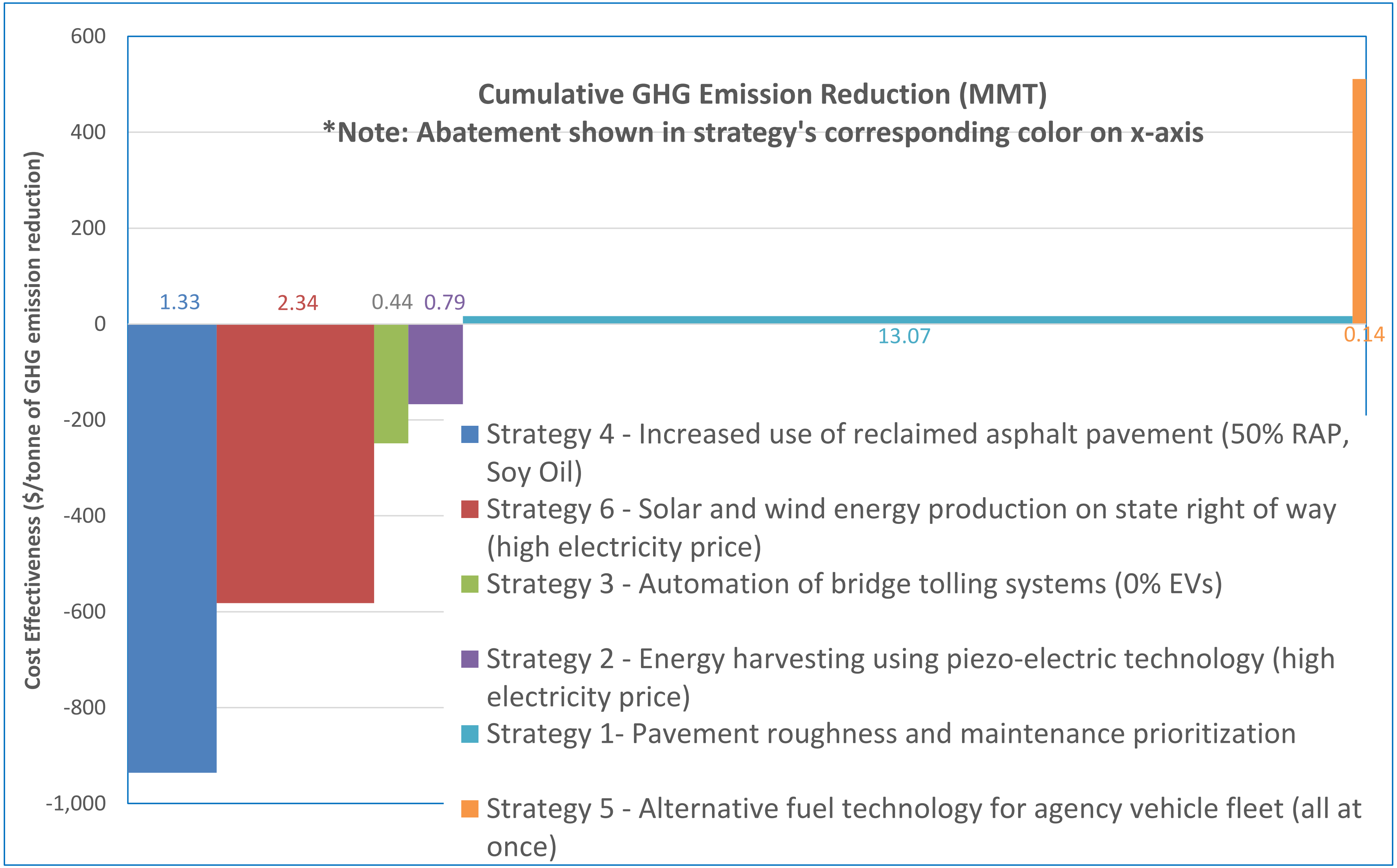
Sergeant.assembly.ca.gov

- Need first-order analysis to prioritize which ideas to further investigate
- "Supply curve"
- Pilot projects at UCPRC, NCST
  - Caltrans changes to internal operations
  - Local government review of climate action plans

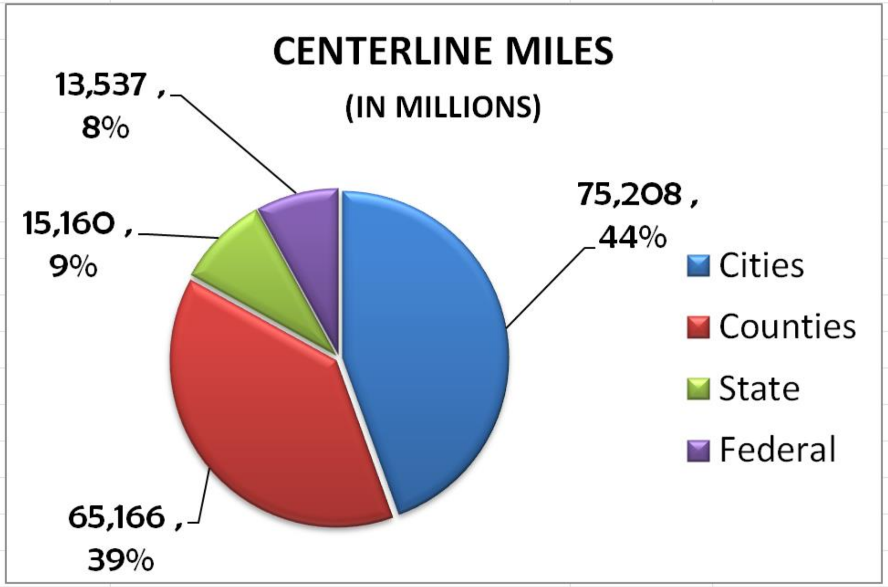


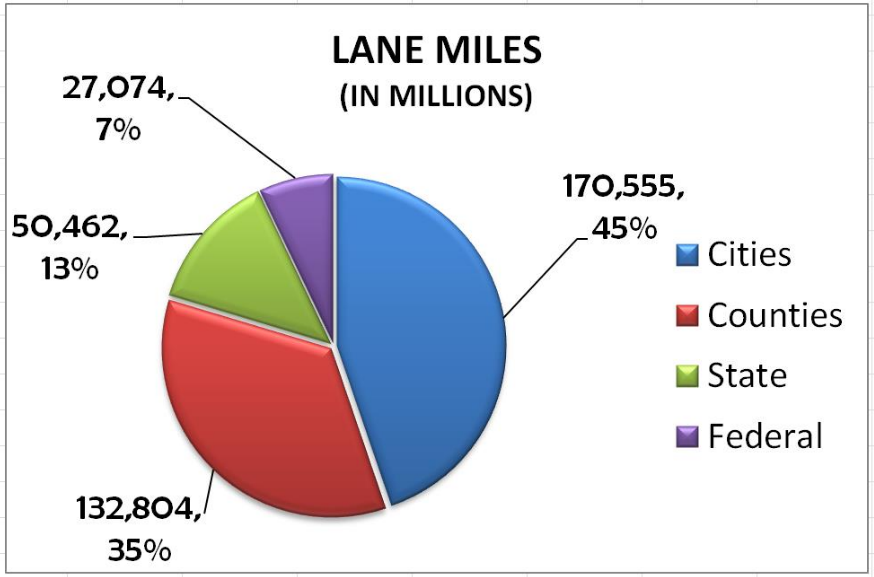
http://www.ucprc.ucdavis.edu/PDF/UCPRC-WH-2019-01.pdf

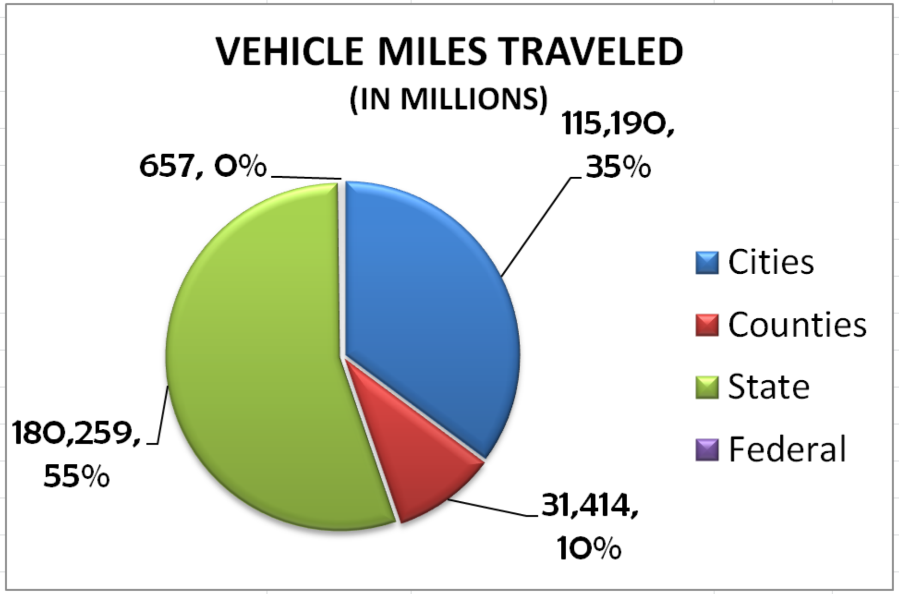
Example Supply Curve Output



The Forgotten 80% of Our Pavements



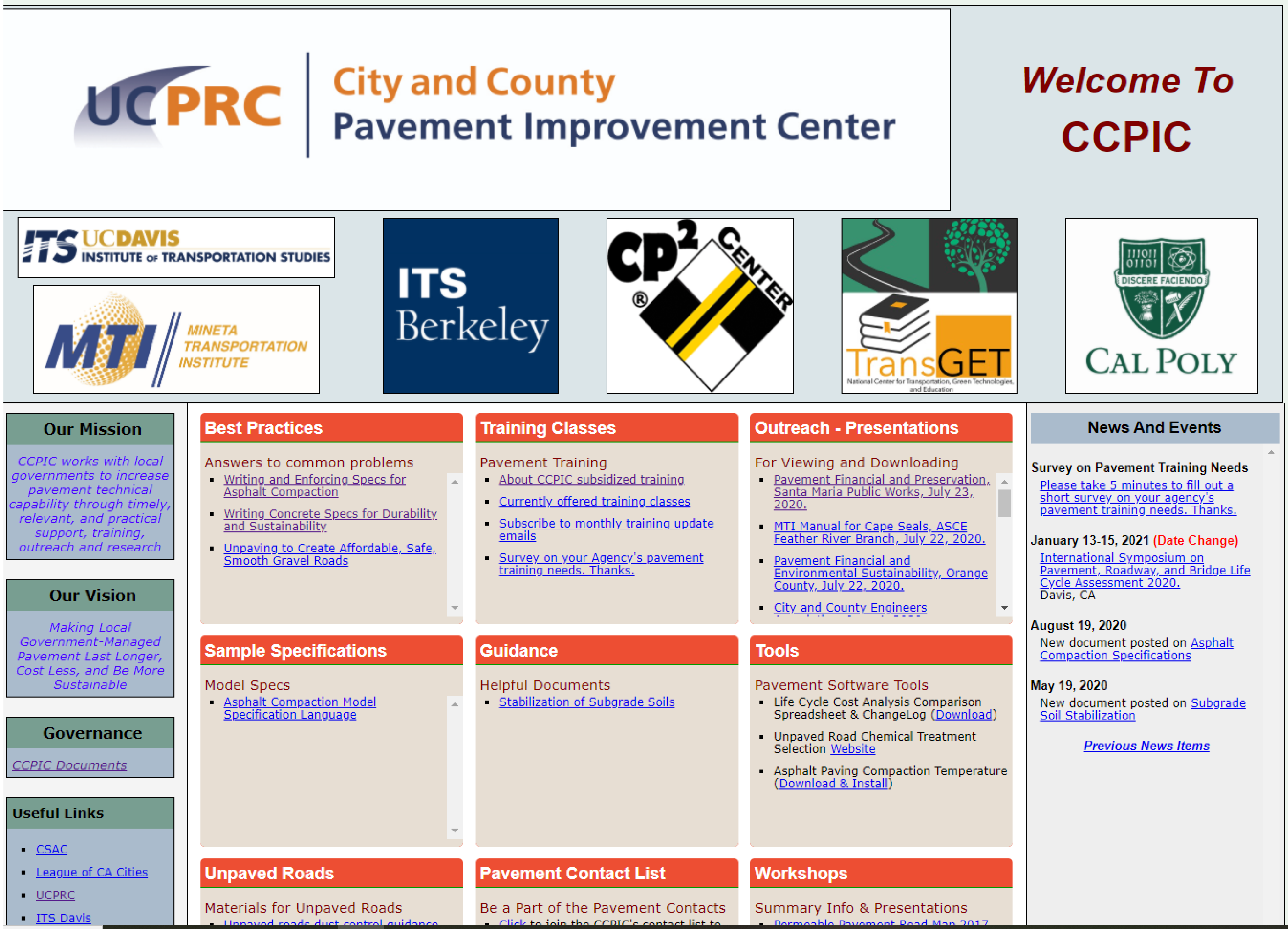




National $ Spent on Transportation in 2008 (US Census Bureau)

STATE GOVERNMENT	LOCAL GOVERNMENT
97,508,989	61,053,150

- Governance: League of California Cities, California State Association of Counties
- Training
  - Classes
  - Certificate program
- Best practices
- Tools
  - Sample specifications
  - Software
- Outreach



Takeaways

- Implementation
  - Is necessary to obtain benefits of research
  - Requires planning and a coordinated strategy
  - Requires data and tools that can be readily used, updated, improved
- In pavement, implementation and continuous improvement facilitated by integration of data and tools
- Implementation of integrated data and tools can achieve cost savings, reduce environmental impacts, answer important questions
- Investment in human capital is essential for successful implementation
- Now is the time: the gray tsunami is upon us!

Expectations for Transportation Segment of the Economy

S. David Freeman

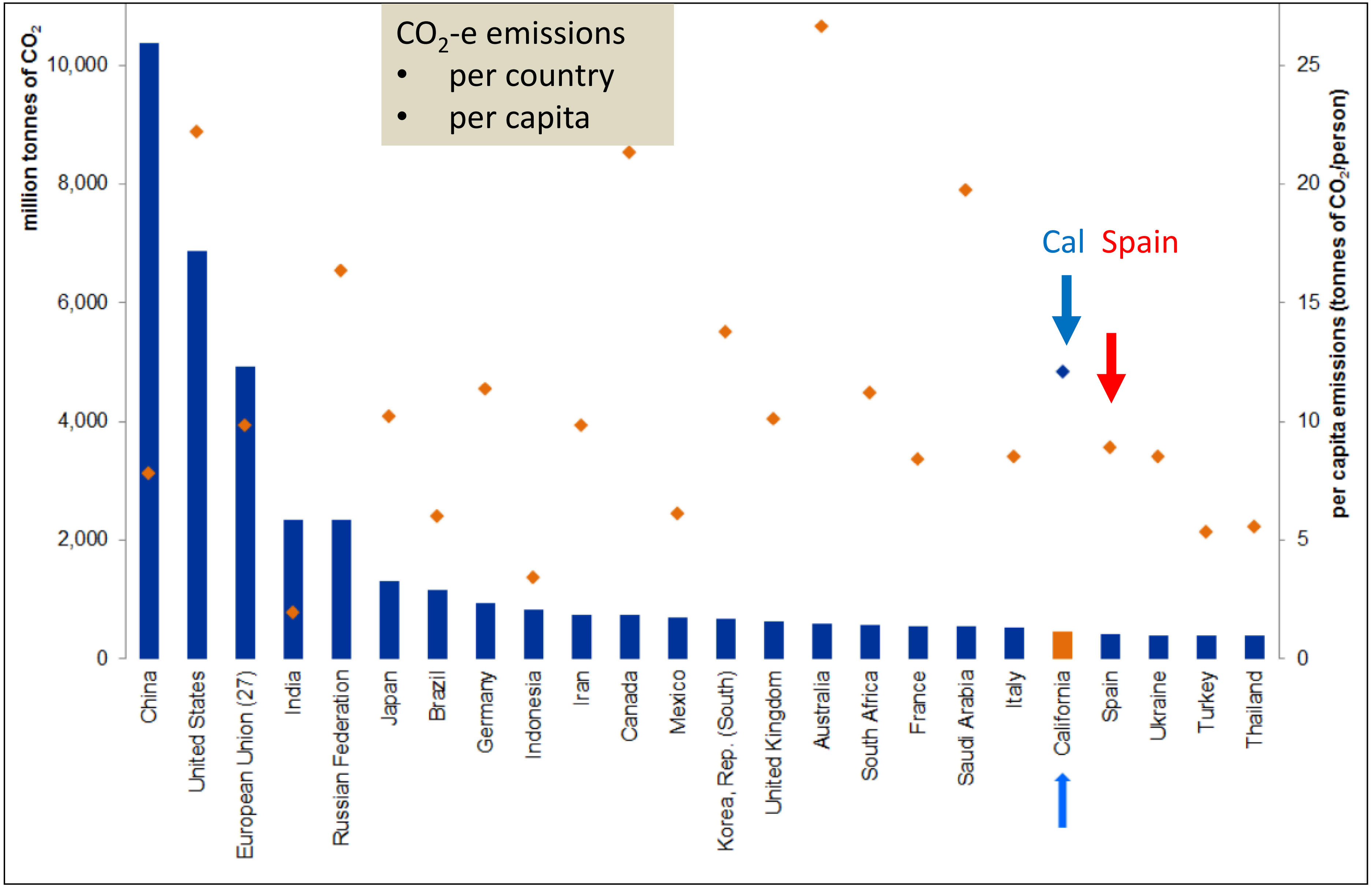
UCLA Seminar: Infrastructure Investment for Sustainable Growth (October, 2010)

- Transportation sector about to enter a period of profound change like the energy sector in 1970s and 1980s
- Regulations will be implemented requiring increasing energy efficiency and environmental performance
- Transformation necessary to maintain economic competitiveness of US
- **We are no longer rich enough to make many mistakes and still be able to achieve our goals**
- **I would add: we need to better focus our research, translate our results into practice, and communicate with the public to achieve our goals**

https://www.eenews.net/stories/1060075943
https://en.wikipedia.org/wiki/S._David_Freeman


Thanks to many colleagues
Questions?

How is California doing with regard to GHG emissions?



2012 data

California Air Resources Board report