Innovation
A practical international guide
– the California/USA Journey

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Content

- Review of historical pavement innovation in US
- Where we are now, and what will change?
- Where do we want get to?
- How do we get there?
- Conclusions and recommendations

- *Intent is to stimulate thought and discussion*

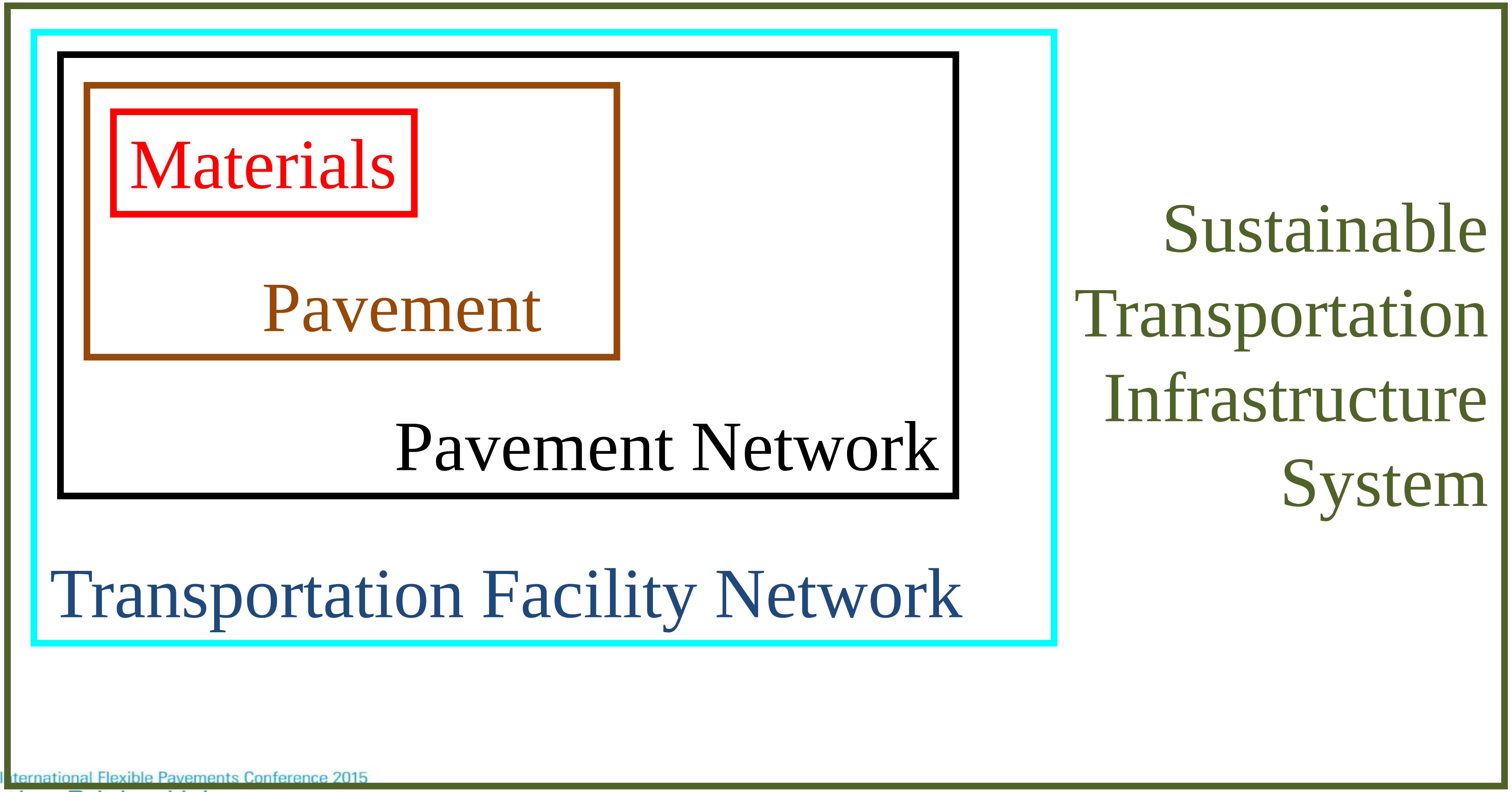
Incomplete review of historical innovation implementation in asphalt pavement in USA

Changing priorities for innovation to respond to conditions

Years	Infrastructure	Innovation
1948-1980	Deployment	Materials, Structural Design, Cost Allocation
1974-1985	Energy crisis	Energy, Recycling
1980-2000	Management	Management systems, M & R Scheduling, Preservation treatments, Condition Assessment

Years	Infrastructure	Innovation
1990-2025	Reconstruction	Reconstruction, Materials Optimization, Traffic Considerations, Longer design lives, Quality Assurance Mix design & binder specs
2010-2050	Sustainability implementation underway	Materials Re-use, New materials Mechanistic design Noise

Continued expansion of the system boundaries in which pavement problems are defined



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Examples of recent innovation driven by reducing cost of performance per ton of asphalt

- Superpave Mix Design, better performance, same cost
  - PG binder specifications (fully implemented)
  - Volumetric mix design (nearly fully implemented)
  - Performance related mix testing (sporadic implementation)
- Polymers, better performance, increased cost
  - Extensively used in a number of states, particularly for surfaces
- Recycled asphalt (RA), reduced cost, same performance
  - US: about 90 % of RA recycled in new plant mix; competition with concrete due to oil cost

NAPA, EAPA, AggBusiness, Caltrans

Examples of recent innovation driven by reducing cost of performance per ton of asphalt

- Warm Mix, reduced cost, same or better performance
  - US: driven by bonuses for quality (compaction) and cost of energy
- Rubberized asphalt, better performance, same cost
  - Overlays in California give superior performance with half thickness
- <u>Putting more knowledge into the product</u>

Asphalt Rubber Binder

NAPA, EAPA, AggBusiness, Caltrans

Barriers to implementation and signs of positive change

- Industry
  - Barriers: need consistent plans for government funding, ability to raise capital, costs of equipment, knowledge, low-bid environment, materials uncertainties
  - Positive: desire to innovate to stay competitive between industries, increase profit (or just survive)
- State/provincial Government
  - Barriers: low-bid environment, risk aversion incentives, low investment in design, lack of expertise
  - Positive: introduction of LCCA, ME design, QC initiatives at state level

Barriers to implementation and signs of positive change

- Local Government
  - Barriers: lack of expertise, low-bid environment, risk aversion incentives, no funding for research or adaption of research, low investment in design
  - Positive: high interest in some locations
- Academia
  - Barriers: ability to train enough students, ability to attract students to pavements, lack of support for pavement faculty positions, lack of incentives or ability to connect research to development and to real practice
  - Positive: improvement in quality of research, move away from empiricism

Where we are now, and what will change

Why do we need to innovate now?

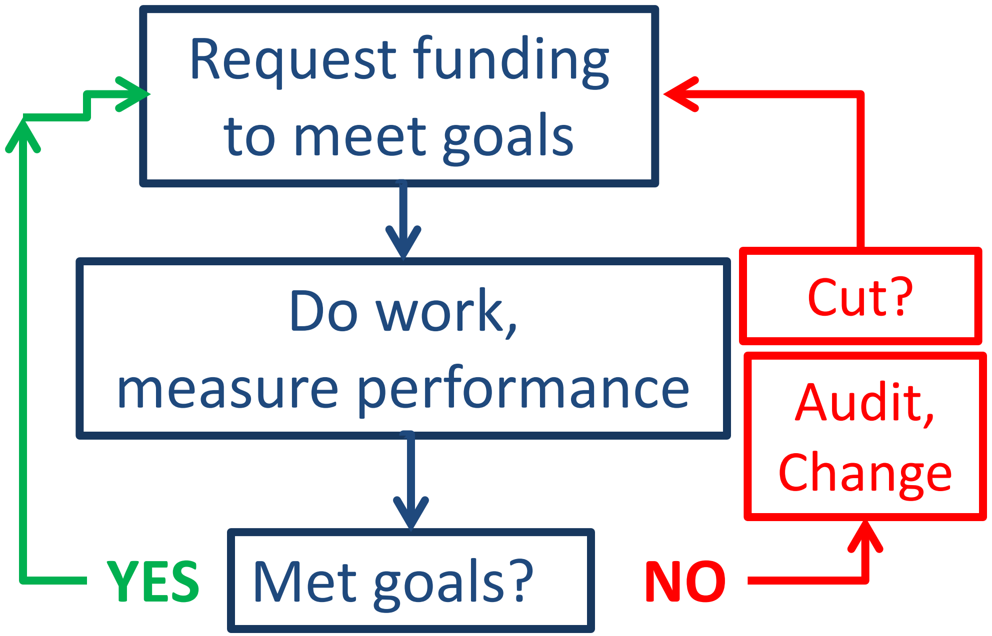
- Goals changing
  - Network demographics: deployment, preservation, maintenance, rehabilitation
  - Traffic changes: numbers, tires, axle loads, suspensions
  - Public awareness of smoothness, noise, environment, cost
- Circumstances changing:
  - Funding levels and willingness of public to pay for roads
  - Bitumen properties
  - Relative costs of materials
  - Climate
  - Workforce
- Knowledge and tools betting better:
  - Mechanics, materials, management, statistical methods
  - Materials, construction and performance data
  - Lab testing capabilities, field testing capabilities
  - New materials, new construction machines and methods

Overall change in demand for asphalt innovation

- Change in customer demand for asphalt technology
  - "We have always had plenty of asphalt and built our roads in this kind of flexible pavement structure and always will"
  - "How can we get maximum pavement value per drop of bitumen and ton of asphalt, since we don't have enough money to maintain our network?"
- Overall trend to remain competitive
  - Increase the knowledge content of the product

MAP-21 federal legislation and performance measures

- *What has been the traditional measure of efficiency?*
- The cornerstone of MAP-21's highway program transformation is the transition to a performance and outcome-based program.
- Pavement Related Goals
  - Infrastructure
    - IRI, cracking, rutting
  - Environmental sustainability
    - Measures?



http://www.fhwa.dot.gov/map21/summaryinfo.cfm

Master equation for environmental impacts

Environmental impact =

$$\text{Population} * \frac{\text{GDP}}{\text{Person}} * \frac{\text{Impact}}{\text{GDP}}$$

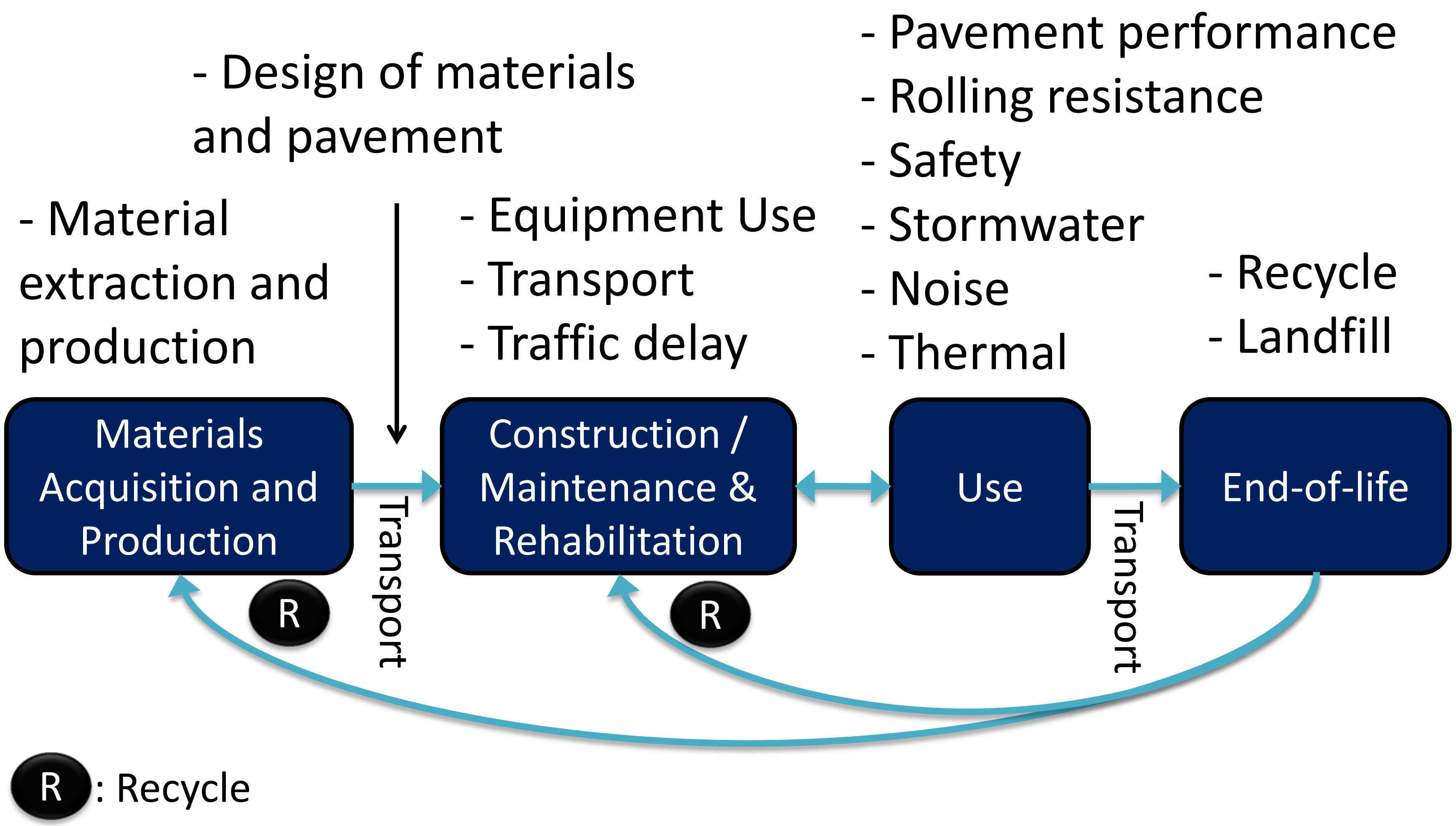
Increase in wealth and economic activity, road networks

Technological efficiency

Ehrlich and Holdren (1971) Impact of population growth. e.g. via LCA *Science* 171, 1211-1217
Slide adapted from R. Rosenbaum, Pavement LCA 2014 keynote address

Pavement Life Cycle Assessment

Where can we improve technological efficiency?



From: Kendall et al., *2010*

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Markets for innovation: Who buys asphalt?

- Most of our research focuses on high volume routes
- Significant amount of spending by local government
- Special needs:
  - Less expertise
  - Lower quality assurance capability
  - Little or no research budget for asphalt
- Are we meeting their needs?
  – New materials, pavement designs, construction practices

US Census Bureau

Thousands of US$

	STATE GOVERNMENT AMOUNT	LOCAL GOVERNMENT AMOUNT
Transportation:		
Highways	97,508,989	61,053,150

Materials and pavement structures for local government low volume urban streets

- Ability to repair under-street utilities
- Easy to construct
- Low-impact development
  - Restoring natural water, thermal energy, nutrient flows in urban areas with different pavement structures
  - Low cost, low environmental impact, maintainable, restorable

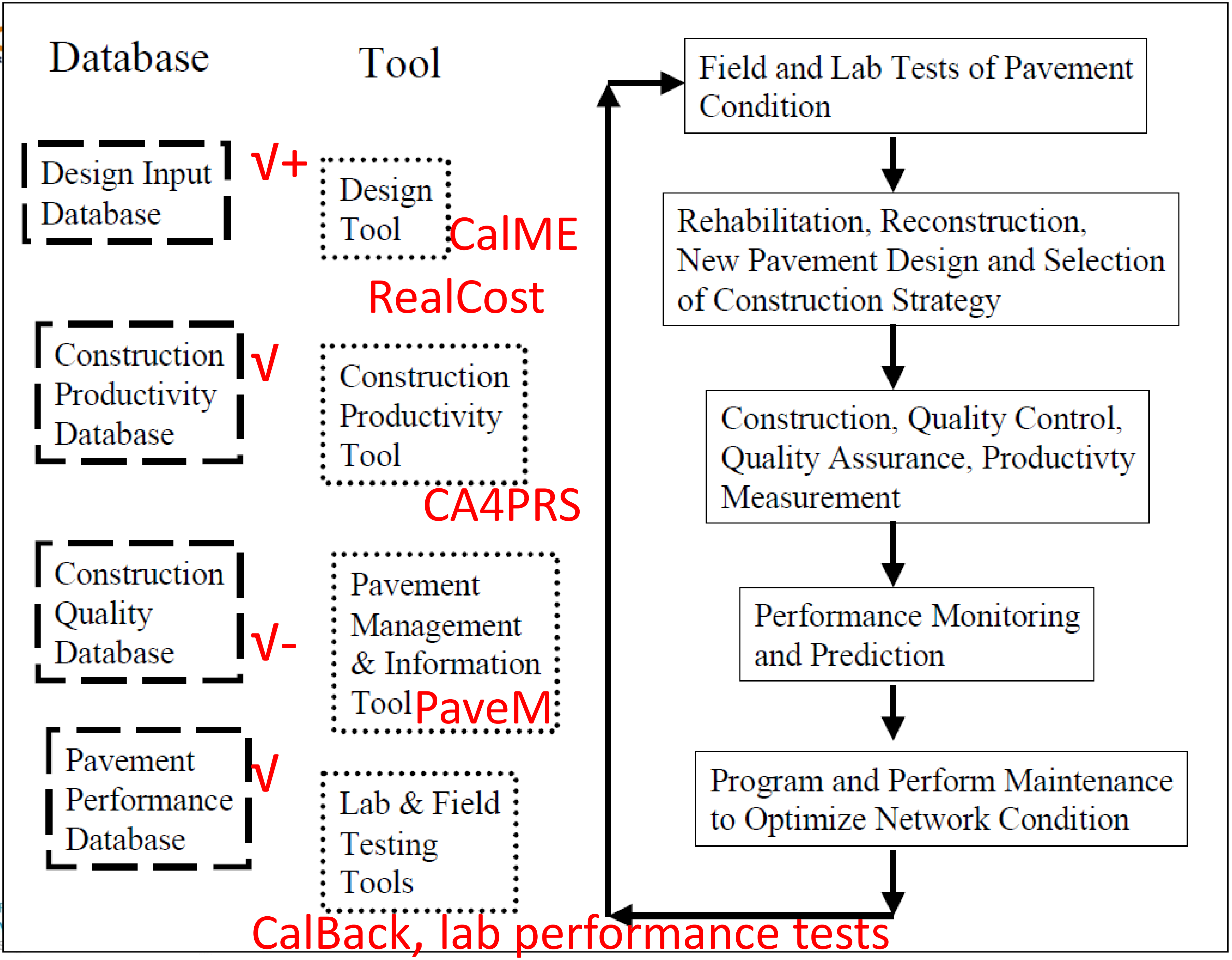
Where do we want get to?

Vision Example:
California Pavement Research Program

- Written in 2000 with 10 to 15 year horizon
- Vision:
  - Processes and ingredients for continuously improving state-of-the-art pavement technology
- Goals
  - Continuous Improvement of the Efficiency of Caltrans Pavement Operations
  - Help Caltrans Improve Its Responsiveness to Its Internal and External Customers
    - Approach: databases and tools

Vision Example

- Goals, cont'd
  - Improve the Sustainability of Pavement Structures
    - Cost
    - Environment
  - Maintain a Strong Research and Academic Instruction Program in Pavements in California
    - Must have paths to excellence or will not attract smart young people looking to achieve
  - Increase pace of change
    - Avoid "not invented here syndrome"
    - Training and access to technology
- Currently writing vision document to 2025


Database
Tool
Design Input Database
√+
Design Tool
CalME
RealCost
Construction Productivity Database
√
Construction Productivity Tool
CA4PRS
Construction Quality Database
√-
Pavement Management & Information Tool
PaveM
Pavement Performance Database
√
Lab & Field Testing Tools
CalBack, lab performance tests
Field and Lab Tests of Pavement Condition
Rehabilitation, Reconstruction, New Pavement Design and Selection of Construction Strategy
Construction, Quality Control, Quality Assurance, Productivty Measurement
Performance Monitoring and Prediction
Program and Perform Maintenance to Optimize Network Condition

2025 Vision for Implementation

- Quantitative sustainability assessment methods
- New materials, re-re-recycling
- Implement these advances into design
  - Aging evolution of mix properties
  - Thixotropy
  - Relationship of laboratory to in-place properties
  - Improved damage laws
  - Tire contact stress distribution, dynamic effects
  - Variability of all of above in the field and their effect on pavement reliability
  - Interaction of all of above and prediction of damage and distress throughout life

How we can get there

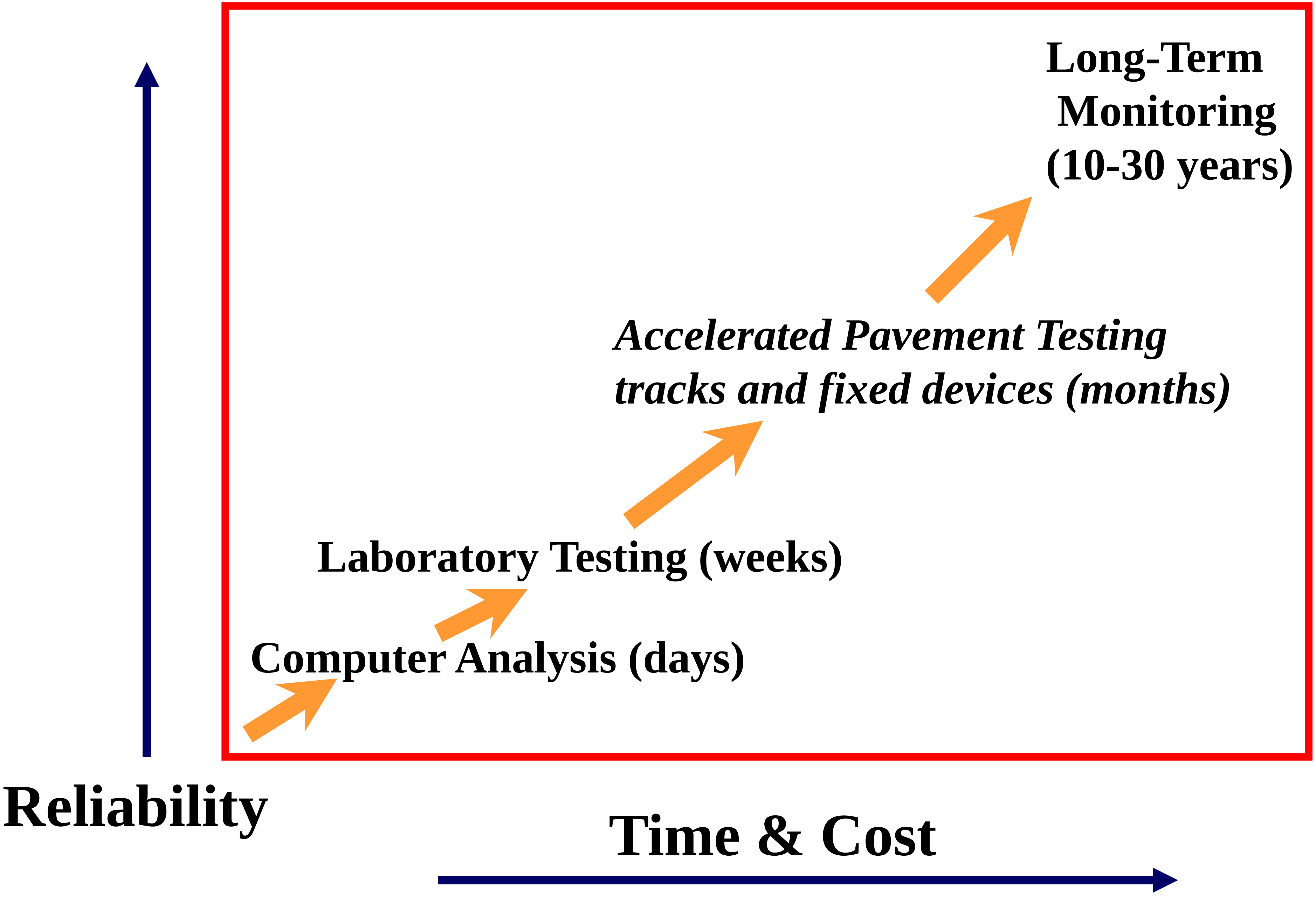
Pavement innovation process

- Conceptualization
  - Need driven or new idea driven
  - Often not completely new
- Research (20% of effort)
- Development (50% of effort)
- Piloting (30% of effort)
- Complete market penetration process after that
  - Further development and piloting in different places
- <u>Average time to complete this process is 10 years</u>

Critical ingredients for success

- Awareness of needs, and of developments around world
- Top level support
  - Sufficient understanding and willingness to take risk
- Strategic Plan
- Human technical + other resources to complete the innovation development and implementation process
- Incentives and mandates
  - Industry (financial incentives and mandates)
  - Government (mandates)
  - Academia (funding incentives)
- Intellectual rigor
  - Documentation of results
  - Outside critical review and benchmarking

Example Process



Example Process

Long-Term Monitoring (10-20 years)

Laboratory Testing

- Binder testing (grams)
- Fine aggregate mix testing (kg)
- Mix testing (tons)

Computer Analysis

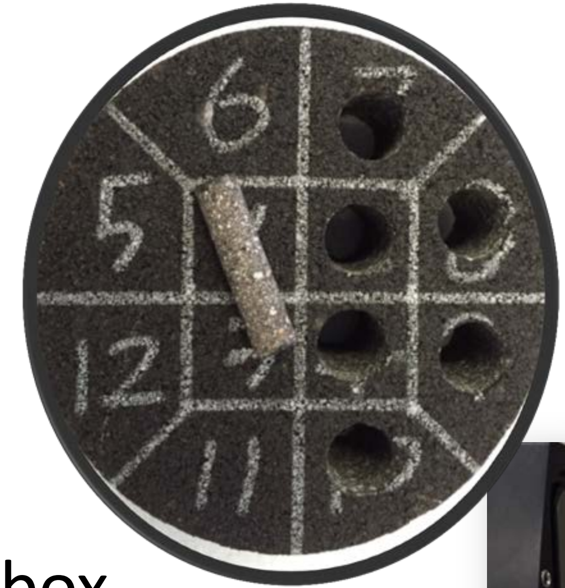
- Mechanistic simulation to evaluate lab results
- Simulation of APT sections to validate and calibrate new models and results

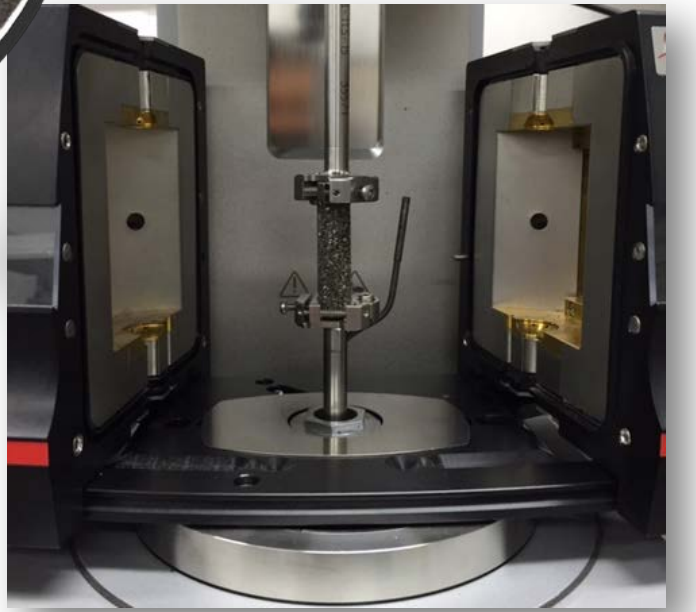
Reliability

Time & Cost

Find ways to keep sophistication of testing and analysis, but make it faster and easier

- Make it
  - Smaller
  - Faster
  - Easier without becoming black box
- Start with full understanding of complexity, then simplify





Implementation and workforce capacity

- 40 % of engineers are within five years of retirement in many pavement industry and government organizations
- Need to recruit and rapidly promote many new people
  - They need much greater skills to handle advanced pavement technology
  - They have little patience with slow pace of innovation
  - They will leave the industry if they don’t see innovation!!

Image: http://www.iis.fraunhofer.de/

Some ideas being put forward

- International development of advanced pavement curriculum requirements for universities
- US Professional licensure as Pavement Engineer, beyond general Professional Engineer
  - Requirement for pavement specific university or professional development courses
  - Examination for advanced knowledge and certification of experience with advanced practice
  - Like Geotechnical Engineer, Structural Engineer

Conclusions

- Innovation and its implementation are essential for survival
- Must develop plans and processes
  - Where you want to go
  - How you are going to get there
  - Who you need to get you there
    - Borrow, adapt, partner
  - Who will use it
  - All of the critical ingredients for success
- It takes a concerted, sustained effort

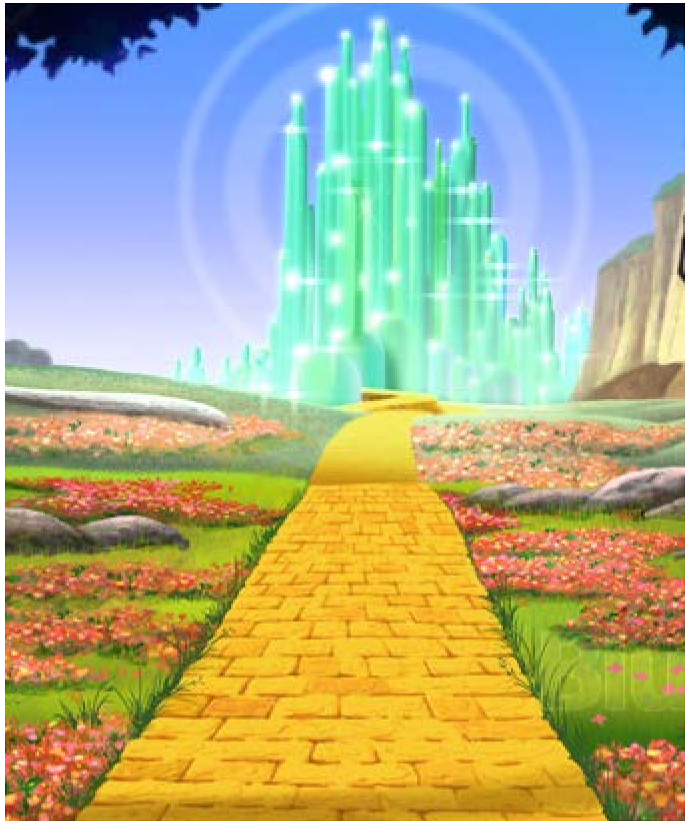


Image: sunnysidepost.com

Questions?