Pavement Condition Index (PCI): There’s More *(and Less)* to the Score

John Harvey, PhD, P.E.
Erik Updyke, P.E.

Summer, 2022
CCPIC Mission and Vision

• **Mission**
  - CCPIC works with local governments to increase pavement technical capability through timely, relevant, and practical support, training, outreach and research

• **Vision**
  - Making local government-managed pavement last longer, cost less, and be more sustainable
City and County Pavement Improvement Center

- Sponsored by the League of California Cities, County Engineers Association of California, and the California State Association of Counties
- Chartered September 28, 2018
City and County Pavement Improvement Center

- University of California Partners
  - University of California Pavement Research Center (lead)
  - UC Berkeley ITS Tech Transfer
- California State University Partners
  - CSU-Chico, CSU-Long Beach, Cal Poly San Luis Obispo

www.ucprc.ucdavis.edu/ccpic
CCPIC Organization

- **Governance**
  - Governance Board consisting of 6 city and 6 county transportation professionals

- **Current Funding**
  - Seed funding from SB1 through:
    - Institute of Transportation Studies at UC Davis, UC Berkeley, UC Los Angeles, UC Irvine
    - Mineta Transportation Institute at San Jose State University
CCPIC Scope

- **Technology Transfer:**
  - Training courses
  - Pavement engineering and management certificate program for working professionals through UC Berkeley ITS Tech Transfer
  - Outreach

- **Technical Resources:**
  - Technical briefs, guidance, sample specifications, tools, and other resources

- **Resource Center:**
  - Outreach, questions, pilot study documentation, and forensic investigations

- **Research and Development:**
  - For local government needs that are not covered by State and Federal efforts
  - Adapting work done for state government
Pavement Engineering & Management (PEM) Certificate Program

- PEM Certificate Program Overview
  - For engineers, asset managers, upper-level managers, technicians and construction inspectors
  - 88.5 hours of training
    - 56.5 hours in core classes, 32 hours in electives
    - Majority of classes to be offered online
  - In four categories:
    - Fundamentals
    - Management
    - Materials and Construction
    - Design
## Pavement Engineering & Management Certificate: Curriculum

<table>
<thead>
<tr>
<th>Fundamentals</th>
<th>Hrs</th>
<th>Management</th>
<th>Hrs</th>
<th>Materials and Construction</th>
<th>Hrs</th>
<th>Design</th>
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City and County Pavement Improvement Center
Pavement Construction Inspection (PCI) Certificate Program

• PCI Certificate Program Overview
  ▪ For engineers, material testing technicians and construction inspectors
  ▪ 80.5 hours of training
    • 68.5 hours in core classes, 12 hours in electives
    • Majority of classes to be offered online
## Pavement Construction Inspection Certificate: Curriculum

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<thead>
<tr>
<th>CORE</th>
<th>Hrs</th>
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### 68.5 Core

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<td>CCC-24</td>
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### 12 Electives

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## CCPIC Training: Upcoming Classes

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<td>Pavement Life Cycle Cost Analysis</td>
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Pavement Distresses

Identifying Types to Better Manage Asphalt Pavement
At *moderate* temperatures, tensile strains under loading:

- **Asphalt**
- **Concrete**
- **Base**
- **Sub-Base**
- **Subgrade**

**Tensile Strain** $\varepsilon_t$
Load-Related: Bottom-Up Fatigue Cracking

- **Interaction** of asphalt concrete layer, support of underlying structure, materials selection, construction compaction
- **Traffic loading:**
  - Only the truck loads count, cars are too light
  - Slower speeds = longer durations = bigger strains
- **Environment:**
  - Temperature
  - Water sensitivity
  - Aging
Initial Wheel Path Cracking

- May be transverse or Longitudinal
- Distress descriptions can be seen in the *FHWA Distress Identification Manual*
Distress descriptions can be seen in the *FHWA Distress Identification Manual*.
Fatigue Cracking in Wheel Paths

- Distress descriptions can be seen in the *FHWA Distress Identification Manual*
Reflective Fatigue Cracking

- Shear and tensile strains from loads passing over, tensile strains from thermal contraction
- Crack pattern resembles pattern before overlay

Asphalt
Concrete
Cracked AC, PCC or CTB
Base
Sub-Base
Subgrade

Strains concentrated above cracks in layer below
Reflective Cracking of Underlying Block Cracking and Longitudinal Joint, 7 Years Old

• Avoid putting longitudinal joints in the wheel paths!
Load-Related: Top-Down Fatigue Cracking

- Identified in the 1990s
- Cracking due to high tensile and shear stresses at the HMA surface near edges of truck tires

![Diagram showing tension causing top-down and shear causing top-down, as well as tension causing bottom-up.](image)
Top-Down Fatigue Cracking

- Thin HMA (< 4”): Fatigue cracking generally starts at the bottom
- Thick HMA (> 4”): Fatigue cracking generally starts at the top
  Note, thickness of AC in photo on the previous slide is 20”
- Traffic loading: High truck tire pressures
Load-Related Fatigue Cracking: Strategies

- Fatigue cracking becomes alligator cracking, and eventually forms potholes.
- Surface treatments will slow a little, but mostly helps with block cracking, not fatigue.
- Will need to do periodic mill and fill with digouts of localized deep cracking.
- Mill and fill may not be cost-effective once alligator cracking is extensive.
  - Consider partial-depth (cold in-place recycling) or full-depth reclamation (FDR) depending on crack and rutting depth.
- Do not let wheel path cracking become extensive or must reconstruct.
Aging

Amount of aging depends on asphalt chemistry, construction compaction, modifiers

2 to 5 times stiffer, and less able to relax stresses from thermal expansion and contraction

Better compaction reduces air permeability, less hot air in mix results in less aging
• **Aging:**
  ▪ Caused by oxidation and volatilization
  ▪ Faster if high permeability and Temperature (curve)
  ▪ Permeability greatly reduced with better HMA/AC compaction (curve)

• **Effects:**
  ▪ Stiffening of the mix over time
  ▪ Won’t relax stresses from thermal contraction as well
Age-Related: Block Cracking

- Typically caused by long-term aging of HMA/AC and daily temperature cycling (expansion/contraction)
- May also be reflection cracking from shrinkage cracks in cement treated base or underlying HMA/AC
- Poor HMA/AC compaction allows air to enter and age the asphalt faster

Good compaction limits entry of air and slows oxidation
Block Cracking

- Block cracking is top-down
- Distress descriptions can be seen in the *FHWA Distress Identification Manual*
Age-Related Cracking: Strategies

- Keep the surface protected from aging
- Can potentially use perpetual fog seals, or slurry seal or micro surfacings
  - Slurry seal typically not applied to RHMA/ARHM
- What frequency?
  - After aging has progressed
    - About 7 to 12 years
  - Before cracking starts
    - Do not let cracking get extensive
  - Doing more frequently is not cost-effective
Moisture Damage

- Moisture damage is assessed by taking both dry and wet cores and measuring the in-situ pavement permeability.

- The extent of moisture damage is evaluated for each core.
Moisture Damage

- Layer 1 AV=13%
- Layer 2 AV=6.3%
- Water entered 1, trapped between layers
AC/HMA Mix Rutting

- High shear stresses at edges of tires
- Asphalt softer under slow moving traffic
- Mix Rutting identified by “humping” of displaced asphalt at the sides of wheelpath
AC/HMA Mix Rutting

- Poor compaction makes rutting happen faster
- Much more shearing
- Some due to more compaction from traffic
  - But only in wheel paths
  - Doesn’t help with aging and block cracking
• Lack of bonding reduces overlay fatigue life by about 50%, even if no shoving
• Due to insufficient tack coat application
• Surface must be dry, clean, free of dust and residual millings
• Place between lifts, even if underlying lift is still hot
• Specify by residual amount
• Track-resistant materials available
• Spray pavers available
Delamination/Debonding: Tack Coat Application

- Proper tack coat application results in the pavement layers acting as a composite section
- Analogous to glue used in structural laminated beam
- Uniform application over the pavement surface, not streaked
- Ensure spray bar is pressurized and discharge cones overlap at least twice
- Encourage proper application by making a separate Bid Item.
Pavement Condition Index (PCI)

The “More” and the “Less”
Choosing Cost-Effective Strategies: Use of PMS Data and LCCA

- Understanding the performance of your pavements is key to good pavement management and life cycle cost analysis (LCCA).

- *Pavement condition* is typically calculated and described in terms of pavement condition index (PCI).

- Agencies need to take one step back behind PCI to better understand *pavement performance* in order to better understand PMS data and make better strategy decisions.
Pavement Condition Index (PCI)

- **Definition/Standard:**
  
  - “A numerical rating resulting from a pavement condition survey that represents the severity of surface distresses.” FHWA, Practical Guide for Quality Management of Pavement Condition Data Collection, page 87
  
Calculation:

- “An equation converts the severity and extent of each distress into a so-called “deduct value”; different deduct equations are used for the different distress types.
- All the deduct values obtained across all the distress types are then added up and subtracted from 100.
- The result is a PCI on a scale of 0 to 100.”
Variables in the PCI

- Fatigue cracking and potholes caused by *heavy loads*:
  - Alligator cracking
  - Potholes

- Cracking caused by *aging*:
  - Block cracking
  - Joint reflections
  - Longitudinal and transverse cracking

- Other distresses:
  - Low ride quality
  - Bleeding
  - Bumps and sags
  - Corrugations
  - Depressions
  - Edge cracking
  - Lane/shoulder drop-off
  - Patching and utility cut patching
  - Polished aggregate
  - Rutting
  - Shoving
  - Slippage cracking
  - Swelling
  - Weathering and raveling
Problems and Limitations:

- “... it has limitations as an engineering tool for local governments making pavement management decisions.”

- “Specifically, when a PCI is developed from condition survey data, a lot of important engineering information is lost, particularly data regarding cracking.”

- “A major deficiency in PCI is that roadway segments can have the same or similar PCI [a tie score] but very different types of distress.”
## Same or Similar PCI:

**Different Distresses = Different Strategies**

### CASE 1: **TRAFFIC LOADING RELATED, PCI = 34**

<table>
<thead>
<tr>
<th>DISTRESS</th>
<th>SEVERITY</th>
<th>QUANTITY</th>
<th>DV</th>
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<tr>
<td>Alligator Cracks</td>
<td>High</td>
<td>1x6</td>
<td>18</td>
</tr>
<tr>
<td>Alligator Cracks</td>
<td>Medium</td>
<td>1x4 1x5 1x7</td>
<td>17</td>
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<tr>
<td>Potholes</td>
<td>Medium</td>
<td>3</td>
<td>48</td>
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<tr>
<td>Potholes</td>
<td>Low</td>
<td>3</td>
<td>30</td>
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<tr>
<td>Rutting</td>
<td>Low</td>
<td>2x5 2x8</td>
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### CASE 2: **AGE, CONSTRUCTION, UTILITIES, OTHER FACTORS, PCI = 32**

<table>
<thead>
<tr>
<th>DISTRESS</th>
<th>SEVERITY</th>
<th>QUANTITY</th>
<th>DV</th>
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</thead>
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<tr>
<td>Long/Trans Crack</td>
<td>High</td>
<td>15 20 8 6 12 18 6x7</td>
<td>43</td>
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<tr>
<td>Long/Trans Crack</td>
<td>Medium</td>
<td>25x2 18 13 9 10</td>
<td>20</td>
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<tr>
<td>Patching/Utility</td>
<td>High</td>
<td>25x4 25x2</td>
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<tr>
<td>Patching/Utility</td>
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<td>12x6 4x7</td>
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<tr>
<td>Block Cracks</td>
<td>High</td>
<td>4x6 6x5</td>
<td>13</td>
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Pavement Condition Index (PCI)

- The “Tiebreaker:”

  “For these cases, examining the distress types and extents of the distresses and their effect on the pavement structure, along with other available project-level data, could serve as a tiebreaker to augment PCI making network-level and project scoping decisions.”
What’s “Less”?
- “PCI is a simple, effective communication tool, but when used alone it is insufficient for choosing the right strategy at the right time to maximize the cost-effectiveness of pavement funding.”
- PCI is not a measure of structure.
- PCI alone is less information than is needed to select the appropriate strategy based on pavement distress.

What’s “More”?
- “Managing pavement networks primarily based on identification of age- and load-related cracking will result in more informed and cost-effective treatment timing and selection.”
- More project-level analysis and information is needed in order to select the appropriate strategy.
Life Cycle Cost Analysis
Life Cycle Cost Analysis (LCCA)

- Net Present Value = the total of costs over the analysis period, including discount rate.
- Equivalent Uniform Annual Cost = spread NPV over time, with discount.
- $(Agency Costs)$
- $(User Costs)$
CCPIC LCCA Excel Tool

- Excel tool to calculate Net Present Value, Salvage Value and Equivalent Uniform Annual Cost
- Can compare 3 scenarios side by side
- Can choose and edit the list and sequence of treatments
Strategy Selection

Considerations for Future Projects
Questions to Ask

• Are the cracks due to fatigue in the wheel paths (traffic), or aging of entire surface (environment), or both?

• Is the network-level strategy in the PMS appropriate for the types of cracking?

• Did the last project on the same route perform as expected? If not:
  ▪ What’s changed?
  ▪ Is the structural section adequate?
  ▪ Was a thorough project-level investigation, associated testing, and calculations performed?
  ▪ Was the appropriate strategy selected?
  ▪ What binder was used? Should a modified binder (polymer, asphalt-rubber) be used in the next project (particularly useful if inlay/overlaying cracking)?
**Pavement “MRI”: Before Strategy Selection**

- **M = Materials:**
  - What is the structural section composed of?
  - Subgrade, base material type and thickness, HMA/AC (gradation, binder type, thickness).

- **R = Review:**
  - Completed projects at 3, 5, and 10-year milestones.
  - As-built plans,
  - Material testing records,
  - Traffic counts/traffic index calculations/projections,
  - Resident Engineer/Inspector records,
  - Change Orders.
Pavement “MRI”: Before Strategy Selection

- **I = Investigation:**
  - Was a project-level site investigation performed?
  - Borings
  - Cores
  - Dynamic Cone Penetrometer (DCP)
  - Falling Weight Deflectometer (FWD)
  - Subgrade Soil Classification Testing (SE, R-Value/CBR, PI)
Summary

Takeaways for thought and application
The ability to make good engineering decisions regarding the timing and type of strategy based only on PCI is limited; analyze the cracking.

Life cycle cost analysis (LCCA) is a practical tool to determine the most cost-effective strategies:

- Needs good performance estimates, agencies can use their own information
- Focus on cracking, separated by:
  - Streets with heavy trucks/buses, wheel path fatigue cracking and age related cracking: will need rehabilitation eventually
  - Streets with no heavy vehicles, age related cracking only: can use only preservation treatments if timely

Takeaways
Resources

References and Links
References/Links

- City and County Pavement Improvement Center (CCPIC):
  www.ucprc.ucdavis.edu/ccpic

- “Pavement Condition Index (PCI): There’s More (and Less) to the Score”
  www.ucprc.ucdavis.edu/ccpic/pdf/PCI 4-Pager final v2.pdf

- University of California Pavement Research Center (UCPRC):
  www.ucprc.ucdavis.edu

- Maintenance Technical Advisory Guides (MTAG):
  https://www.csuchico.edu/cp2c/library/caltrans-documents.shtml
References/Links

- FHWA “Distress Identification Manual:”

- Caltrans “Tack Coat Guidelines:”
  www.ucprc.ucdavis.edu/ccpic/pdf/Caltrans%20Tack%20Coat%20Guidelines.PDF
Sustainable Pavements

- FHWA Sustainable Pavements Task Group
  - Covers everything about pavement and sustainability
    - Cost
    - Environment
    - (they usually go together)
  - Tech briefs and webinars

Questions?

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• Shadi Saadeh: Shadi.Saadeh@csulb.edu
• Ashraf Rahim: arahim@calpoly.edu