Module 1 Part 4: Methodology for Determining Pavement Condition Index (PCI)

Basic Components
- PMS
- Physical Description
- Failure Mechanism
- Severity Levels
- How to Quantify Them

Fundamental Theory of Typical Pavement Defects and Failures
- Methodology for Determining Pavement Condition Index (PCI)
- Guides for the Selection of Sample Unit
- Field / Classroom Workshop

Evaluation of Flexible Pavements
- Maintenance of Flexible Pavements

PCI Definition
- Index of pavement structural integrity and surface operational condition;
- Index from 0 (failed) to 100 (perfect)
- Repeatable system
- Visual condition survey

PCI Scale

<table>
<thead>
<tr>
<th>Rating</th>
<th>100</th>
<th>85</th>
<th>70</th>
<th>55</th>
<th>40</th>
<th>25</th>
<th>10</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
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<td>Very Good</td>
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<td>Fair</td>
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<td>Poor</td>
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<tr>
<td>Very Poor</td>
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<td>Failed</td>
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</tr>
</tbody>
</table>

CITY OF LUCAS
PAVEMENT CONDITION INDEX MAP

Legend
- No Data
- Fair
- Failed
- Satisfactory
- Serious
- Good
- Very Poor
- Poor
- citylim
**Pavement Condition Life Cycle**

**PCI Methodology**

A. Network identification and definition  
B. Identification and selection of sample units  
C. Pavement condition survey  
D. Distress density computations  
E. PCI computation  
F. Identification of primary causes

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**A. NETWORK IDENTIFICATION AND DEFINITION**

**Network Definition**

- All paved areas that provide access to traffic  
  - Highways  
  - Parking lots  
  - Airfields (runway, taxiways aprons)  
  - Other unpaved / paved vehicular facilities  
  - Other possible networks  
    - Use  
    - Funding  
    - Minimum operational standards
**Branch Definition**

- Any pavement section that within the network that has a well-defined function (i.e. individual streets, parking areas, runway, taxiway, etc.)
- A branch is a relatively large unit within the pavement network

**Section Definition**

- A subdivision of a branch with uniform characteristics
  - Pavement structure (thickness / materials)
  - Traffic volume and load intensity
  - Construction history
  - Pavement rank / functional classification
  - Drainage and shoulders

**Sample Unit Definition**

- The smallest component within the pavement network
- Any identifiable area within a pavement section
- For pavement evaluation, each pavement section is divided in sample units
B. SELECTION OF SAMPLE UNITS

1. Divide section into sample units (not required to have same size)

<table>
<thead>
<tr>
<th>AC Pavement Type</th>
<th>Sample Unit Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt paved or unpaved roads</td>
<td>2500 ± 1000 ft²</td>
</tr>
<tr>
<td>Airfields</td>
<td>5000 ± 2000 ft²</td>
</tr>
</tbody>
</table>

Example of Selection of Sample Units

Pavement Section
22 ft – wide x 4,720 ft – long

46 sample units of 2200 ft² and 1 sample unit of 2640 ft²

Selection of Sample Units

2. Determine sample units to inspect
   – Network level: limited sampling
     • Budget planning
     • Predict future condition
   – Project level: higher degree of sampling
     • Evaluate specific sections (minimum 5 units)

Number of Sample Units to Inspect

\[ n = \frac{N \times s^2}{\frac{e^2}{4} \times (N - 1) + s^2} \]

where:
\( N \) = total number of sample units in the section
\( e \) = allowable error (5%)
\( s \) = standard deviation of PCI between sample units (for AC pavements = 10)
### Number of Sample Units to Inspect

<table>
<thead>
<tr>
<th>No. of Sample Units in Section (N)</th>
<th>No. of Sample Units to Inspect (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 5</td>
<td>1</td>
</tr>
<tr>
<td>6 – 10</td>
<td>2</td>
</tr>
<tr>
<td>11 – 15</td>
<td>3</td>
</tr>
<tr>
<td>16 – 40</td>
<td>4</td>
</tr>
<tr>
<td>Over 40</td>
<td>10% (round up to next whole sample unit)</td>
</tr>
</tbody>
</table>

### Selection of Sample Units

1. Determine sampling interval $i$
   
   $$i = \frac{N}{n}$$

2. Select random start (S) between sample unit 1 and i
3. Identify specific sample units to inspect (S, S + i, S + 2i, etc.)

### Example of Selection of Sample Units

- **N** = total # of sample units in section = 47
- **n** = minimum # of units to be inspected = 12.1 = 13
- **i** = interval = N / n = 47 / 13 = 3.6 = 3
- **S** = random start = 3

Sample units to inspect: 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39, 42, 45, 48.
Drawbacks of Selection Scheme

- Not selecting an exceptionally poor (or excellent) sample unit
- Selecting a sample unit with a one-time occurrence type of distress
- To overcome this:
  - Sample units in the conditions stated above should be inspected as additional units
  - Need to adjust PCI

C. PAVEMENT CONDITION SURVEY

- Inspect sample units
- Determine distress types and severity levels
- Calculate total quantity for each distress type at each severity

D. DISTRESS DENSITY COMPUTATION

1. Area Measurements
   Density = \( \frac{\text{distressed area per defect in ft}^2 \times 100}{\text{sample unit area in square feet}} \)

2. Linear Feet Measurements
   Density = \( \frac{\text{amount of defects in linear feet} \times 100}{\text{sample unit area in square feet}} \)

3. Pothole Frequency
   Density = \( \frac{\# \text{ of potholes of same diameter and depth} \times 100}{\text{sample unit area in square feet}} \)

E. PCI COMPUTATION FOR A SINGLE UNIT

1. Determine Deduct Values (DV)
2. Compute Total Deduct Value (TDV)
3. Compute Corrected Deduct Value (CDV)
4. Compute PCI = 100 - CDV
Determine PCI: 1. DEDUCT VALUE

Determine the penalty associated with each defect-density-severity combination.

<table>
<thead>
<tr>
<th>DISTRESS</th>
<th>QUANTITY</th>
<th>TOTAL</th>
<th>DENSITY</th>
<th>DEDUCT VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>10L</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>1M</td>
<td>15</td>
<td></td>
<td></td>
<td>0.6</td>
</tr>
<tr>
<td>12</td>
<td>2200</td>
<td></td>
<td>2200</td>
<td>100</td>
</tr>
</tbody>
</table>

**TDV**
Determine PCI:

2. TOTAL DEDUCT VALUE

- TDV = sum of individual DV
  \[ TDV = 4 + 17 + 20 = 41 \]
- CDV (from graph)
  - If only one individual DV (or none) is over 2 (paved roads), or over 5 (airfields / unpaved roads), TDV is used instead CDV
  - otherwise, list the individual DV in descending order and determine the maximum allowable number of deducts \( m \) for sample unit

Determine PCI:

3. CORRECTED DEDUCT VALUE

Determine the maximum allowable number of deducts \( m \) for sample unit

For airfields & unpaved roads

\[
m_i = 1 + \left( \frac{9}{95} \right) (100 - HDV_i)
\]

For paved roads

\[
m_i = 1 + \left( \frac{9}{98} \right) (100 - HDV_i)
\]

where

HDV = Highest Individual Deduct Value for sample unit
Determine PCI:

3. CORRECTED DEDUCT VALUE

The number of individual DV is reduced to $m$, including the fractional part
- If less than $m$ DV are available, then all the DV are used

$$m_i = 1 + \left( \frac{9}{98} \right) (100 - 20) = 8.35$$

Determine the number of deducts $q$, over 2 for paved roads, or over 5 for airfields and unpaved roads

$q = 3$

Then CDV is determined for $q = 3$

DETERMINE PCI FOR SAMPLE UNIT

Compute PCI for each sample unit using CDV that corresponds to the maximum value for a pavement without visible defects
- PCI = 100 – CDV
- PCI = 100 – 25 = 75
- Condition: VERY GOOD
DETERMINE PCI FOR PAVEMENT SECTION

- Compute the average PCI of all the sample units within the section being evaluated at random
- If additional sample units were inspected (non-random) calculate weighted average

\[
PCI_{section} = \left( \frac{(N - A)PCI_{random} + A(PCI_{additional})}{N} \right)
\]

A = # of additional samples inspected
N = total # of samples in section

F. DETERMINE PRIMARY CAUSES OF PAVEMENT DETERIORATION

Add the DV for the three deterioration causes
1. Load
2. Climate
3. Other

\[
\text{% of Pavement Deterioration} = \left( \frac{DV_{cause}}{TDV} \right) \times 100\%
\]

Load-related Distress
- Alligator cracking
- Edge cracking
- Potholes
- Rutting
- Shoving

Climate-related Distress
- Block cracking
- Joint reflection
- Longitudinal & transverse cracking
- Weathering / raveling

Other Causes Related Distress
- Bleeding
- Bumps and Sags
- Corrugation
- Depression
- Lane / Shoulder Drop-off
- Patching and Utility Cut Patching
- Polished Aggregate
- Railroad Crossing
- Slippage Cracking
- Swell
# Primary Causes of Pavement Deterioration

\[
\text{% of Pavement Deterioration} = \left( \frac{DV_{\text{cause}}}{TDV} \right) \times (100\%)
\]

<table>
<thead>
<tr>
<th>% of Pavement Deterioration</th>
<th>Calculation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>(\frac{17}{41} \times (100%))</td>
<td>41.5 %</td>
</tr>
<tr>
<td>Climate</td>
<td>(\frac{4}{41} \times (100%))</td>
<td>9.8 %</td>
</tr>
<tr>
<td>Other</td>
<td>(100 - 51.3) = 48.7 %</td>
<td></td>
</tr>
</tbody>
</table>

**QUESTIONS / COMMENTS**
Module 1 Part 5: Field Workshop

Field Workshop Objectives

- Provide participants "hands-on" application of the distress identification and reporting principles learned in the classroom
- Field exercise provides the opportunity to apply the principles of:
  - Distress Identification
  - Severity Rating
  - Distress Measurements
  - Mapping
  - Map Summarization

Distress Identification Basics

- Distress Identification / type of distress present
- Distress Severity / How severe is the distress?
  - Early stages (Low)
  - Well manifested (Moderate)
  - Can't get much worse! (High)
- Distress Quantity / Measurement Types
  - Linear measurements
  - Area measurements
  - Number of occurrences
  - Varies by level and type of survey - Network / Project / Research level

Inspection Equipment

- PCI Distress Manual
- Hand odometer
- Spray paint / chalk
- Straightedge
- Ruler / measuring tape
- Laptop
- Calculator
- Clipboard / blank forms / pencils
- Video camera & digital camera
- Hard hat & safety vest
Sample Unit Area

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Distress Maps
- Show exact location of each distress type existing on the sample unit
- One map is used for each sample unit
- Distress types and severity levels should be identified by using the DIM
- Each sample unit must be laid out consistently each time a survey is conducted

Field Procedure
- To map the test section, a 30 meter (100 feet) tape measure may be placed on the shoulder adjacent to the sample unit (or use a wheel) and mark 5-10 ft intervals with chalk/spray
- Distresses are drawn on the map at the scaled location and extent
- Label distresses using the distress type number and the severity level (L, M, or H)
- Any observed distress not described in the DIM should be photographed and/or video taped and identified on the map
Cheat Sheet
(developed for LTPP survey, different severity levels)

Useful for identifying typical symbols

Distress Data Sheet

- Record measured values for each distress type and severity observed in each sample unit in the left column
- The number and units of measurement for each distress are shown in the top box
- The particular measurement of each distress-severity combination is entered in the QUANTITY columns

Distress Data Sheet

- Add the measurements for each distress-severity combination and record the total on the TOTAL column
- Calculate the density for each distress-severity combination using the respective density equation (length, area, or frequency)
- Use the deduct curves for each distress-severity combination to record its penalty value
1. Hats and safety vests worn at all times if going on the road! Visibility is crucial for safety.
2. No one on the road until traffic control is set: this includes all signs, cones, etc.
3. Stay within traffic cones at all times.
4. Surveys to be performed from the shoulder. Although distresses can look different from different angles, in no case should personal safety be compromised for distress ratings.
5. Conduct surveys “with one eye” and always face oncoming traffic!
6. Warn others of unsafe conditions: if any unsafe condition is noticed (e.g., wide loads, high speed traffic, debris or pets in the road, etc.) yell a warning to the entire group.
7. Summarize distress data off the roadway - When finish mapping and rating the section, find a safe place off of the roadway to summarize the data.
8. Traffic control will remain in place until everyone has completed their summaries, to ensure any missed information can be collected under safe conditions.

QUESTIONS / COMMENTS
D. Distress Density Computations

1. Area Measurements
   Density = distressed area per defect in ft\(^2\) X 100 sample unit area in square feet

2. Linear Feet Measurements
   Density = amount of defects in linear feet X 100 sample unit area in square feet

3. Pothole Frequency
   Density = # of potholes of same diameter and depth X 100 sample unit area in square feet
E. Determine PCI:

2. Total Deduct Value

\[ TDV = 22 + 9 + 9 + 61 = 101 \]

Determine the maximum allowable number of deducts \((m)\) for sample unit

\[ m_i = 1 + \left( \frac{9}{98} \right) (100 - 61) = 4.6 \]
E. Determine PCI:
3. Corrected Deduct Value

- Determine the number of deducts \( q \), over 2 for surfaced roads, or over 5 for airfields and unsurfaced roads

\[
m = 1 + \left( \frac{9}{98} \right) * (100 - \text{MaxDV})
\]

\[
q = 4
\]

Then CDV is determined for \( q = 4 \)

\[
m = 4.6 > q = 4
\]

PCI = 100 – CDV
PCI = 100 – 58 = 42
Condition: FAIR
E. Determine PCI:

2. Total Deduct Value

2. TDV = sum of individual DV

\[ TDV = 9 + 0 + 27 + 62 + 9 + 61 = 168 \]

Determine the maximum allowable number of deducts \( m \) for sample unit

\[ m = 1 + \left( \frac{9}{98} \right) (100 - 62) = 4.5 \]
E. Determine PCI:

3. Corrected Deduct Value

- Determine the number of deducts \( q \), over 2 for surfaced roads, or over 5 for airfields and unsurfaced roads

\[
q = 5
\]

\[
m = 4.5 < q = 5
\]

Then CDV is determined for \( q = 4 \)

\[
TDV = 27 + 62 + 9 + 61 = 159
\]

E. Determine PCI for Sample Unit 2

\[
PCI = 100 - CDV
\]

PCI = 100 - 86 = 14

Condition: VERY POOR

Determine PCI for SECTION A

- Average PCI = \((42 + 14) / 2 = 28\)

Condition: POOR