Rationalize Ontario Pavement Condition Evaluation and Data Collection Procedures towards Automation

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2008 RPUG Meeting
Austin, Texas
October 29, 2008

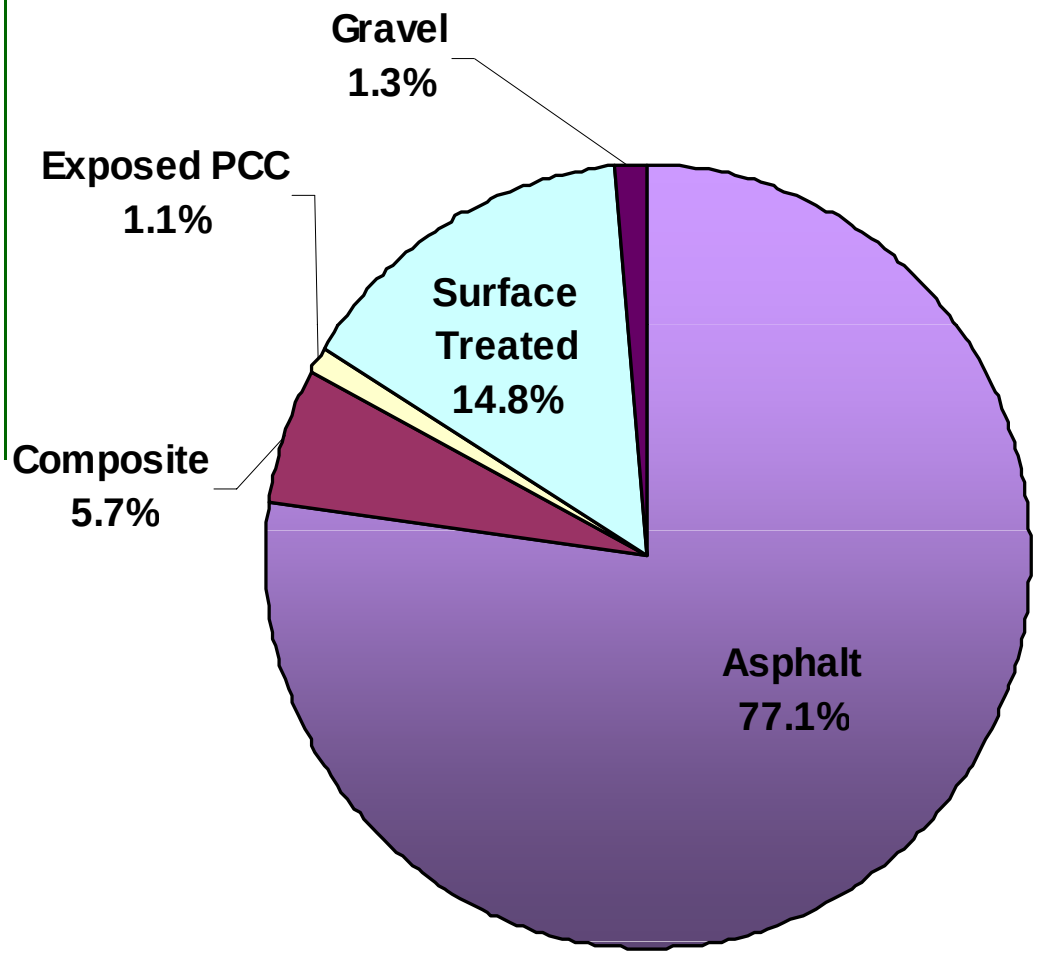
Presentation Outline

- **Pavement Condition Survey**
  - **MTO Pavement Network**
  - **Acquisition of Pavement Condition Data**
    - **Pavement Distress**
    - **Pavement Roughness**
- **Evaluation of Pavement Distresses**
  - **Distress Manifestation Index (DMI)**
  - **DMI Definition**
  - **Rationalize DMI**

Pavement Condition Survey

- **MTO Pavement Network consists of five pavement types:**
  - **Hot mix asphalt, AC**
  - **Concrete, PCC**
  - **Composite, COM**
  - **Surface treated, ST**
  - **And gravel roads**
- **Currently, there are 1706 pavement mgmt sections in the provincial network, the average length of each section is 10km**
- **Each pavement section is uniform in terms of performance and pavement structure**

MTO Pavement Network



Total 18,688 km

AC: 14,408

PCC: 206

COM: 1065

ST: 2766

Gravel: 243

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Pavement Condition Survey

Acquisition of Pavement Condition Data:

- **Pavement Distress (DMI)**
- **Pavement Ride Quality (IRI)**

Pavement Distress

- **Pavement Distress is subjectively evaluated by MTO regional pavement evaluators in the field using reference Manuals for Pavement Condition Rating**
- **Depending pavement type, there are 13 to 16 individual distresses to be evaluated in the field for each pavement section**
- **Pavement distresses are summarized using a Distress Manifestation Index (DMI) for each section**

Pavement Condition Rating Manuals

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Sample Individual Distresses

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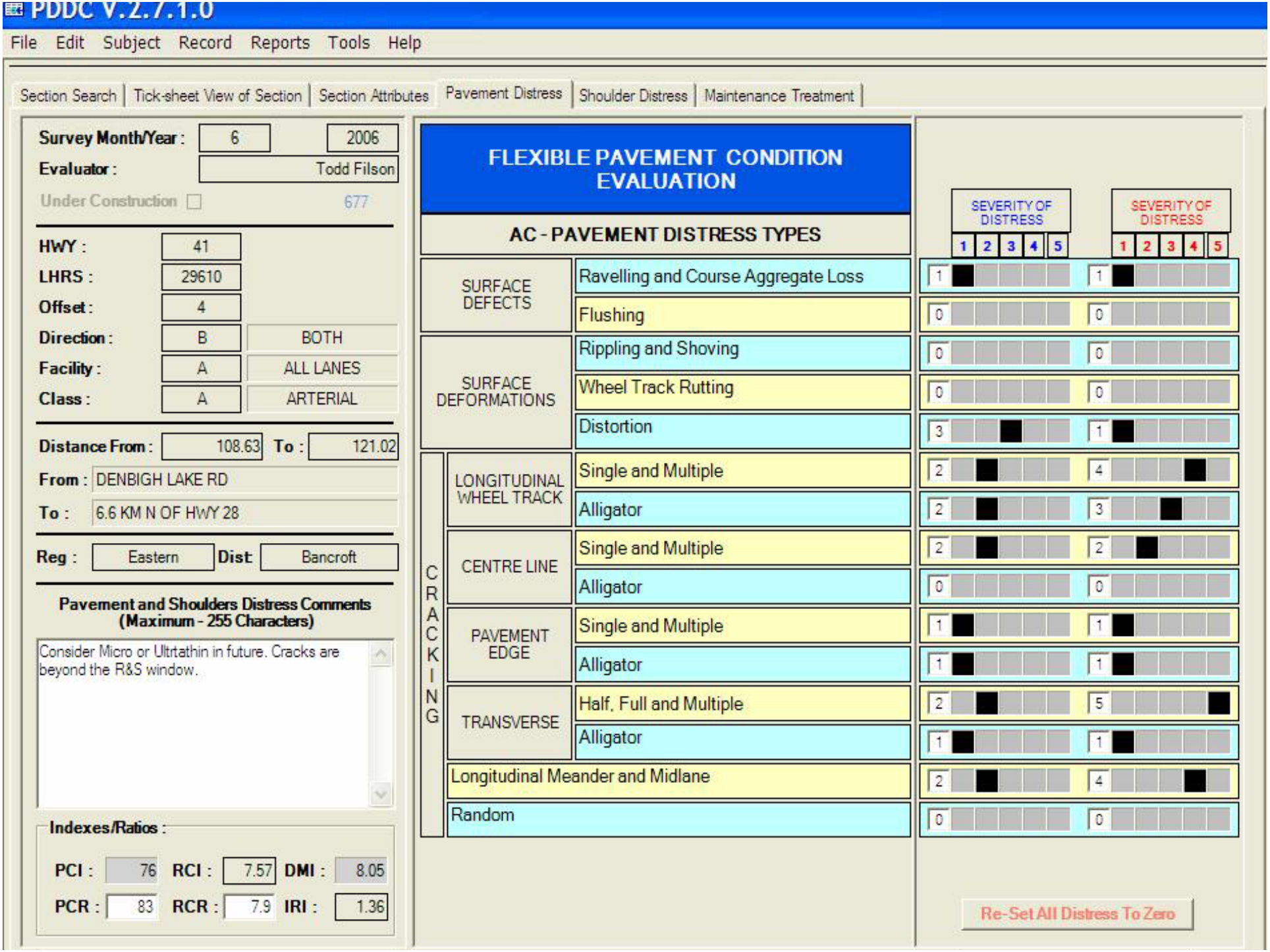
Sample Individual Distresses

List of Distress Components

Asphalt Concrete Pavement (AC)
Ravelling and Coarse Aggregate Loss
Flushing
Rippling and Shoving
Wheel Track Rutting
Distortion
Longitudinal Wheel Track: Sing. / Multi.
Longitudinal Wheel Track: Alligator
Longitudinal Meandering and Midlane
Transverse: Half, Full and Multiple
Transverse: Alligator
Centreline: Single and Multiple
Centreline: Alligator
Pavement Edge: Single and Multiple
Pavement Edge: Alligator
Random/Map

Portland Cement Concrete (PCC)
Ravelling and Coarse Aggregate Loss
Polishing
Scaling
Potholing
Joint and Crack Spalling
Faulting
Distortion
Joint Failure
Longitudinal Joint Separation
Longitudinal and Meandering Cracking
Transverse Joint Creep
Transverse Cracking
Joint Sealant Loss
Diagonal Corner and Edge Crescent
“D” Cracking


PDDC V.2.7.1.0
File Edit Subject Record Reports Tools Help
Section Search
Tick-sheet View of Section
Section Attributes
Pavement Distress
Shoulder Distress
Maintenance Treatment
Survey Month/Year : 6 2006
Evaluator : Todd Filson
Under Construction
677
HWY : 41
LHRS : 29610
Offset : 4
Direction : B BOTH
Facility : A ALL LANES
Class : A ARTERIAL
Distance From : 108.63 To : 121.02
From : DENBIGH LAKE RD
To : 6.6 KM N OF HWY 28
Reg : Eastern Dist: Bancroft
Pavement and Shoulders Distress Comments (Maximum - 255 Characters)
Consider Micro or Ultrtathin in future. Cracks are beyond the R&S window.
Indexes/Ratios :
PCI : 76 RCI : 7.57 DMI : 8.05
PCR : 83 RCR : 7.9 IRI : 1.36
FLEXIBLE PAVEMENT CONDITION EVALUATION
AC - PAVEMENT DISTRESS TYPES
SEVERITY OF DISTRESS
1 2 3 4 5
SEVERITY OF DISTRESS
1 2 3 4 5
SURFACE DEFECTS
Ravelling and Course Aggregate Loss
Flushing
SURFACE DEFORMATIONS
Rippling and Shoving
Wheel Track Rutting
Distortion
CRACKING
LONGITUDINAL WHEEL TRACK
Single and Multiple
Alligator
CENTRE LINE
Single and Multiple
Alligator
PAVEMENT EDGE
Single and Multiple
Alligator
TRANSVERSE
Half, Full and Multiple
Alligator
Longitudinal Meander and Midlane
Random
Re-Set All Distress To Zero

Distress Manifestation Index (DMI)

$$DMI = \sum_{i=1}^{15} w_i (s_i + e_i)$$

i = individual distress types

w_i = weighting factor of distress (i) (0.5 to 3.0)

s_i = severity of distress (1 to 5)

e_i = extent of distress (1 to 5)

Scale for Severity Rating

- **Five (5) severity Levels for AC, PCC and COM type of pavement, ranging from 1 to 5**

$$S_i(n) = \begin{Bmatrix} VerySlight, & n = 1 \\ Slight & n = 2 \\ Moderate & n = 3 \\ Severe & n = 4 \\ VerySevere, & n = 5 \end{Bmatrix}$$

- **Three (3) severity Levels for ST pavement**

$$S_i(n) = \begin{Bmatrix} light & n = 2 \\ Moderate, & n = 3 \\ Severe & n = 4 \end{Bmatrix}$$

Scale for Density Rating

- Five (5) Density/Extent levels for AC, PCC and COM pavement, in terms of percentage %

$$D_i(n) = \begin{Bmatrix} 0-20\%, & n=1 \\ 20-40\%, & n=2 \\ 40-60\%, & n=3 \\ 60-80\%, & n=4 \\ 80-100\%, & n=5 \end{Bmatrix}$$

- Three (3) Density/Extent levels for ST pavement

$$D_i(n) = \begin{Bmatrix} 0-20\%, & n=2 \\ 20-50\% & n=3 \\ 50-100\%, & n=4 \end{Bmatrix}$$

Goal and Objectives

- The goal is to reduce number of distresses in pavement condition survey at network level
- Examine how individual surface distress contributes to the overall assessment of pavement condition
- Identify and eliminate individual distresses that have minor impacts on DMI
- Provide inputs and technical guidelines for developing and applying automatic data collection technology

Technical Approach

- **Identify individual distress' impact/contribution to DMI value**
- **Eliminate the distresses that have minor impacts on DMI without affecting historic and current pavement condition assessment**
- **Verify and confirm analysis results by applying additional data and information**

Weights of Individual Distresses

Asphalt Concrete Pavement (AC)	Weight (W_i)
Ravelling and Coarse Aggregate Loss	3
Flushing	1.5
Rippling and Shoving	1
Wheel Track Rutting	3
Distortion	3
Longitudinal Wheel Track: Sing. / Multi.	1.5
Longitudinal Wheel Track: Alligator	3
Longitudinal Meandering and Midlane	1
Transverse: Half, Full and Multiple	1
Transverse: Alligator	3
Centreline: Single and Multiple	0.5
Centreline: Alligator	2
Pavement Edge: Single and Multiple	0.5
Pavement Edge: Alligator	1.5
Random/Map	0.5

Portland Cement Concrete (PCC)	Weight (W_i)
Ravelling and Coarse Aggregate Loss	0.5
Polishing	1.5
Scaling	1.5
Potholing	1
Joint and Crack Spalling	2
Faulting	2.5
Distortion	1
Joint Failure	3
Longitudinal Joint Separation	1
Longitudinal and Meandering Cracking	2
Transverse Joint Creep	0.5
Transverse Cracking	2
Joint Sealant Loss	0.5
Diagonal Corner and Edge Crescent	2.5
"D" Cracking	3

Weights of Individual Distresses (Cont')

Composite Pavement COM	Weight (W_i)
Ravelling and Coarse Aggregate Loss	3
Flushing	1.5
Spalling	2
Tenting/Cupping	2.5
Wheel Track Rutting	3
Joint Failures	3
Distortion and Settlement	1
Longitudinal Meandering (Single & Multiple)	2
Transverse: Single	1
Transverse: Multiple	1
Transverse Joints: Sawed	0.5
Transverse Joints: Reflective	2
Centreline: Single	0.5
Centreline: Multiple	1.5
Diagonal, Corner and Edge Crescent	2.5
Random/Map	0.5

Surface Treated ST	Weight (W_i)
Cover Aggregate Loss	3
Flushing	2
Streaking	1
Potholing	1
Rippling and Shoving	2
Wheel Track Rutting	3
Distortion	3
Longitudinal Cracking	1
Transverse Cracking	0.5
Pavement Edge Break	2
Pavement Edge Cracking	1
Alligator Cracking	3

Re-definition of DMI (#)

- DMI(#) standards for DMI that is calculated by use of the existing formula but excluding individual distresses that have weight factors lower than #
  - DMI(1) contains distresses with weight >=1
  - Similar definition for DMI(1.5), DMI(2) and DMI(3)
- DMI(C) and DMI(C&R) include only cracking / cracking & rutting as distresses
- DMI (T) is the original DMI (including all distresses)

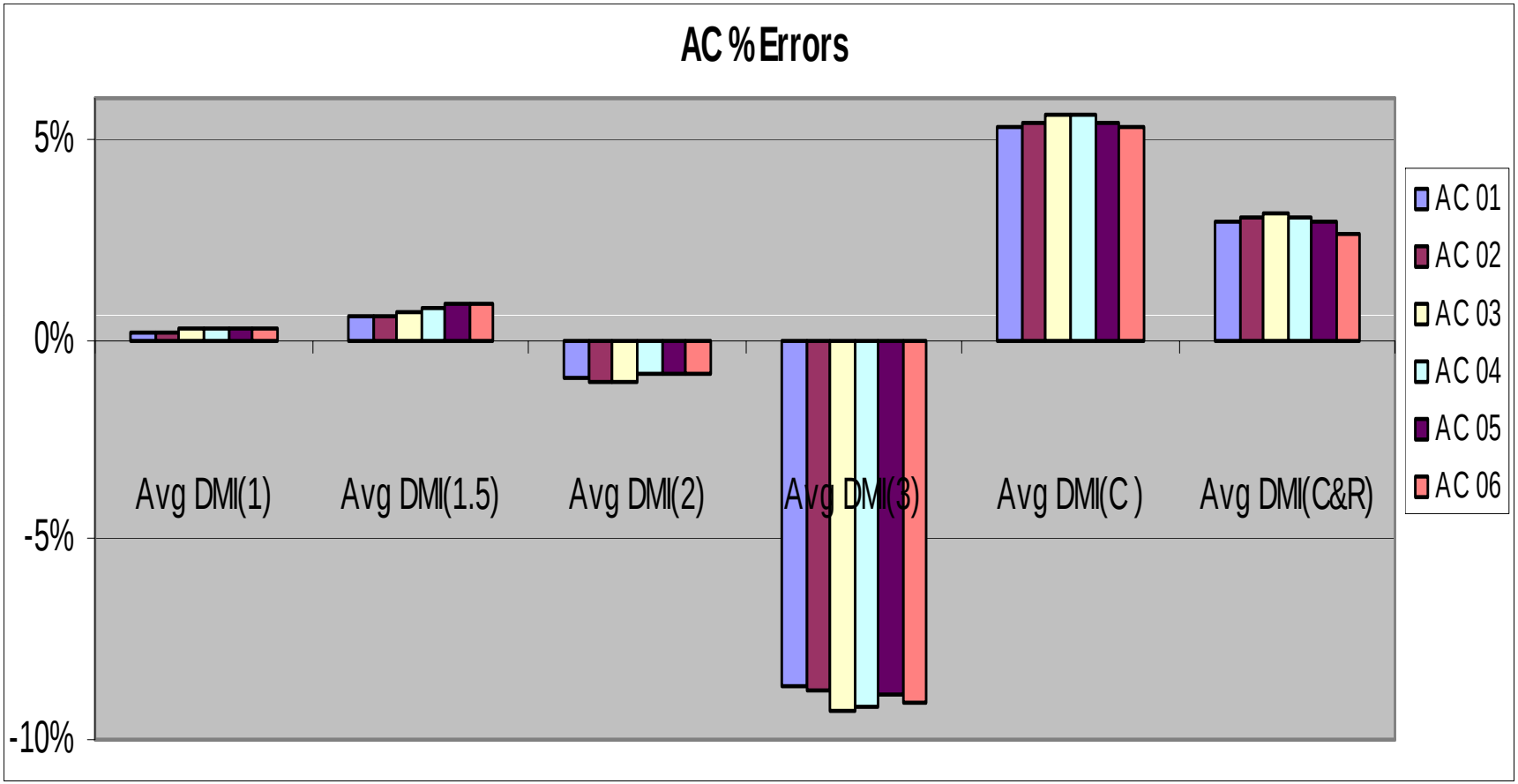
Analysis of Re-defined DMI (#)

- Use six years historic data (from 2001 to 2006) extracted form MTO pavement management databases
- DMI (#) were calculated and then compared with the DMI (T) to produce an error percentage
- Note that the sample size varies significantly between the four pavement types:
  - 1344 AC Sections, 26 PCC Sections, 22 COM Sections, and 271 ST Sections

Results for AC Pavement

	AC 01	err%	AC 02	err%	AC 03	err%	AC 04	err%	AC 05	err%	AC 06	err%	avg err%	avg |err| %
DMI (T)	8.26		8.24		8.16		8.17		8.19		8.19			
Avg DMI(1)	8.27	0.2%	8.26	0.2%	8.18	0.2%	8.19	0.2%	8.22	0.3%	8.21	0.2%	0.2%	0.2%
Avg DMI(1.5)	8.31	0.6%	8.29	0.6%	8.22	0.7%	8.23	0.8%	8.26	0.9%	8.26	0.9%	0.7%	0.7%
Avg DMI(2)	8.18	-1.0%	8.15	-1.1%	8.07	-1.1%	8.10	-0.9%	8.13	-0.8%	8.12	-0.9%	-1.0%	1.0%
Avg DMI(3)	7.55	-8.7%	7.51	-8.8%	7.40	-9.3%	7.42	-9.1%	7.46	-8.9%	7.45	-9.0%	-9.0%	9.0%
Avg DMI(C)	8.70	5.3%	8.68	5.4%	8.61	5.6%	8.63	5.6%	8.63	5.4%	8.62	5.3%	5.4%	5.4%
Avg DMI(C&R)	8.50	2.9%	8.49	3.0%	8.41	3.1%	8.42	3.0%	8.43	2.9%	8.40	2.6%	2.9%	2.9%

Results for AC Pavements (Cont')

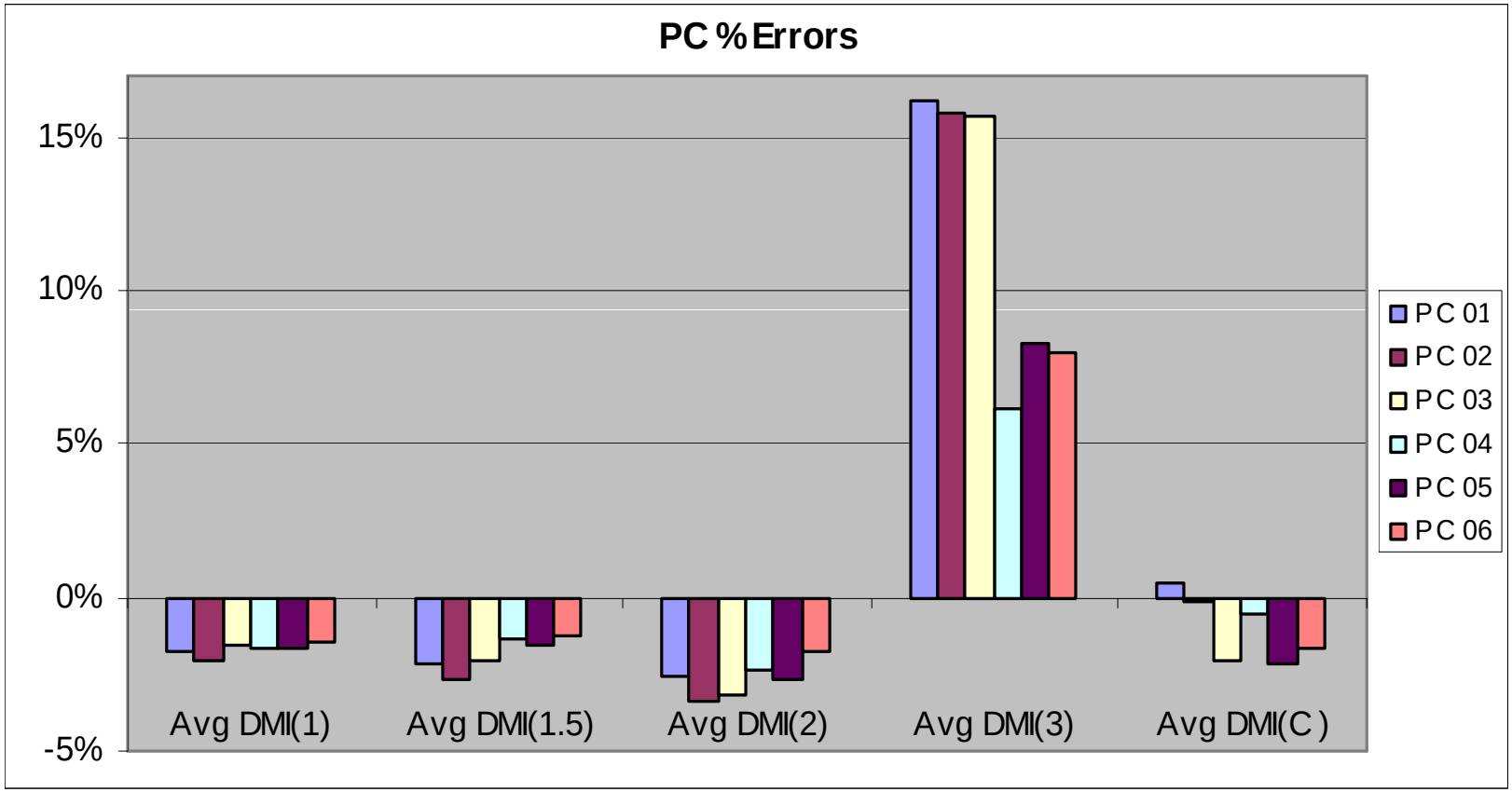


Comparison between errors from each modified DMI (AC)

Results for PCC Pavement

	PC 01	err%	PC 02	err%	PC 03	err%	PC 04	err%	PC 05	err%	PC 06	err%	avg err%	avg |err|%
T_DMI	7.95		7.65		7.81		8.32		8.16		8.49			
Avg DMI(1)	7.81	-1.8%	7.49	-2.1%	7.68	-1.6%	8.18	-1.6%	8.02	-1.7%	8.37	-1.4%	-1.7%	1.7%
Avg DMI(1.5)	7.78	-2.2%	7.44	-2.6%	7.65	-2.1%	8.20	-1.4%	8.04	-1.5%	8.38	-1.3%	-1.8%	1.8%
Avg DMI(2)	7.74	-2.6%	7.38	-3.4%	7.56	-3.1%	8.12	-2.3%	7.95	-2.6%	8.34	-1.8%	-2.6%	2.6%
Avg DMI(3)	9.24	16.2%	8.85	15.8%	9.03	15.7%	8.83	6.1%	8.84	8.3%	9.17	8.0%	11.7%	11.7%
Avg DMI(C)	7.98	0.5%	7.64	-0.1%	7.65	-2.1%	8.27	-0.5%	7.98	-2.2%	8.35	-1.6%	-1.0%	1.2%

Results for PCC Pavement (Cont')

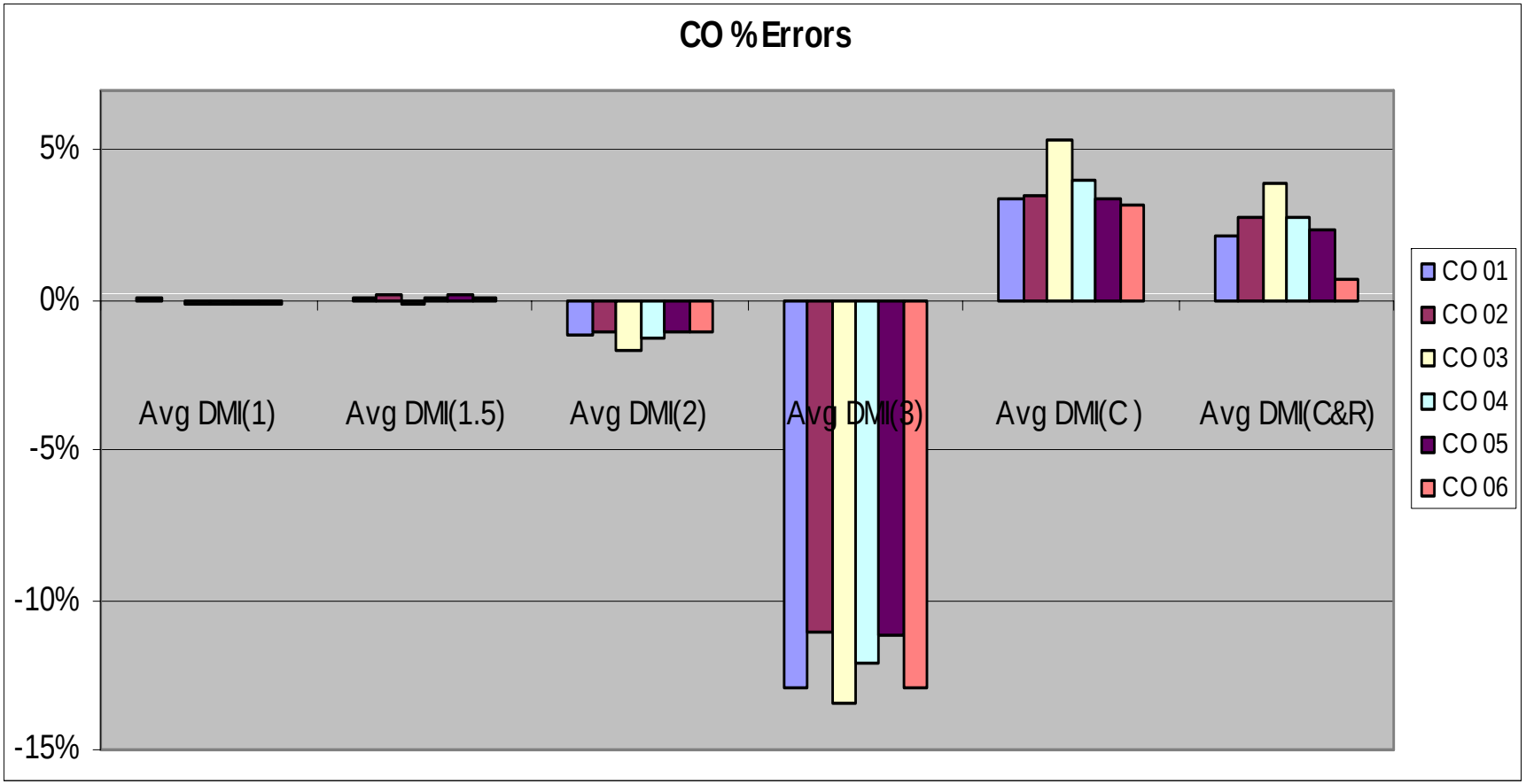


Comparison between errors from each modified DMI (PC)

Results for COM Pavement

	CO 01	err%	CO 02	err%	CO 03	err%	CO 04	err%	CO 05	err%	CO 06	err%	avg err%	avg |err| %
DMI (T)	8.67		8.84		8.70		8.72		8.73		8.55			
Avg DMI(1)	8.68	0.1%	8.83	-0.1%	8.69	-0.1%	8.71	-0.1%	8.71	-0.1%	8.54	-0.1%	-0.1%	0.1%
Avg DMI(1.5)	8.68	0.1%	8.85	0.2%	8.70	-0.1%	8.73	0.1%	8.74	0.2%	8.56	0.1%	0.1%	0.1%
Avg DMI(2)	8.58	-1.1%	8.74	-1.1%	8.56	-1.6%	8.61	-1.3%	8.64	-1.0%	8.46	-1.1%	-1.2%	1.2%
Avg DMI(3)	7.55	-12.9%	7.86	-11.0%	7.53	-13.4%	7.67	-12.1%	7.75	-11.2%	7.44	-13.0%	-12.3%	12.3%
Avg DMI(C)	8.96	3.3%	9.14	3.5%	9.17	5.3%	9.07	4.0%	9.02	3.4%	8.82	3.2%	3.8%	3.8%
Avg DMI(C&R)	8.86	2.1%	9.08	2.8%	9.05	4.0%	8.96	2.7%	8.93	2.3%	8.61	0.7%	2.4%	2.4%

Results for COM Pavement (Cont')

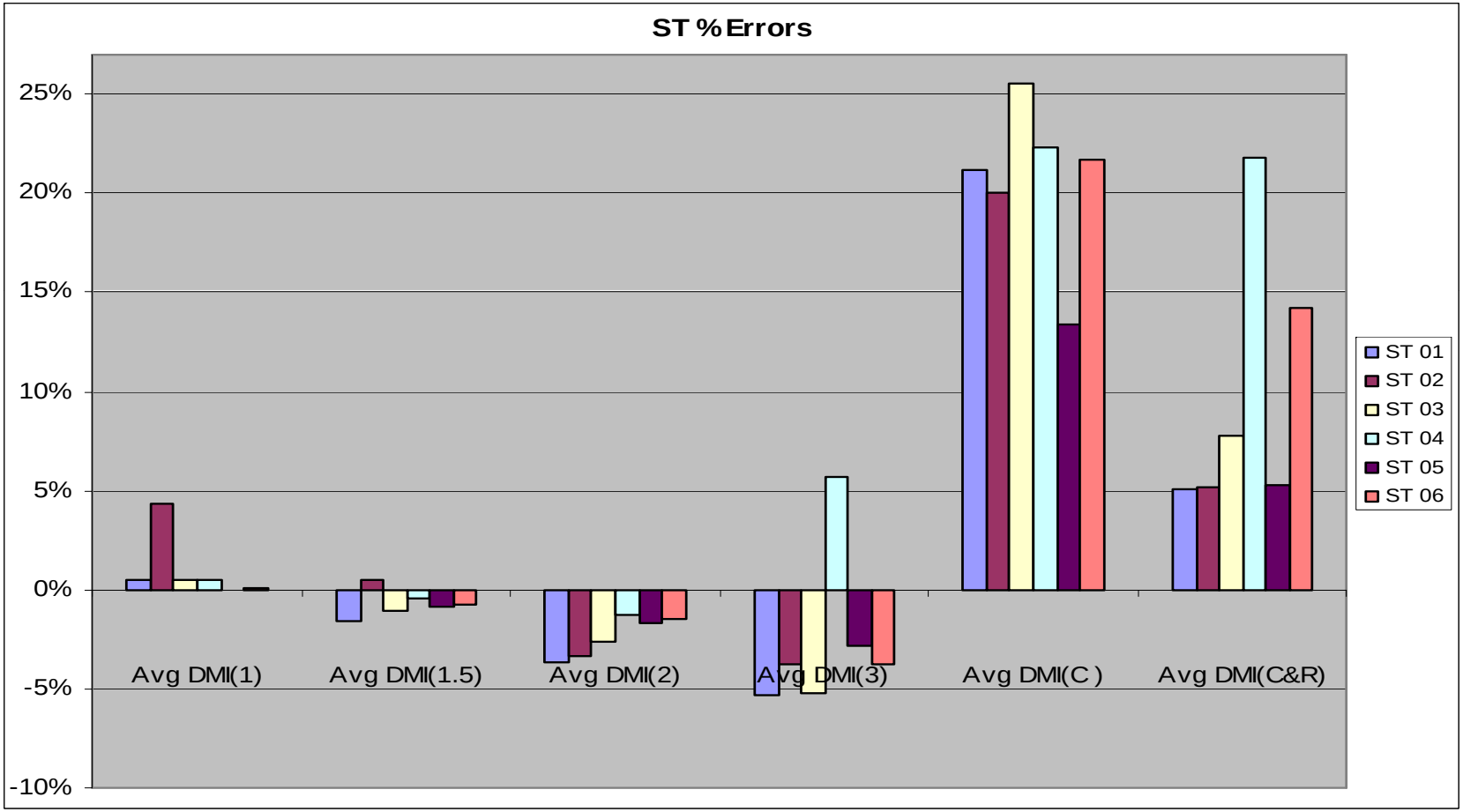


Comparison between errors from each modified DMI (COM)

Results for ST Pavement

	ST 01	err%	ST 02	err%	ST 03	err%	ST 04	err%	ST 05	err%	ST 06	err%	avg err%	avg |err|%
DMI(T)	4.38		4.66		4.67		4.69		6.74		6.84			
Avg DMI(1)	4.40	0.5%	4.86	4.3%	4.69	0.5%	4.71	0.5%	6.74	0.0%	6.85	0.1%	1.0%	1.0%
Avg DMI(1.5)	4.31	-1.6%	4.68	0.5%	4.62	-1.1%	4.67	-0.4%	6.69	-0.8%	6.80	-0.7%	-0.7%	0.9%
Avg DMI(2)	4.22	-3.7%	4.50	-3.3%	4.55	-2.6%	4.63	-1.3%	6.63	-1.7%	6.74	-1.5%	-2.4%	2.4%
Avg DMI(3)	4.15	-5.3%	4.48	-3.8%	4.42	-5.3%	4.96	5.7%	6.55	-2.8%	6.59	-3.7%	-2.5%	4.4%
Avg DMI(C)	5.31	21.2%	5.59	20.1%	5.86	25.6%	5.73	22.3%	7.65	13.4%	8.33	21.7%	20.7%	20.7%
Avg DMI(C&R)	4.61	5.1%	4.90	5.2%	5.03	7.8%	5.71	21.8%	7.10	5.3%	7.82	14.3%	9.9%	9.9%

Results for ST Pavement (Cont')



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Summary and Conclusions

- DMI(2) produces good results for all pavement types, which results in a maximum average deviation from DMI (T) of about 3%
  - maximum magnitude of error in DMI(2) in any year for any type was only 3.7% (ST 2001)
  - maximum average error for a type over the six years was 2.6% (in PCC)

Summary and Conclusions

- Using DMI(2) will result in a reduction of 50% individual distresses currently evaluated
- DMI(C&R) may be considered to replace DMI(T) for AC and COM pavements, particularly where automated data collection is planned
- DMI(3) shows severe deviations from DMI(T) for all pavement types
- DMI(C) shows large variations from DMI (T)

Two-tailed Z test

- The following formula was used:

$$p(value) = 2 * P\left(Z > \frac{\overline{X} - \mu}{\sigma / \sqrt{n}} \right)$$

- A lower p-value translates to higher confidence that the null hypothesis (no systematic bias exists) needs to be rejected
- A High p-value signifies the deviation of a modified DMI from DMI(T) could have happened naturally

Z-test Results (Cont')

p-value	Interpretation
>10%	No evidence against null hypothesis
5%-10%	Weak evidence against null hypothesis
1%-5%	Some evidence against null hypothesis
0.1%-1%	Strong evidence against null hypothesis
<0.1%	Very strong evidence against null hypothesis

Z-test Results (Cont')

	AC		PCC		COM		ST	
DMI (T)	8.1944		8.1616		8.7273		6.7417	
DMI(1)	8.2160	60.03%	8.0243	38.00%	8.7143	96.76%	6.7427	99.12%
DMI(1.5)	8.2643	9.00%	8.0362	42.26%	8.7404	96.73%	6.6863	54.28%
DMI(2)	8.1254	9.42%	7.9454	16.68%	8.6360	77.53%	6.6298	21.94%
DMI(3)	7.4640	0.00%	8.8352	0.00%	7.7514	0.23%	6.5529	3.83%

Results of 2-tailed z-test, σ=1.0

Remaining Distress Components of DMI(2) for AC Pavement

Asphalt Concrete Pavement (AC)	Weight (W_i)
Ravelling and Coarse Aggregate Loss	3
Flushing	1.5
Rippling and Shoving	1
Wheel Track Rutting	3
Distortion	3
Longitudinal Wheel Track: Sing. / Multi.	1.5
Longitudinal Wheel Track: Alligator	3
Longitudinal Meandering and Midlane	1
Transverse: Half, Full and Multiple	1
Transverse: Alligator	3
Centreline: Single and Multiple	0.5
Centreline: Alligator	2
Pavement Edge: Single and Multiple	0.5
Pavement Edge: Alligator	1.5
Random/Map	0.5

Asphalt Concrete Pavement (AC)	Weight (W_i)
Ravelling and Coarse Aggregate Loss	3
Wheel Track Rutting	3
Distortion	3
Longitudinal Wheel Track: Alligator	3
Transverse: Alligator	3
Centreline: Alligator	2

Remaining Distress Components of DMI(2) for PCC Pavement

Portland Cement Concrete (PCC)	Weight (W_i)
Ravelling and Coarse Aggregate Loss	0.5
Polishing	1.5
Scaling	1.5
Potholing	1
Joint and Crack Spalling	2
Faulting	2.5
Distortion	1
Joint Failure	3
Longitudinal Joint Separation	1
Longitudinal and Meandering Cracking	2
Transverse Joint Creep	0.5
Transverse Cracking	2
Joint Sealant Loss	0.5
Diagonal Corner and Edge Crescent	2.5
"D" Cracking	3

Portland Cement Concrete (PCC)	Weight (W_i)
Joint and Crack Spalling	2
Faulting	2.5
Joint Failure	3
Longitudinal and Meandering Cracking	2
Transverse Cracking	2
Diagonal Corner and Edge Crescent	2.5
"D" Cracking	3

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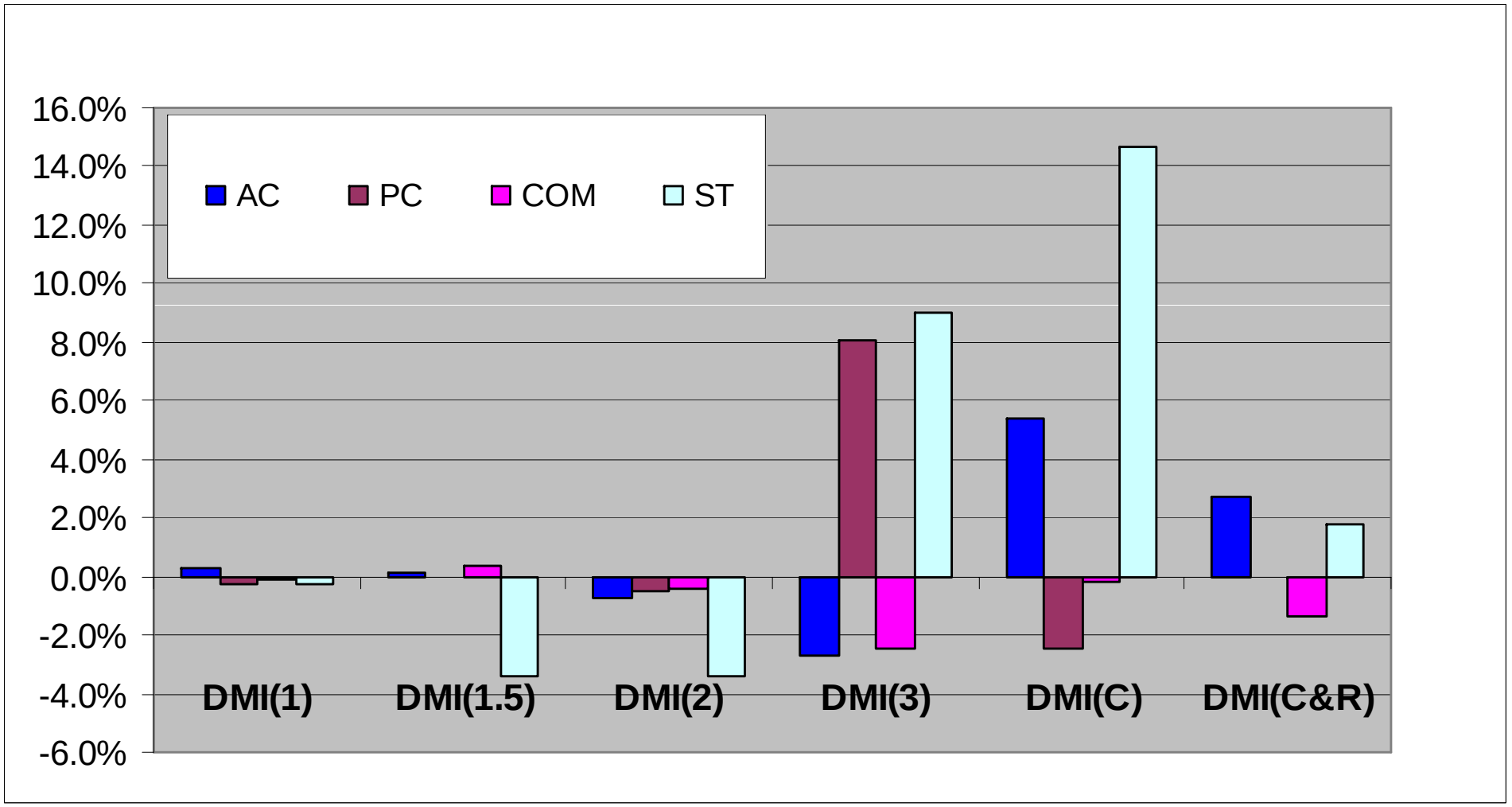
Verification by Applying 2007 Data

	AC		PCC		COM		ST	
	DMI Avg.	Error %	DMI Avg.	Error %	DMI Avg.	Error %	DMI Avg.	Error %
DMI	8.16		8.85		8.72		8.06	
DMI(1)	8.19	0.3%	8.82	-0.3%	8.71	-0.1%	8.04	-0.3%
DMI(1.5)	8.24	0.1%	8.85	0.0%	8.76	0.4%	7.79	-3.4%
DMI(2)	8.10	-0.7%	8.80	-0.5%	8.68	-0.4%	7.79	-3.4%
DMI(3)	7.95	-2.7%	9.56	8.1%	8.50	-2.5%	7.34	9.0%
DMI (C)	8.61	5.4%	8.62	-2.5%	8.70	-0.2%	9.25	14.7%
DMI(C&R)	8.38	2.7%	-	-	8.60	-1.4%	8.21	1.8%

Verification by Applying 2007 Data



Thank You!

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