Quality Assurance of Pavement Profile Measurements in Managing Ontario Provincial Highway Network

Road Profiler User Group (RPUG)
Stateline, Nevada
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Li Ningyuan
Ministry of Transportation of Ontario

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Presentation Highlights

- Current Practice in Ontario Pavement Condition Surveys and Evaluation Methods
- Issues Concerned with Quality of Pavement Profile Measurements
- Issues Concerned with Subjective Evaluation of Pavement Distresses
- Improving Quality of Pavement Profile Measurement and Performance Evaluation
- Summary and Conclusion

Ontario Pavement Condition Surveys and Evaluation Methods

- Pavement riding quality and rutting are measured by using high-speed laser distance measuring instruments
  - Longitudinal profiles – converting to IRI
  - Transverse profiles – calculating Rut
  - Automated process since 1997
- Pavement distresses are subjectively assessed in the field by experienced pavement evaluators
  - Field visual assessment since 1980
  - Severity and density of each distress in a pre-defined section
  - Rated by Distress Manifestation Index (DMI)
- PCI (Pavement Condition Index) is a function of IRI and DMI

Automated Road Analyzer (ARAN)

- Measure rutting and roughness on network level surveys, utilizing 36 ultrasonic sensors mounted on the Smart Bar.
- Measure roughness utilizing two infrared lasers and two accelerometers mounted in the instrument enclosure in front of the wheels.


ARAN
Automatic Road Analyzer
ARAN

Pavement Condition Rating Manuals

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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	1	1
		Flushing	0	0
SURFACE DEFORMATIONS		Rippling and Shoving	0	0
		Wheel Track Rutting	0	0
		Distortion	3	1
CRACKING	LONGITUDINAL WHEEL TRACK	Single and Multiple	2	4
		Alligator	2	3
	CENTRE LINE	Single and Multiple	2	2
		Alligator	0	0
	PAVEMENT EDGE	Single and Multiple	1	1
		Alligator	1	1
	TRANSVERSE	Half, Full and Multiple	2	5
		Alligator	1	1
		Longitudinal Meander and Midlane	2	4
		Random	0	0

Re-Set All Distress To Zero

Distress Evaluation Reporting

MTO PMS

Highway Distress Data

Print Preview 100%

2001/05/20

Location From: NIAGARA/HALDIMAND REGIONAL BNDRY **Location To:** DUNNVILLE-TAYLOR RD

Highway: K 3 0 0 **Traffic Direction:** B **Lane ID:** 0 **From:** 49.568 11700 + 49.568 **Data Year:** 1999

Pavement Type: Bituminous **Survey Date:** 1999/06/30 **To:** 59.568 11700 + 59.568 **PCR:** 45.00

Shoulder Pavement: Bituminous **Shoulder Fully Paved:** Yes **Facility:** Others **DMI:** 5.40 **RCR:** 5.20

Pavement Distress	SEVERITY					DENSITY (%)				
	V. SLIGHT	SLIGHT	MODERATE	SEVERE	V. SEVERE	FEW	INTERMIT	FREQUENT	EXTENSIVE	THROUGH
	1	2	3	4	5	< 10	10-20	20-50	50-80	> 80
Ravel/C.A. Loss				X						X
Flushing										
Rippling/shoving										
W.T. Rutting		X					X			
Distortion		X								X
Long Crck SM			X				X			
Long Crck Allig				X		X				
C.Line Crck SM				X					X	
C.Line Allig			X				X			
Pvt Edge SM			X						X	
Pvt Edge Allig		X				X				
Trans Crck HFM				X						X
Trans Crck Allig			X					X		
Long Crck MM			X					X		
Random Crck			X					X		

Shoulder Distress	SEVERITY				DENSITY (%)			
	Right		Left		Right		Left	
	Mod	Severe	Mod	Severe	10-30	> 30	10-30	> 30
	1	2	1	2	1	2	1	2
Cracking		X		X		X		X
Pvt edge/curb se				X				
Disturtion								

Maintenance Distress		EXTENT OF OCCURRENCE, %				
		< 10	10 - 20	20 - 50	50 - 80	> 80
		1	2	3	4	5
Pavement	Manual patching		X			
	Machine patching	X				
	Spray patching			X		
	Rout & Seal					
	Chip seal					
Shoulders	Manual patching					
	Machine patching					
	Rout & Seal					
	Chip seal					

Comment:

Distress Manifestation Index (DMI)

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

i = distress type i
w_i = weighting factor assigned to distress i
s_i = severity of distress i
e_i = extent of distress i

The scale of DMI is ranged from 0 to 10 in MTO PMS

Issues with Pavement Roughness and Distress Measurements

- Both IRI and DMI represent evaluation of an individual pavement section, which ranges from 600 meters to 56 kilometres, with average length of 10 km
- Distress Manifestation Index (DMI), which is an integrated with 12 to 16 individual distresses, indicates evaluator's overall assessment of a pavement section
- DMI is a subjective evaluation of pavement condition rated by trained and experienced pavement evaluators
- MTO's Pavement Condition Rating Manuals

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

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

Issues Concerned with DMI

- Safety and Accessibility in Field Operation
  - Impossible to operate on high-volume traffic freeways
  - Restricted by vehicle operation speed and visual assessment
- Quality and Productivity of Data Collection
  - Poor quality (accuracy, repeatability and accountability)
  - Subjective bias and errors in evaluation
- Impacts on Pavement Management Process
  - Performance evaluation and needs analysis
  - Decisions in selecting pavement treatments
  - Maintenance programming and investment planning

Facts Considered in Reducing Some individual Distresses

- Type and number of distresses
- Weighting factors of individual distresses
- Distress severity and density
- Minimize impacts on current practice
- Preserve historic data and consistency
- Six years of data were used in performing this study, covering four pavement types, AC, PCC, COM, ST

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

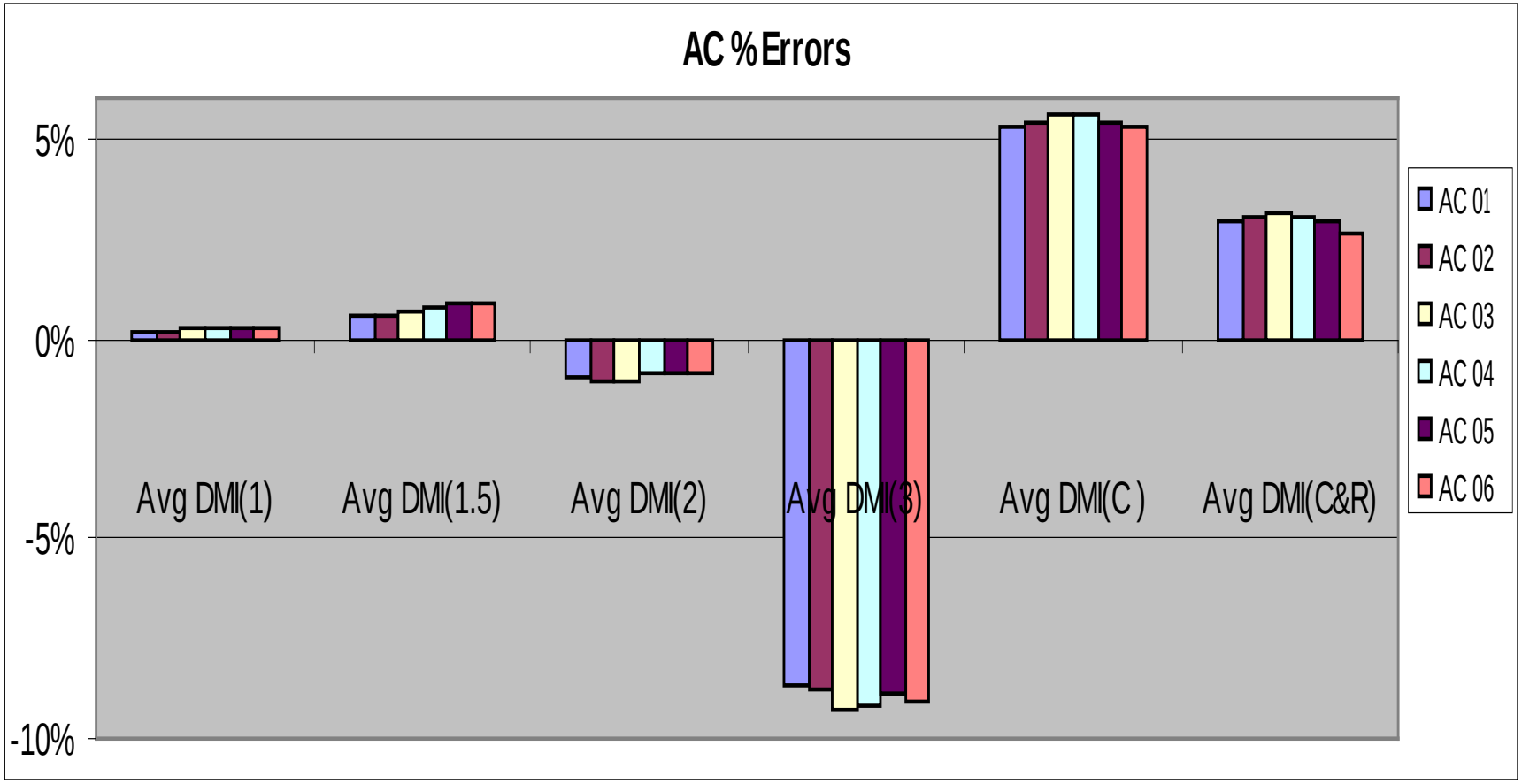
Test Design and Analysis

- Group distress and re-define DMI(#)
- DMI(#) stands for DMI calculated by using the existing formula without 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)

Test Design and Analysis (Cont's)

- Use six years historic data 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*

Analysis Results for AC Pavements



Comparison between errors from each modified DMI (AC)

Analysis Results for PCC Pavements

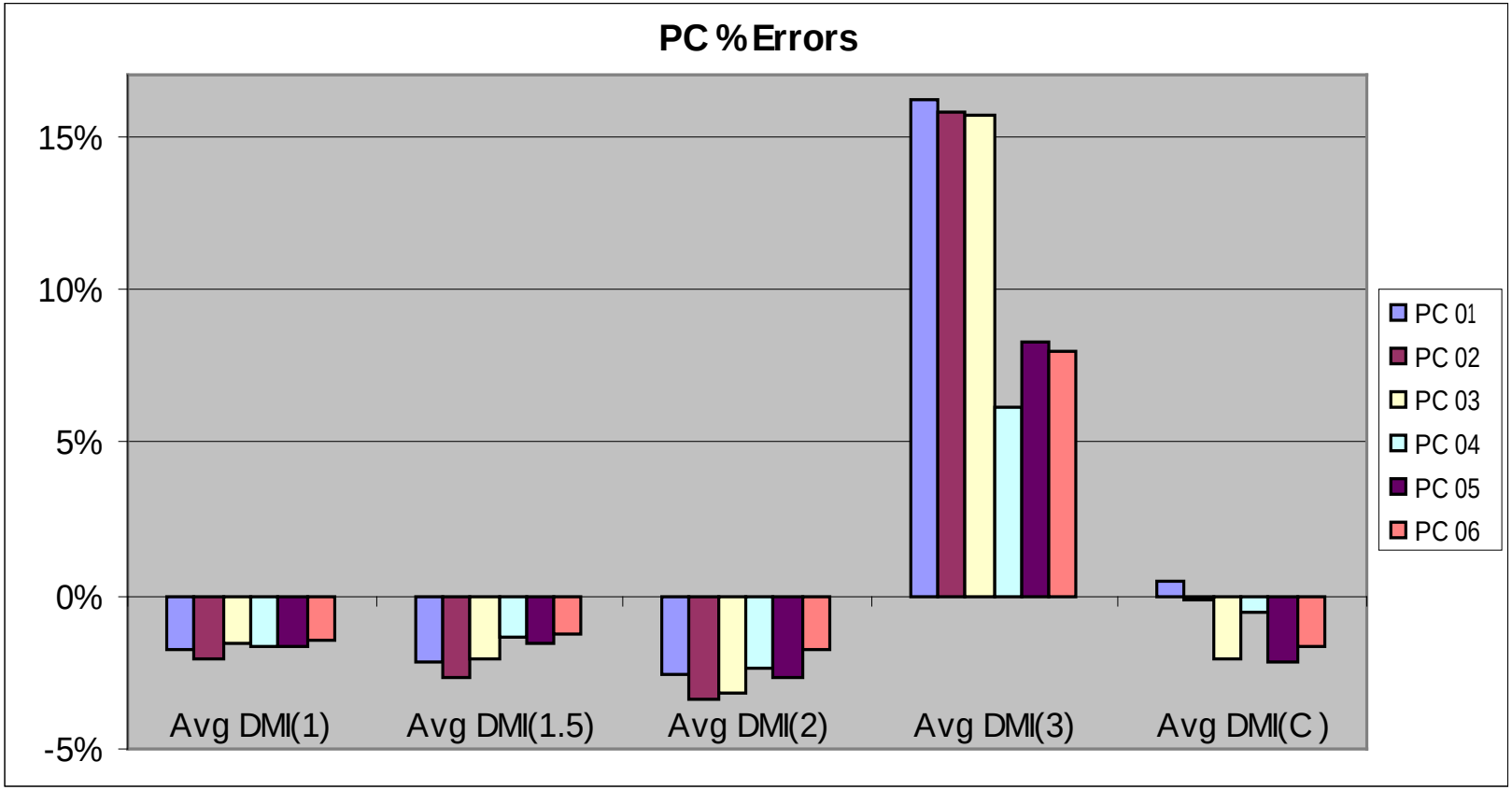
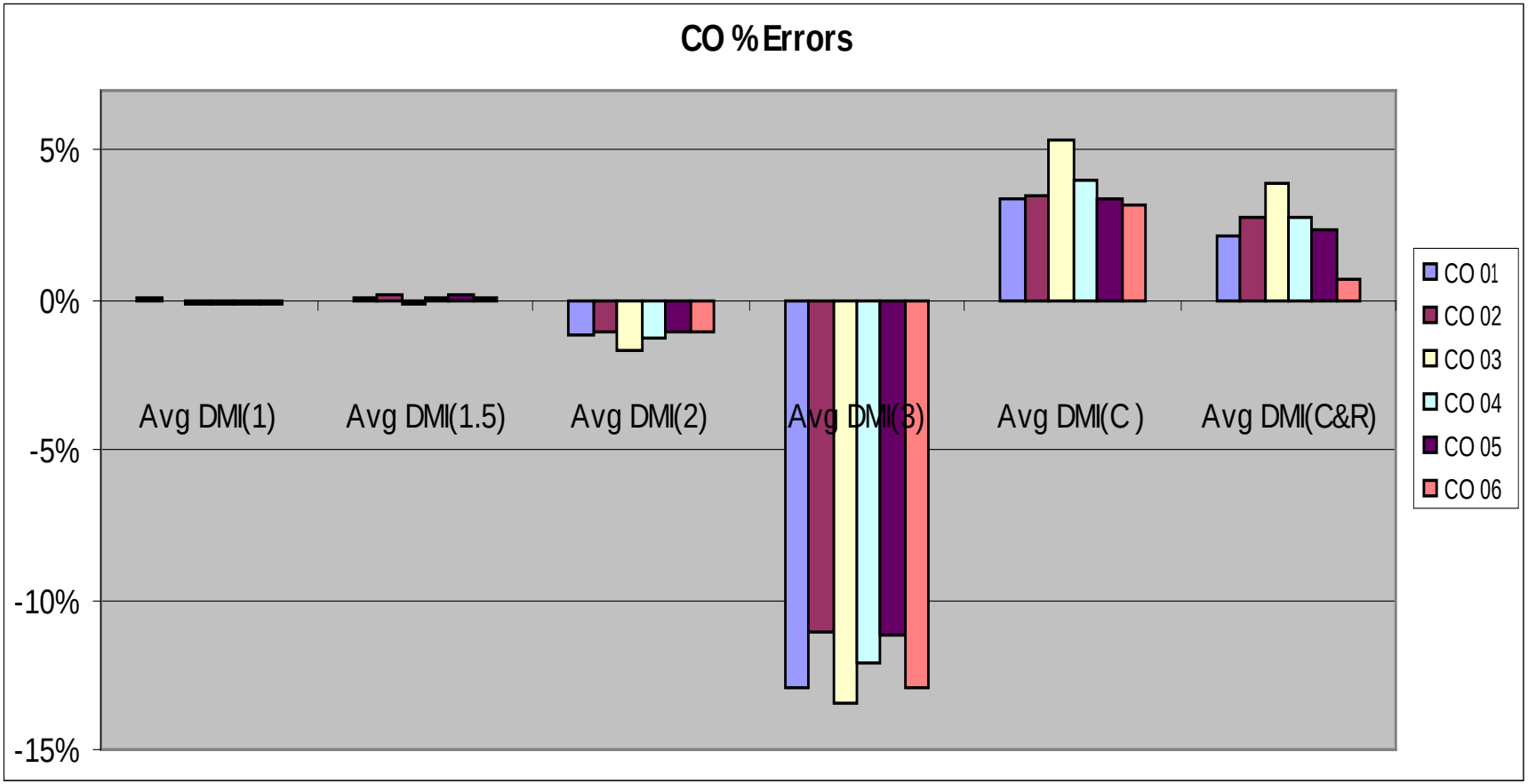


Figure 2: Comparison between errors from each modified DMI (PC)

Analysis Results for COM Pavements



Comparison between errors from each modified DMI (CO)

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Moving towards Automated Data Collection

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Sony HDTV Video Camera

Video Collection

- Images captured by a Sony HDTV wide angle camera.
  - Great image quality and contrast
    - 1920 x 1080 resolution
    - 16:9 aspect ratio
    - 90 degree field of view
  - Camera mounted inside ARAN cabin
    - This allows environmental control

- Capture Interval is 5 meters, total storage per year ~ 2 TB
  - Network Level: Primary Highways, North/West bound, Lane 2
  - Bidirectional information acquired from all of Central, Southern & Eastern Ontario
    - Also where possible in Northern and Northwestern Ontario
  - Project Level testing - as requested

ARAN Data Delivery

- Currently in Excel Format
- Main delivery at year end
  - CD to each region with all pavement data incl:
    - 50m Detailed Data
    - Chart File
    - Summary sheet
- *New for 2007 plotted network/monitor data by region/district

* Still have to determine best method of delivery

Network Level Program

- Collection of:
  - Transverse Profile (Rutting)
  - Longitudinal Profile (Roughness)
  - Orientation (Crossfall)
  - GPS data
- Over 1390 PMS Sections
- North and West on non-divided highways
- Both directions on freeways

Quality Examples - Acceptable

Proposed Method

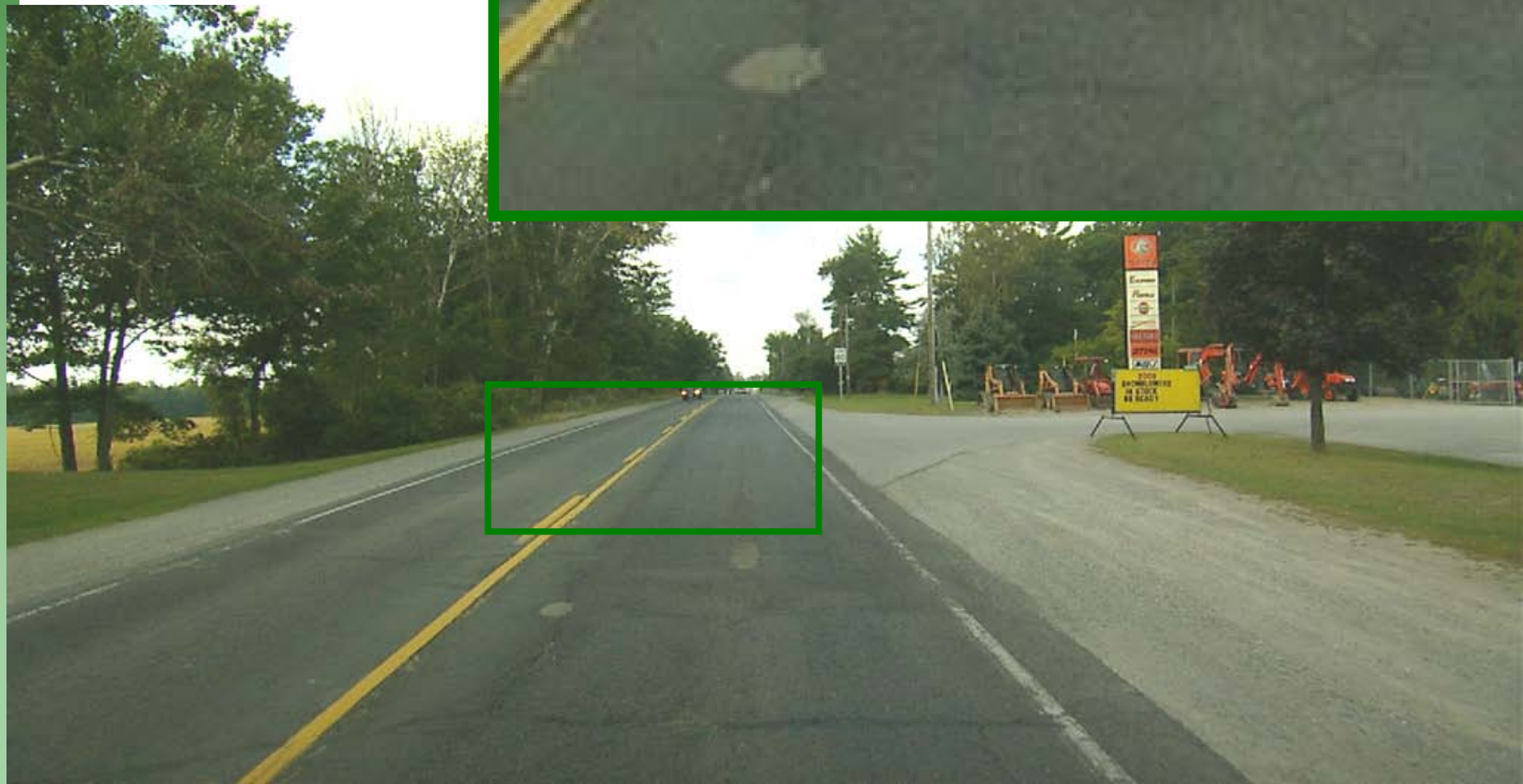
- ARAN will continue to collect HD video-logs
- Raters will then be able to play these video-logs at the office, and manually evaluate roads from images
- This would take care of safety and accessibility issues for high-volume roads, as well as allow raters to make more accurate evaluations

Suggested Implementation

- Images must be viewed on large monitors to ensure that the resolution of HD images is not lost

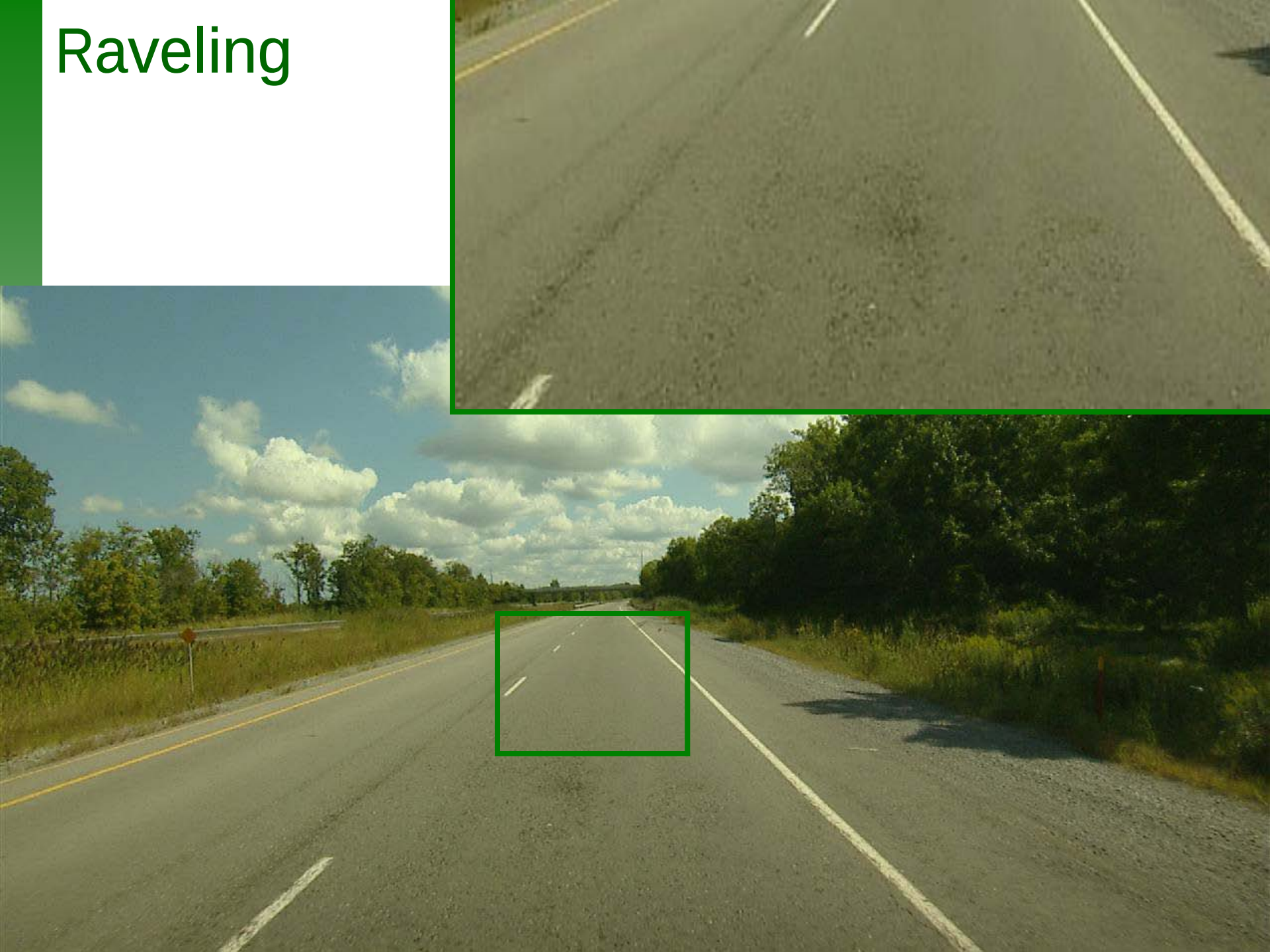
- Video software must be installed, and videos can be viewed on a secondary monitor so that section data and other information can be viewed on the first

Potholing

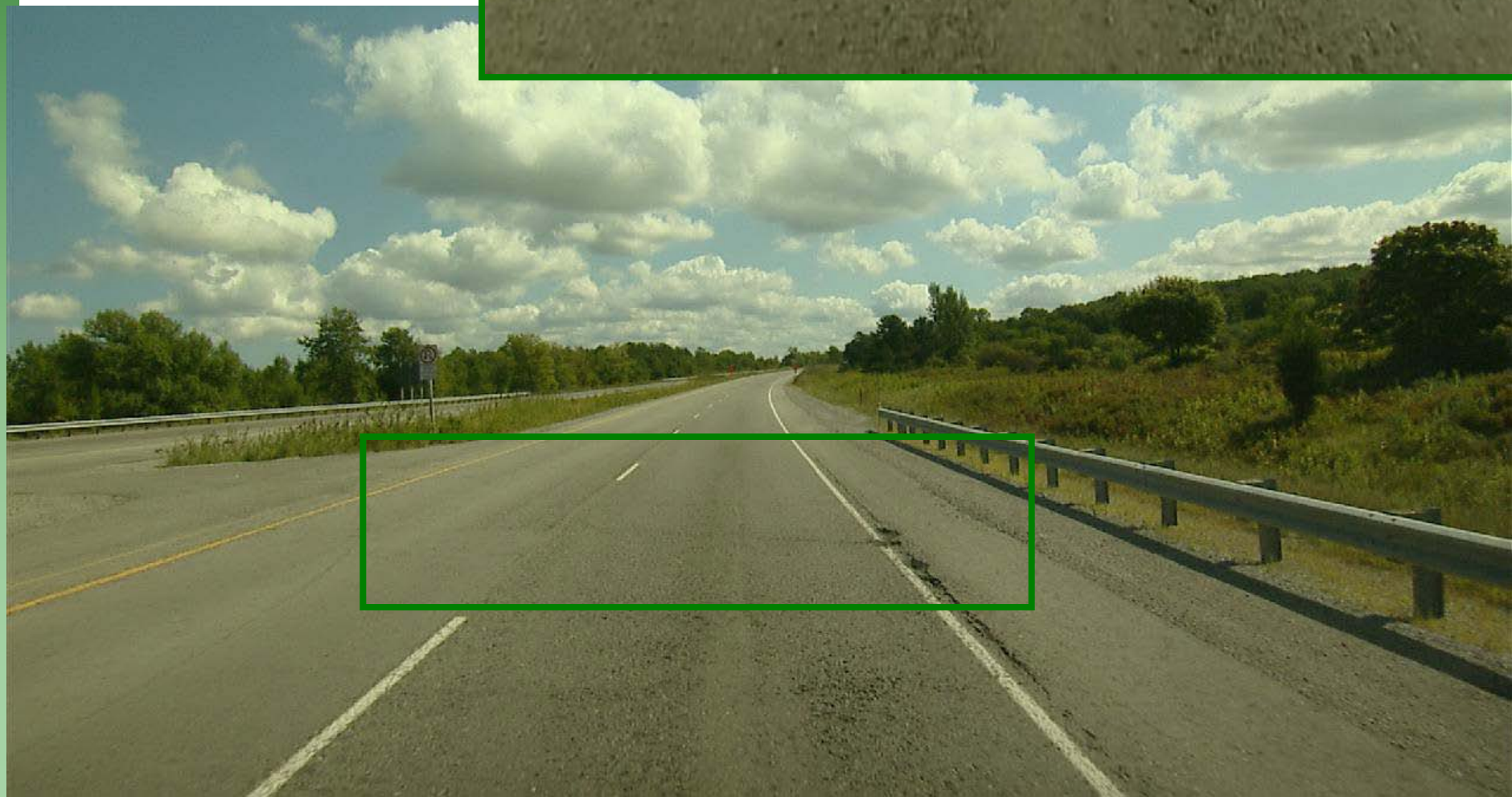


Coarse Aggregate Loss

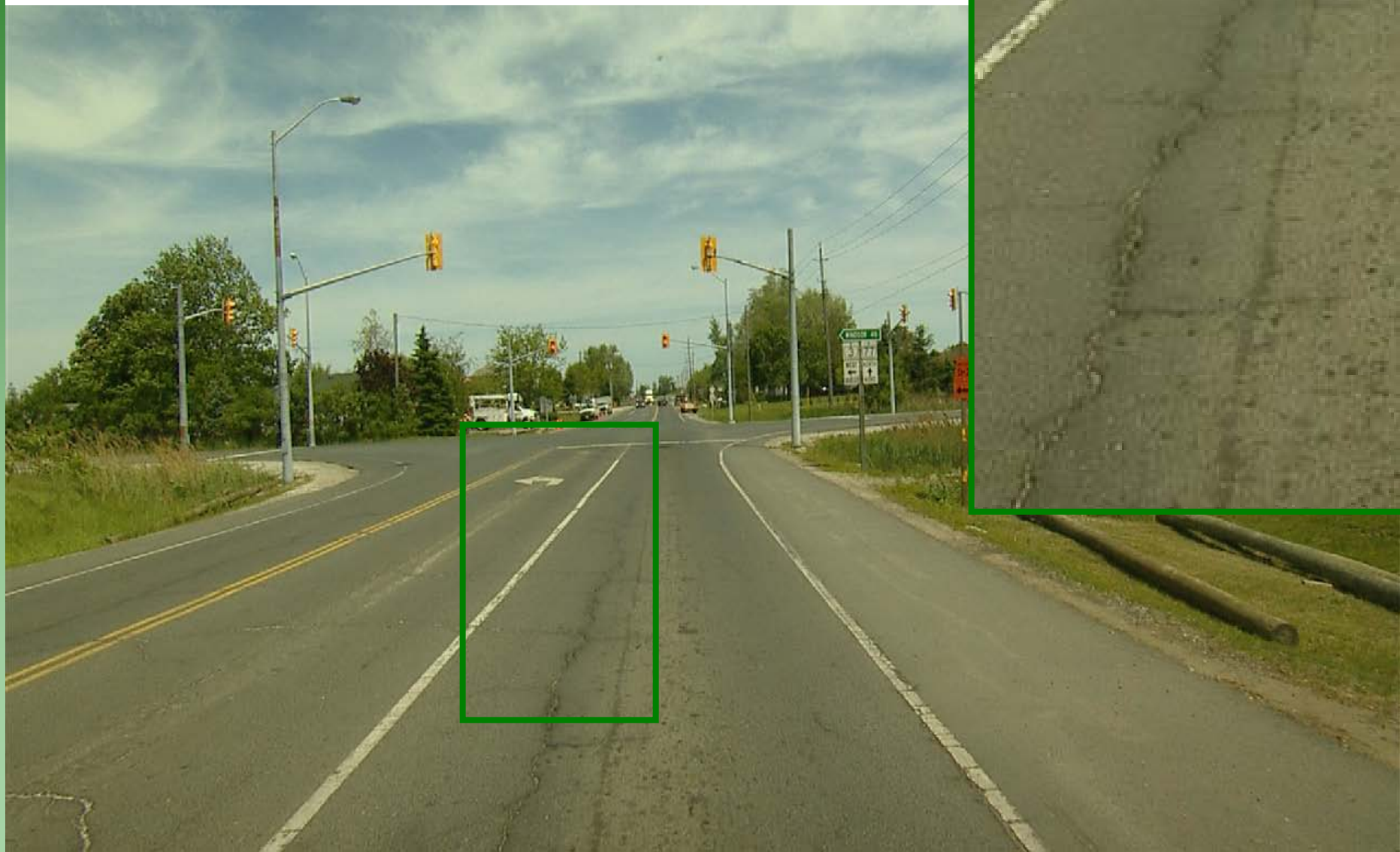
Raveling



Raveling 2

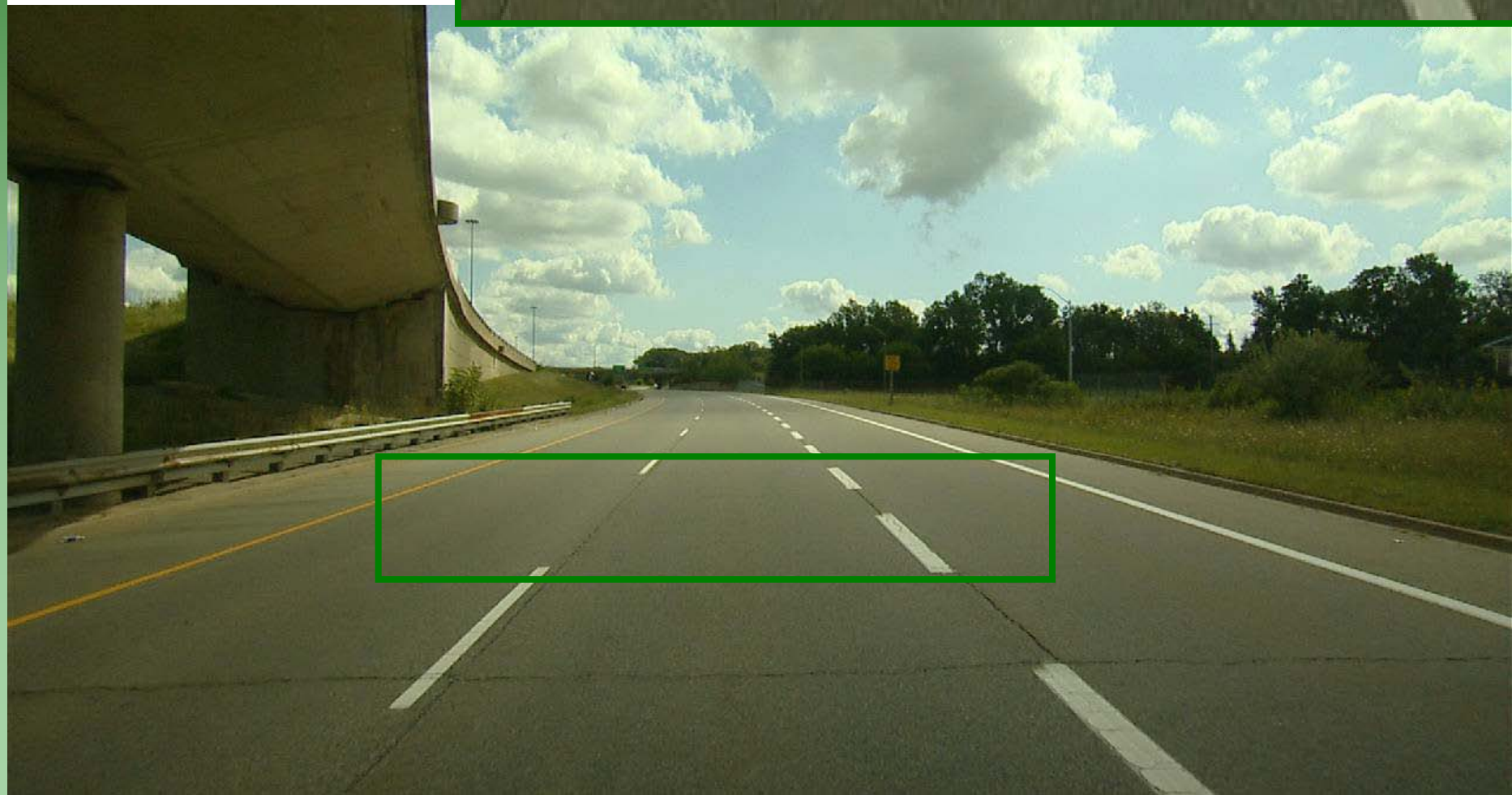


Longitudinal Cracking

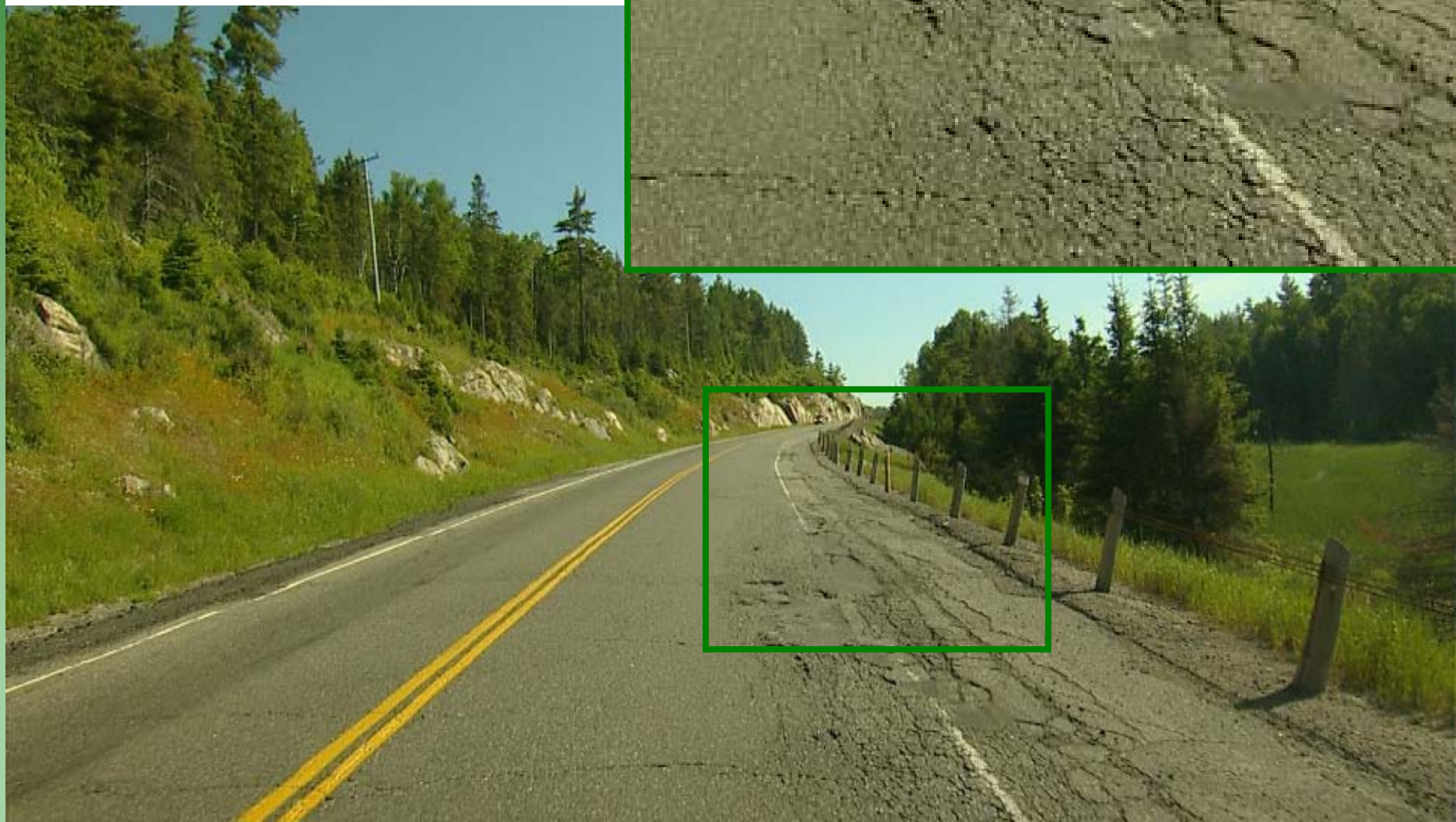


Transverse Cracking

Transverse Cracking 2



Alligator Cracking



More Benefits of Video-logging

- Repeatability is also increased, as any video-log can be revisited for verification purposes
- Video logs can be paused, rewound, and even played backwards at any time for further inspection
- Images are tied to GPS, roughness and retting, and positioning data allowing raters to return to areas of high distress as necessary

Benefits

- In-office view of highway network
  - reduction of field trips
  - faster response to inquiries

- Historical record of highway conditions
- Validation/QA of field data
- Roadside asset inventory data collection

Identifying Severity & Density Levels

- Images of different severity and density levels will be gathered from video-logs
- Corresponding level guidelines will then be made for raters
- The number of severity levels will be decreased to 3 to make evaluations easier

Study of Current Evaluation Methods

- A more thorough study of current evaluation methods will be done in order to determine how video-logging can be incorporated in the future

- There is no standard definitions for severity, so an inter-region group study will be carried out for determining bench marks

Developing Evaluation Procedure

- By combining the new distress list with severity levels, current evaluation methods, and video-logging, an evaluation procedure will be developed

- Once the procedure is developed, training can be implemented and tested for quality by comparing manual ratings from roadside evaluations and manual ratings from video-logs

Future Technology

- The New Road Analyzer deliverables:

- 50% reduction in computing hardware over the previous platform with the same functionality
- Database driven systems
- Robust, fault tolerant systems
- Plug and play system integration
- Microsoft.net platform
- Real-time sub-cm data synchronization
- Advanced mission management software
- Increased portability of subsystem components
- Global solution with interfaces in several languages
- User friendly operating system to minimize training costs and operator error
- Industry-defining warranty
- Dynamic architecture supporting future upgrades

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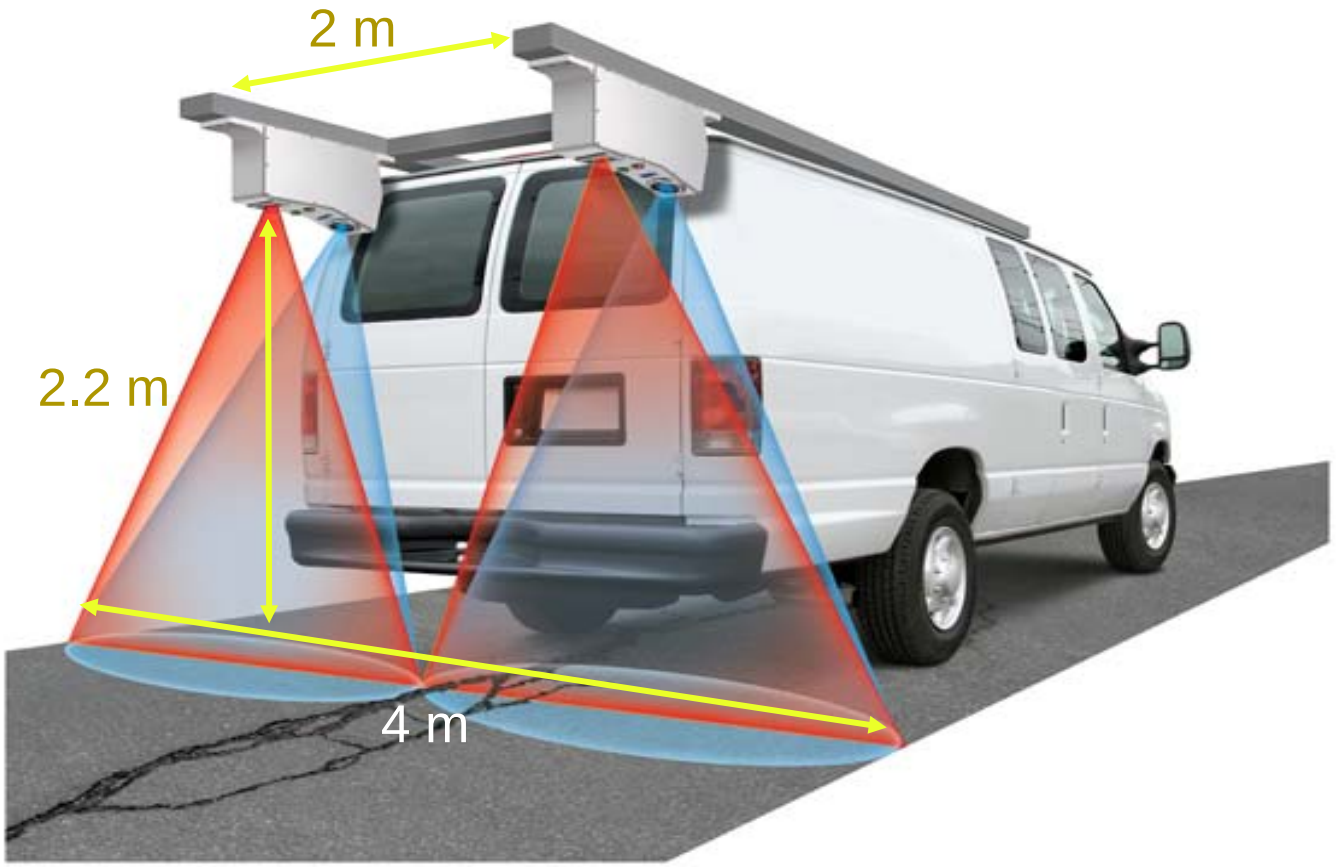
http://www.roadware.com/products/9000/

LCMS - System configuration



Thank You!

Li Ningyuan, P.Eng.

Tel: 416-235-3518

Li.Ningyuan@Ontario.ca