MODELS RELATING PAVEMENT QUALITY MEASURES

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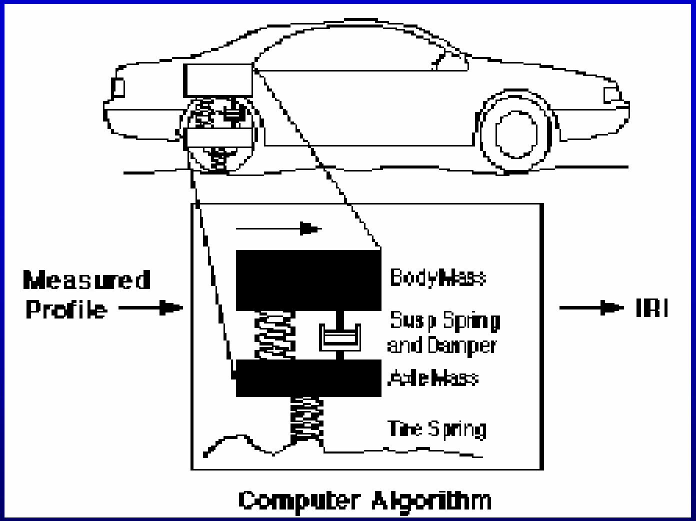
Background

- ***International Roughness Index-*** (IRI) is a mathematical representation of the accumulated suspension stroke of a vehicle, divided by the distance that it travels during the same time period
- Lower values represent a smoother ride; while higher values indicate a rougher one



(Sayers and Karamihas 1998)

Background

- **IRI:**
  - **Easy to collect**
  - **Reliable and repeatable**
  - **Limited knowledge as to IRI's relationship with other measures of distress**

Previous Research

- California's LTPP (Long Term Pavement Performance)
  - Rutting, cracking, patching, weathering and raveling
  - Based on 39 observations measured at 15 m intervals on a 152.4 m test section
  - Linear relationship developed between IRI and a measure of pavement distress.
    - $R^2 = 0.52$

(Dewan and Smith 2002)

Previous Research

Westrack project

- $IRI = 0.597(IRI_{init}) + 0.0094\textit{(Fatigue \%)} + 0.00847\textit{(RutDepth)} + .0382$
  - $R^2 = 0.71$
  - Mean error = 0.107 m/km
- IRI is most sensitive to the initial IRI

(Mactutis et al. 2000)

Previous Research

Neural network techniques

- Automatic Road Analyzer (ARAN) videolog vehicle
- 125, 1-km segments of provincial highways and country roads in Taiwan
- IRI as a function of ;
  - rutting, alligator cracking, cracking, digging/patching, potholes, corrugations, man-holes, stripping, patching, and bleeding
- Correlation coefficient reached 0.944
- Severe potholes, digging/patching, and rutting were determined to have the largest impact on IRI

(Lin et al. 2003)

Study Objectives

- **Investigate the relationships between IRI, pavement rutting and cracking on real world limited access highways.**

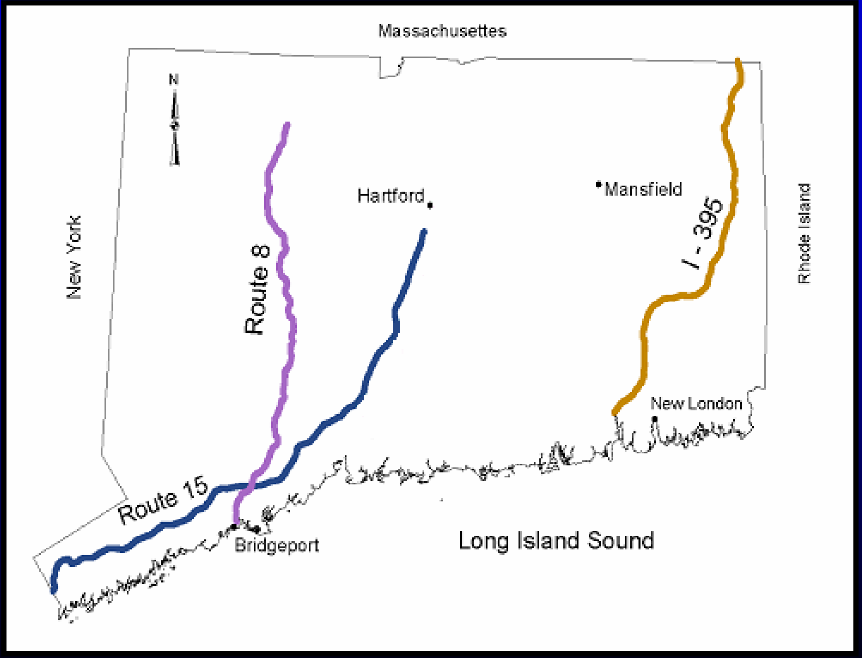
- **Determine if IRI can be used as a surrogate for pavement distress**

Data Collection

- ARAN photologging van
- Summer and fall of 2001
- 3 routes in Connecticut
- 650 highway km
- 65,530 observations (10 m intervals)

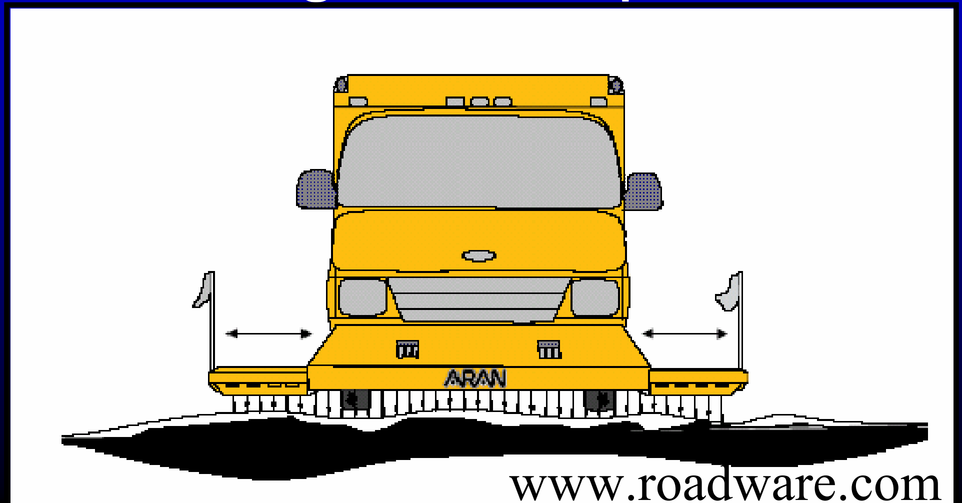
Route Description

- Full depth hot-mixed asphalt (HMA)
  - OR -
- HMA over Portland Cement Concrete (PCC).
- Routes pavement ranged from 1986 to 2001



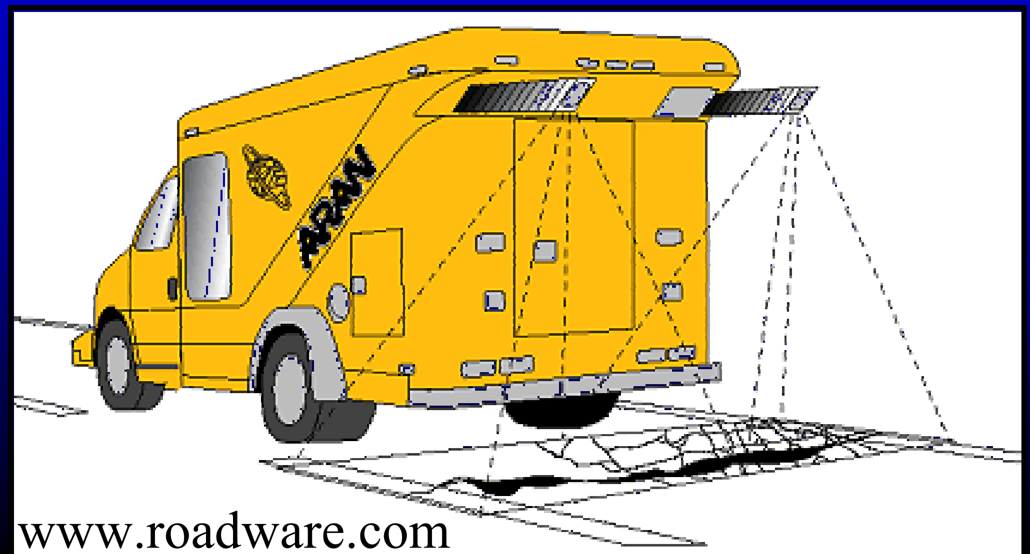
Rut Data Collection

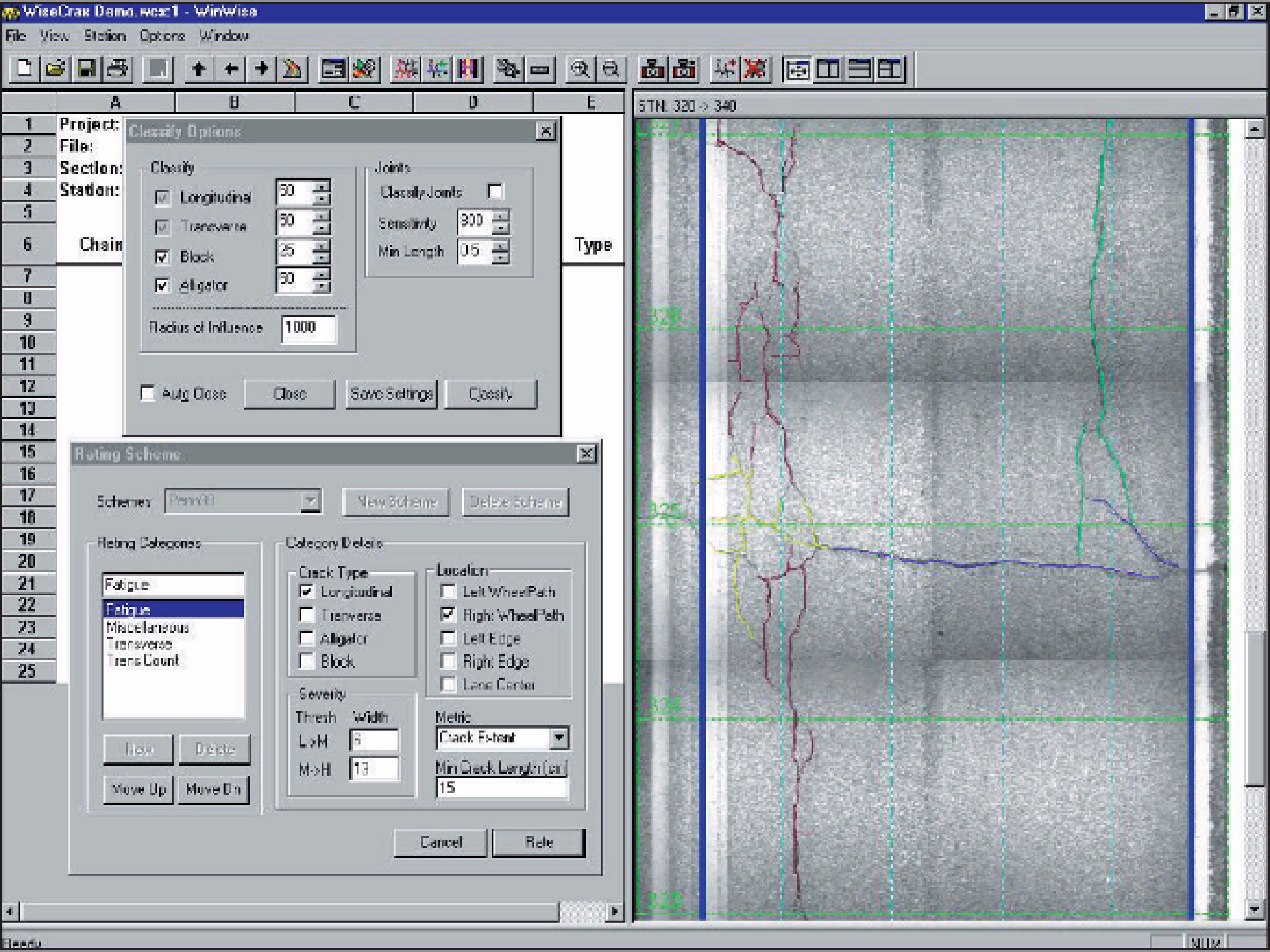
- Rutting
  - Measured at 5 m intervals
  - Ultrasonic sensors
  - Reports the maximum depth of rut (mm) in the left and right wheelpaths.



Cracking Data Collection

- Cracking
  - Downward facing cameras on the ARAN van.
  - WISECRAX® software
    - Automated crack detection software
  - Total number, Total length and Average width per 10 m section




WinWise
File View Station Options Window
A B C D E
Project:
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Section:
Station:
Chain
Type
Classify Options
Classify
Longitudinal 50
Transverse 50
Block 25
Alligator 50
Radius of Influence 1000
Joints
Classify Joints
Sensitivity 300
Min Length 0.5
Auto Close
Close
Save Settings
Classify
Rating Scheme
Scheme
New Scheme
Delete Scheme
Rating Categories
Fatigue
Fatigue
Miscellaneous
Transverse
Trans Count
New
Delete
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Category Details
Crack Type
Longitudinal
Transverse
Alligator
Block
Location
Left WheelPath
Right WheelPath
Left Edge
Right Edge
Lane Center
Severity
Thresh
Width
L->M
M->H
13
Metric
Crack Extent
Min Crack Length (cm)
15
Cancel
Rate
STN 330 -> 340
Ready
NUM

IRI VS. Rut Depth

- Appears there is little to no correlation

Route	Mean IRI (m/km)	Mean Rut Depth (mm)	Mean Number of Cracks (per 10 m section)
395	1.19	2.53	0.32
8	1.54	3.22	2.25
15	1.78	2.81	3.57

IRI VS Mean Number of Cracks (per 10 m section)

- An increase in the mean number of cracks, corresponds to a higher IRI

•IRI with and without cracking

Student's t-test ($p<0.0005$) indicating the average difference in IRI is significant

Route	With Detectable[1] Cracks			Without Detectable Cracks			All Records		
	Number of Records	Mean IRI (m/km)	IRI Standard Deviation	Number of Records	Mean IRI (m/km)	IRI Standard Deviation	Number of Records	Mean IRI (m/km)	IRI Standard Deviation
8	13811	1.56	0.82	7635	1.5	0.82	21446	1.53	0.82
15	19170	1.79	0.83	7348	1.75	0.9	26518	1.78	0.85
395	2181	1.48	0.82	15385	1.15	0.49	17566	1.19	0.55
All routes	35162	1.68	0.83	30368	1.38	0.74	65530	1.54	0.81

[1] Defined as cracks that are greater than 4 mm in width

•IRI and Rutting and Cracking

Analysis of Variance (ANOVA) ($p<0.0005$) indicating increased rut depth increases IRI

Rut Depth (mm)	Mean IRI (m/km)	Number of Cracks (10 m)	Total Length of Cracks (m)	Average Crack Width (mm)
0-2	1.25	1.32	1.16	7.78
2.01-4	1.59	2.53	2.13	8.22
4.01-6	1.9	3.2	2.56	8.38
6.01-8	2.23	3.32	2.8	8.45
>8	2.89	3.57	3.13	9.15

Results

- Several statistical tests indicate that there is an overall relationship between IRI, rutting, and cracking.

- Linear Regression

	IRI (m/Km)		
	10 m segments	30 m segments	90 m segments
Constant	0.79	0.82	0.84
Rut Depth Mean 10 m	0.12		
Rut Depth Mean 30 m		0.1	
Rut Depth Mean 90 m			0.1
Rut Standard Dev. 30 m	0.15	0.13	
Rut Standard Dev. 90 m	0.35	0.38	0.44
Mean Crack Length 90 m	0.07	0.07	0.06
Mean Crack Width 90 m			0.02

	IRI (m/Km)		
	10 m segments	30 m segments	90 m segments
Mean Absolute Error (for actual data)	0.52	0.42	0.35
R^2	17.70%	24.20%	29.90%

- Neural Networks

	IRI (m/Km)		
	10 m segments	30 m segments	90 m segments
Mean Absolute Error (from testing stage)	0.5149	0.412	0.3437

- 20 different rutting and cracking variables were used
- 80% of data used for training
- Sensitivity analysis reveals that rutting is a much stronger predictor of IRI than cracking

- Linear Regression

	IRI (m/Km)		
	10 m	30 m	90 m
Mean Absolute Error (for actual data)	0.52	0.42	0.35
R^2	17.70%	24.20%	29.90%

- Neural Networks

	IRI (m/Km)		
	10 m segments	30 m segments	90 m segments
Mean Absolute Error (from testing stage)	0.515	0.412	0.344

Linear regression and neural network models have similar success at predicting IRI, which differs from previous research

Conclusions

- There are statistically significant relationships among IRI, rutting and cracking but the predictive power of the models developed are weak.
- Predictive relationships with real world are weaker than have been found recently by others using controlled experiments or aggregated data.

Conclusions

- Given the ability of neural networks to successfully find patterns in non-linear and correlated data for other applications, these results suggest the relationship between IRI, cracking and rutting may simply not exist.
- Overall, these findings do not provide strong support that IRI can be used as a surrogate measure for overall pavement condition.
- IRI may simply be a rideability measure

Recommendations

- An investigation into other pavement stress variables might prove beneficial in determining a relationship between distress and IRI

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