Striving for Smoothness:

A case study in ride quality measurement and performance specifications

By

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PE 2019

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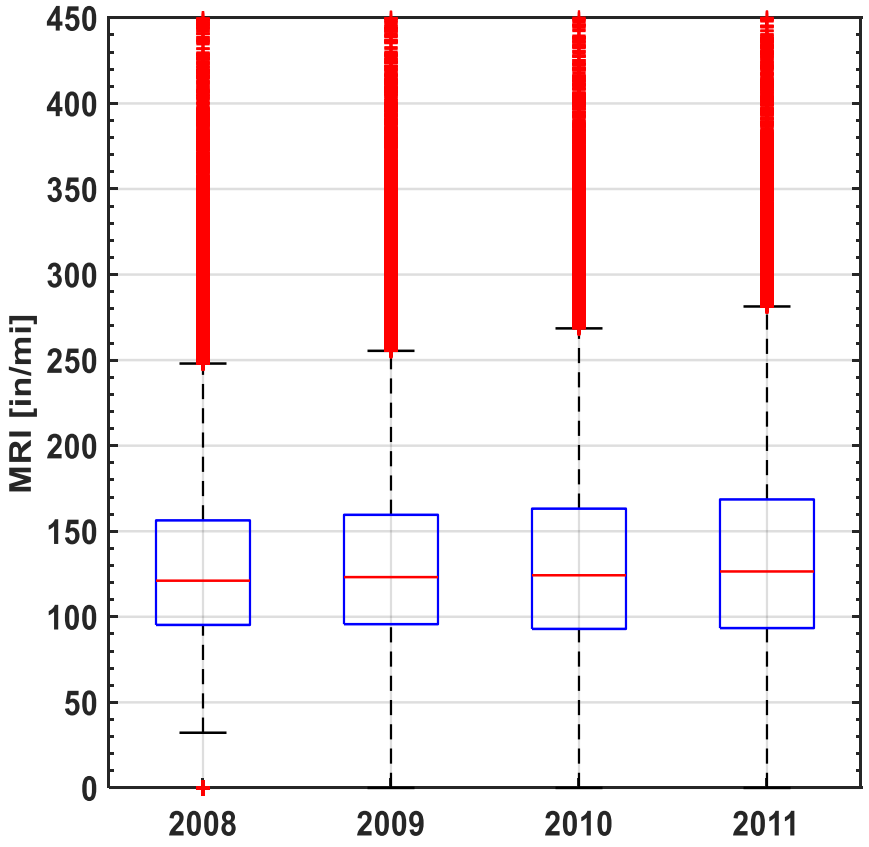
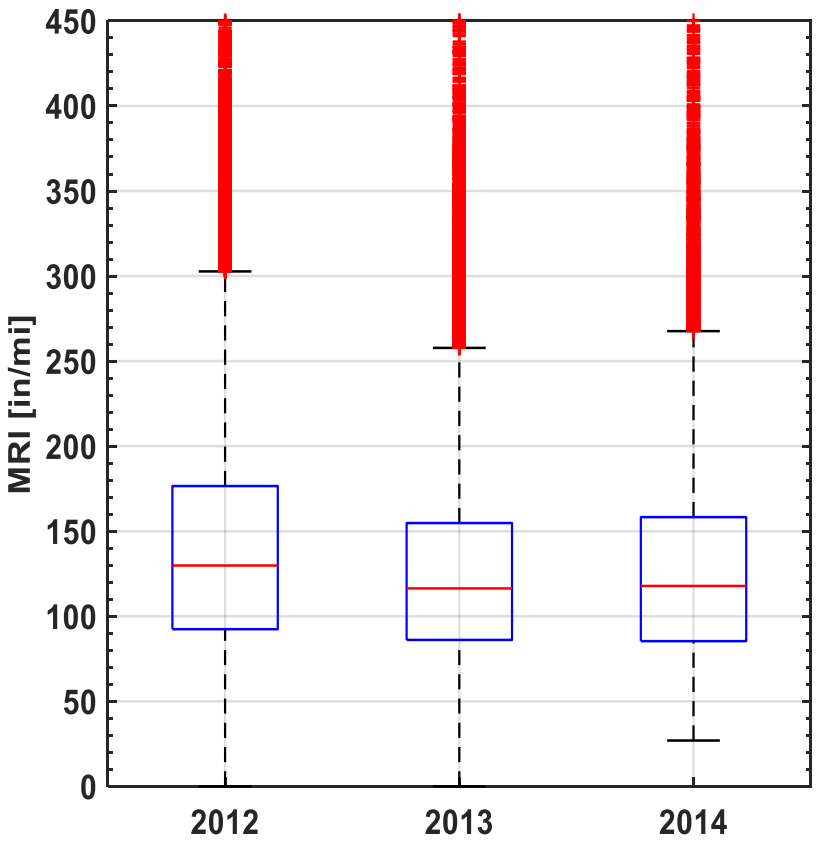
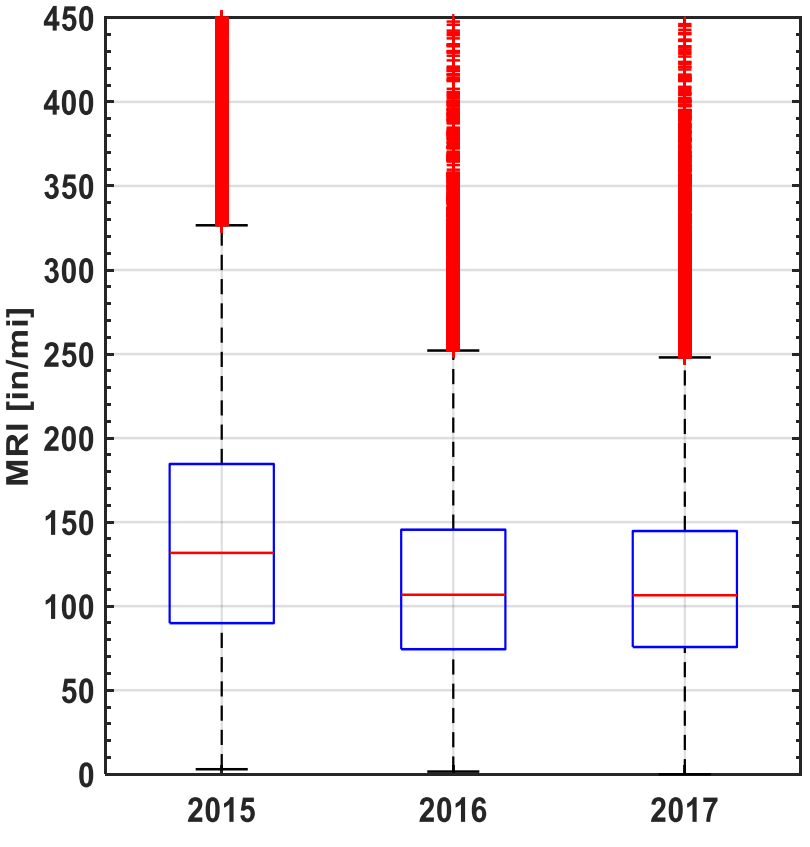
Overview

- Background on Automated Network Survey in CT
- Issues with Roughness Data
- Addressing Protrusions
- Proposed Specifications

Automated Survey in CT







Automated Survey in CT

- Automated Road Analyzer (ARAN)
- Roughness data by Axle-mounted accelerometers since 2000
- 3 different vehicles in use since 2000
- QMP prepared last year (presentation by J. Henault/CT DOT at RPUG)

Slide Adapted from RPUG, 2018 (Henault/CT DOT)

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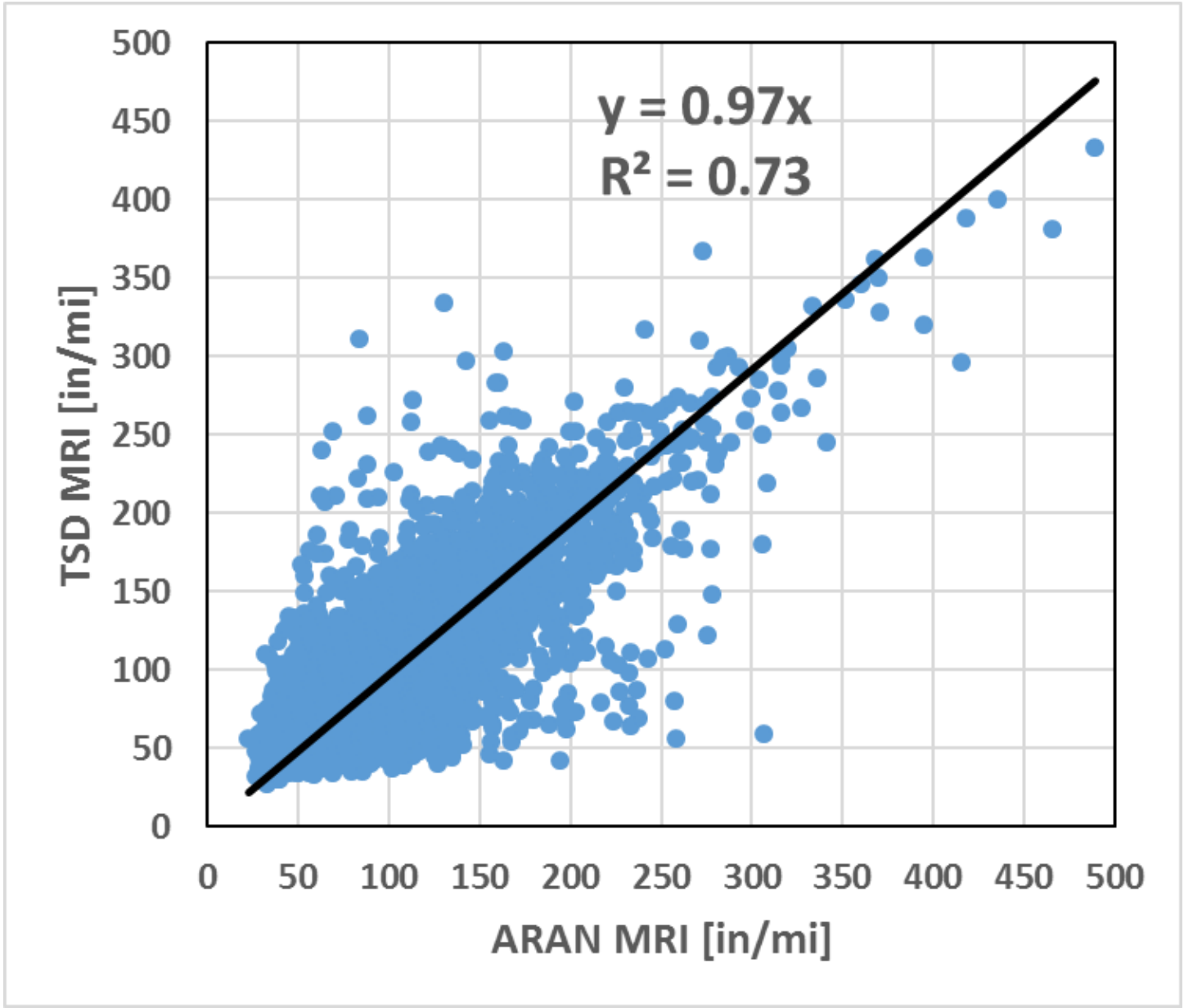
Automated Survey in CT

- Traffic Speed Deflectometer (TSD)
- Surveyed over 1,000+ miles in 2018
- Slated for 1,000+ mile survey again this year
- UConn is currently running side-by-side analysis with ARAN network data

http://arrbgroup.net/services/pavement-structural-assessment/#lightbox/0/

Automated Survey in CT

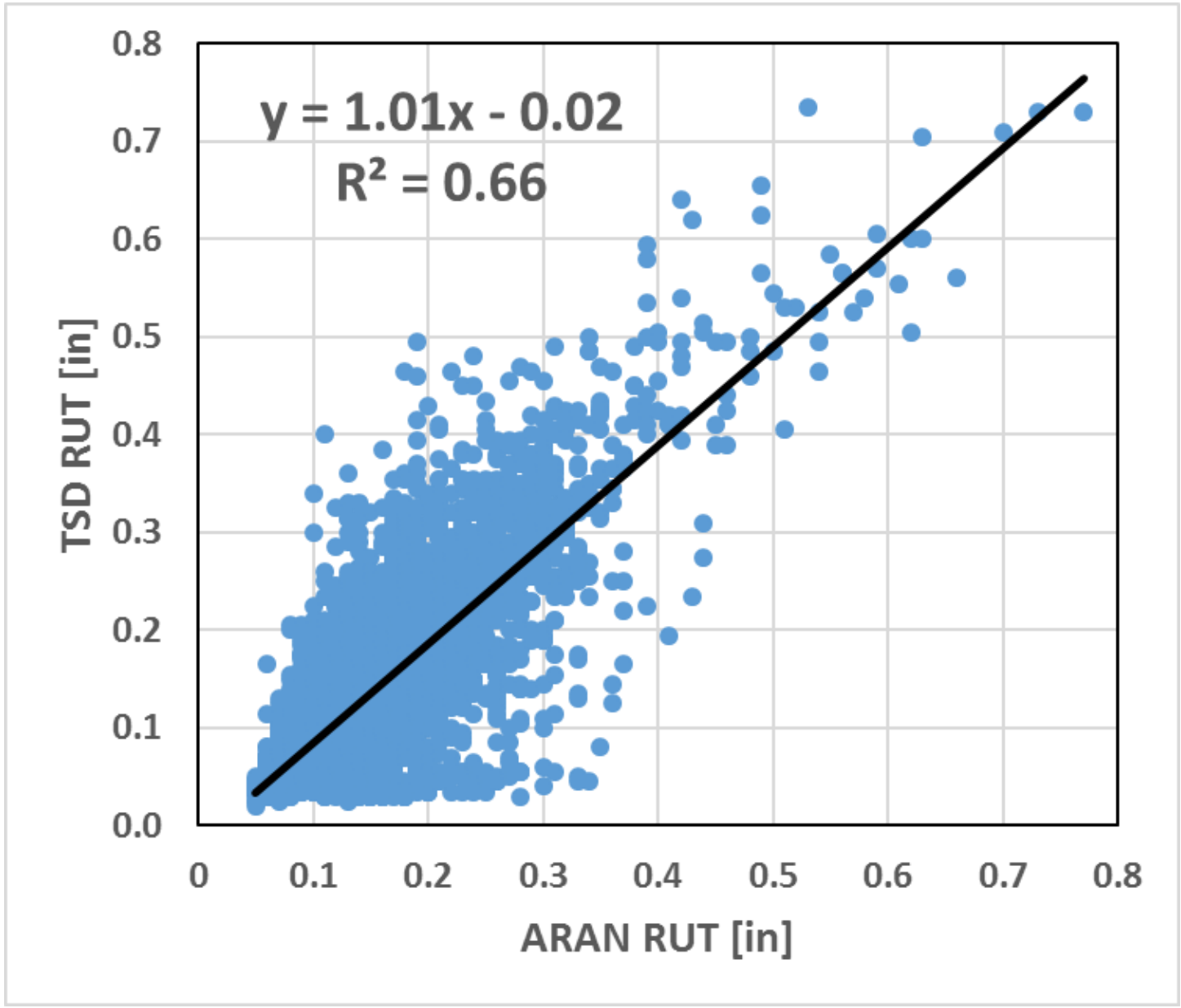
- TSD vs. ARAN - MRI



Automated Survey in CT

- TSD vs. ARAN – Rutting

- TSD – rounds measurement to 0.1”
- ARAN – no rounding



Issues with IRI

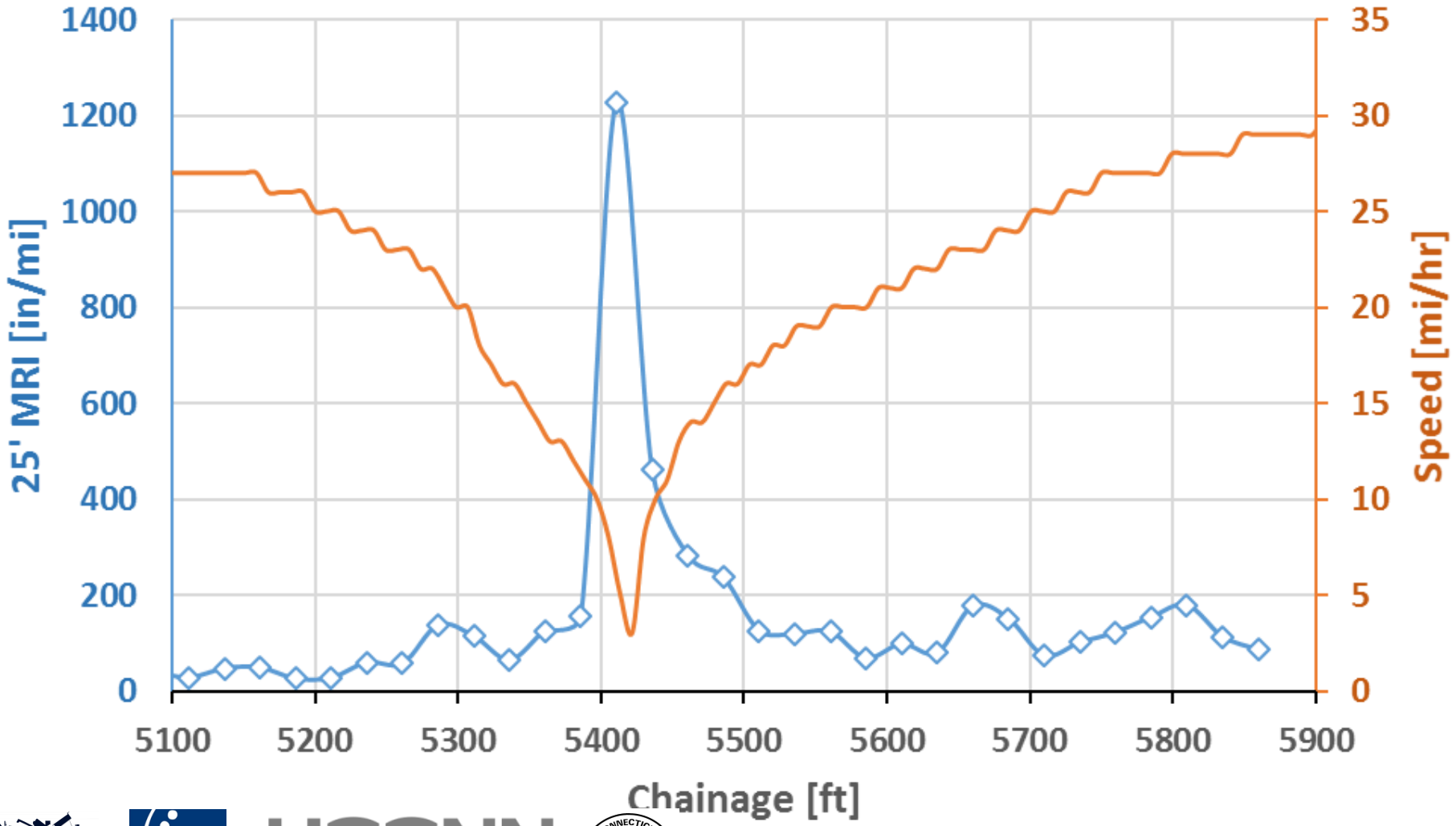
Event Type

- Stop & Go
- Turns/Curves
- Bridges + Joints
- Protrusions

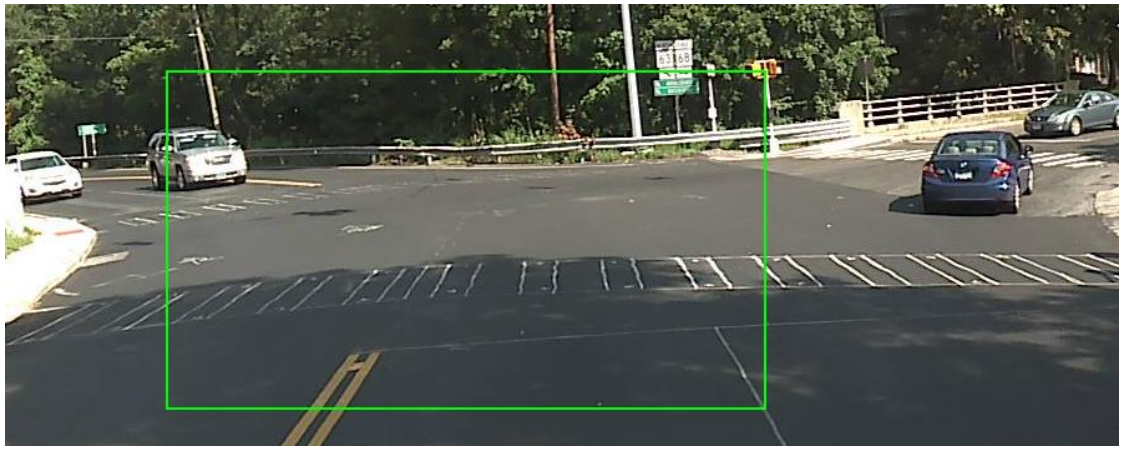
Challenges

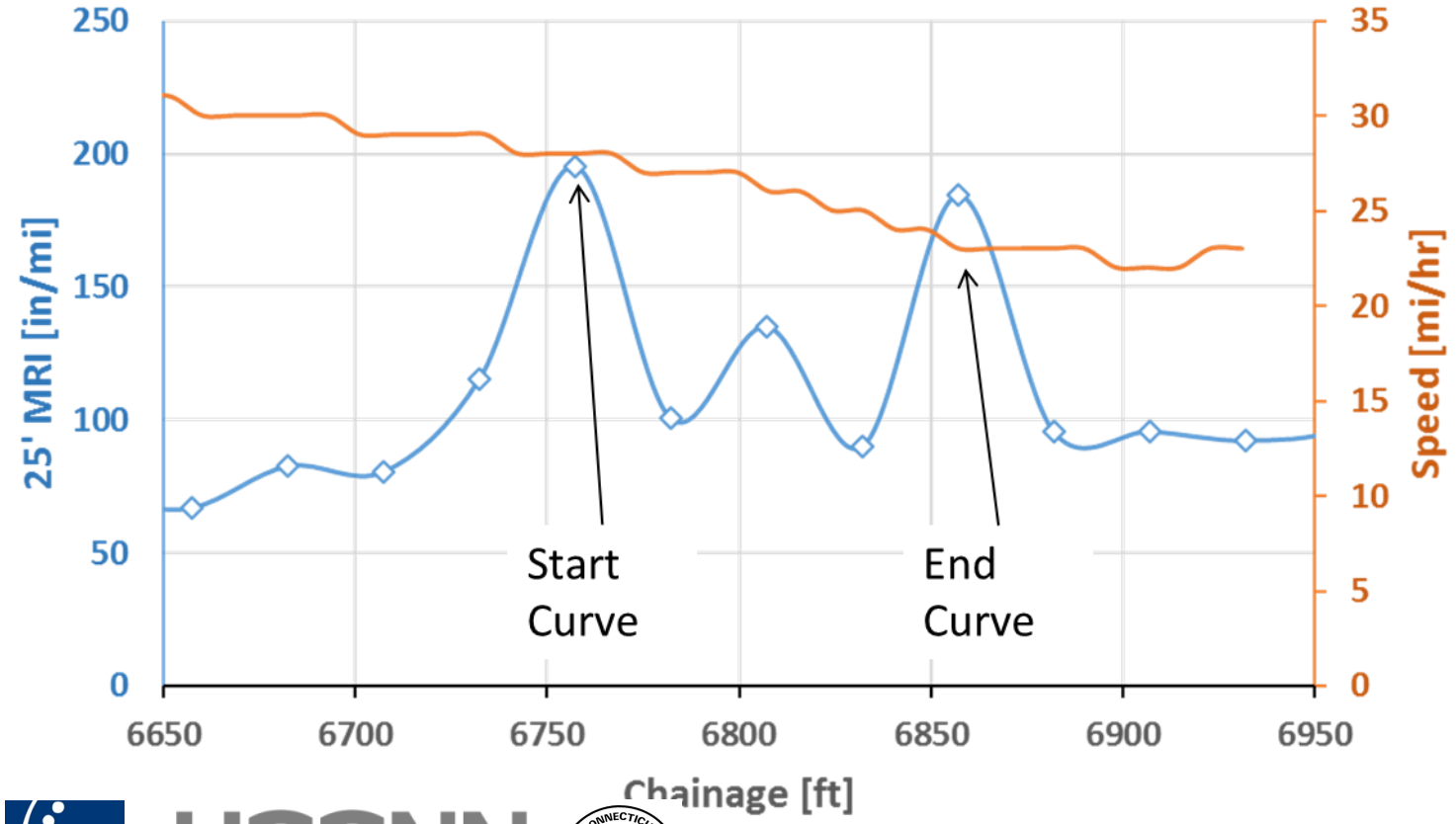
- Additional post-processing
- Inherent in geometry
- Challenges collecting data in busy areas

Issues with IRI stop and go



Issues with IRI
sharp turns and curves





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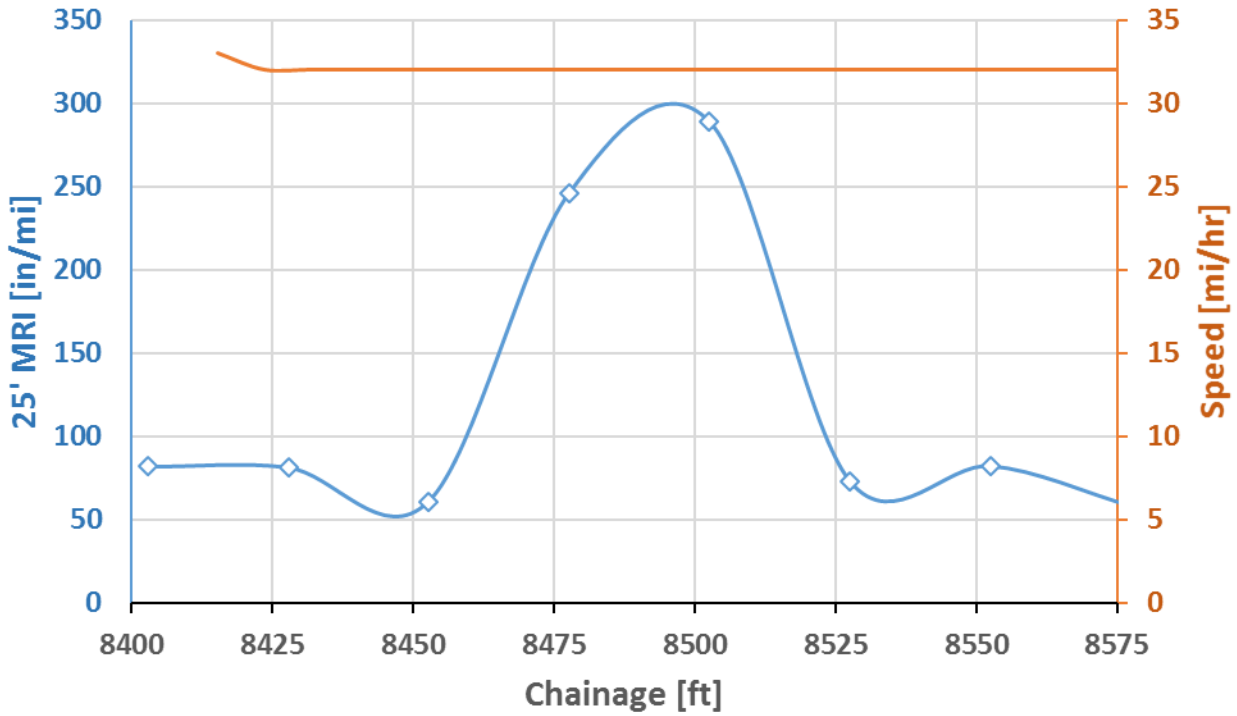
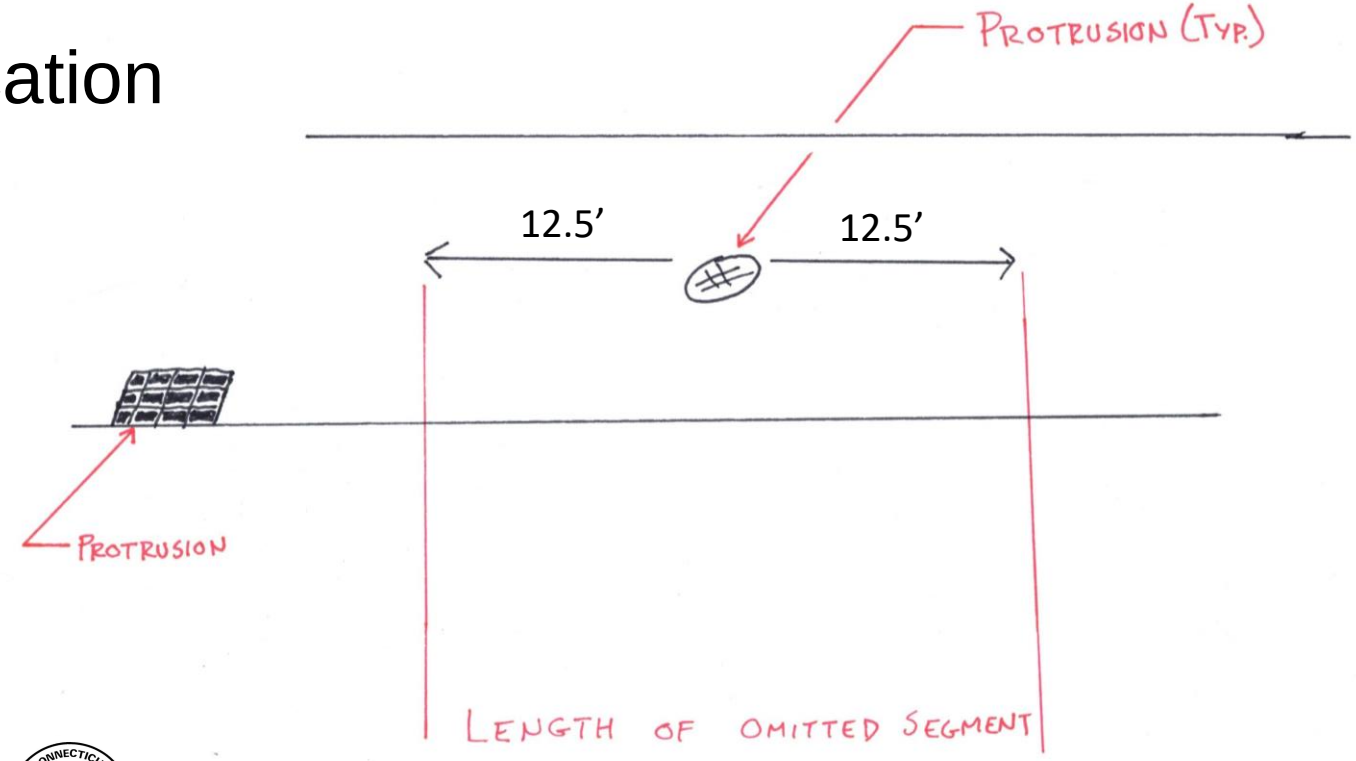
Issues with IRI
protrusions



Protrusions
omissions

- Manually process post-construction
- Impact on outcome of IRI/MRI (and useable data)
- +/- 12.5 ft omitted at each location

(R54 6.4)



Protrusions
smoothness specifications

- Addressing by omission
  - time consuming
  - Over/under predicts

Alternatives

- ‘Deduct’ Model
- ΔIRI for given profiles

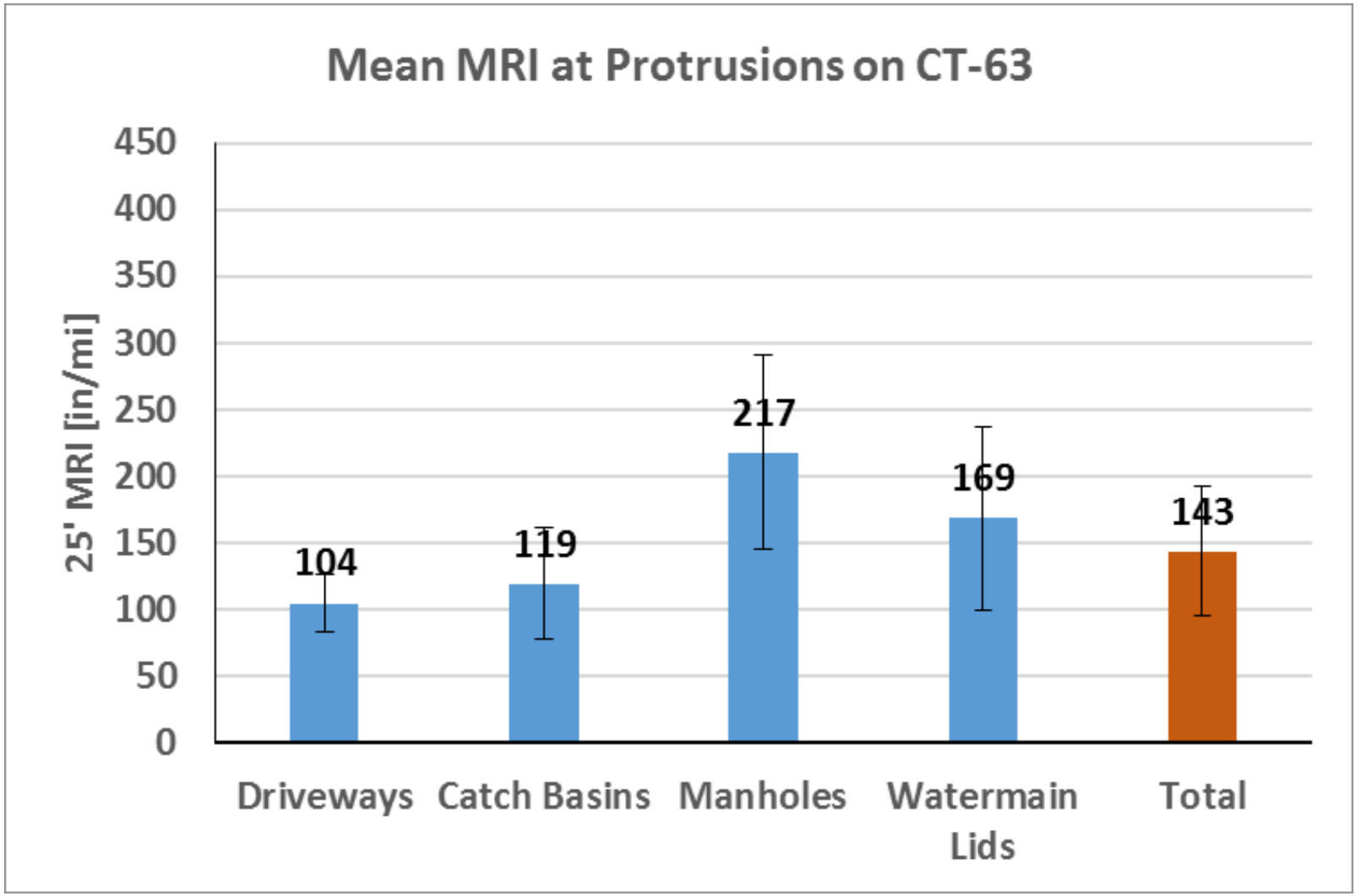
Proposed Specifcations
deduct models

- Concept of localized roughness
- Evaluated projects with sufficient pre/post construction IRI information
- Identified MRI at mileage for each protrusion
- Modeled contributions and correlations

Table 1. Summary of project information

Project ID	Route, Direction, Lane	Limits [ft]	Length Analyzed [ft]	Overall MRI [in/mi]	Number of Protrusions				
					Drive ways	Catch Basins	Man holes	Water Mains	Total
1	CT-63 NB L1	13000-16200	2522	79.6	-	7	7	-	14
2	CT-63 NB L1	6750-12750	5999	83.2	4	13	7	5	29
3	CT-63 NB1 L1	670-6200	5510	70.2	7	16	-	2	25
4	CT-63 NB2 L1	1030-4825	1545	87.0	-	1	2	6	9
5	CT-63 NB2 L2	0-4500	4463	60.3	-	10	-	-	10
6	CT-63 SB1 L1	5000-12300	2169	95.7	1	3	3	-	7
7	CT-63 SB2 L1	660-11500	3416	94.6	5	10	3	1	19

Proposed Specifications
deduct models



Proposed Specifications
deduct models

Average Contribution of Protrusions to the terminal project 25-ft MRI on Rt 63

Route	Route CT-63 Overall MRI range = 60 to 95 in/mi		
Protrusion Type	Contribution with all localized roughness (>80) excluded)	Contribution with all localized roughness (>80) included)	Contribution of Protrusions on the top of Localized Roughness
Driveways	34 (48%)	22 (27%)	11.7 (21%)
Catch Basins	48 (70%)	37 (48%)	10.3 (23%)
Manholes	128 (167%)	119 (138%)	9.2 (29%)
Watermain Lids	75 (101%)	65 (77%)	10.1 (24%)
Average	**65 (92%)**	**54 (67%)**	**10.3 (24%)**
NWP Protrusions Combined (DRW+CB)	**45 (65%)**	**34 (43%)**	**11 (22%)**
WP Protrusions Combined (MH+WM)	**107 (142%)**	**98 (115%)**	**10 (27%)**

Proposed Specifications
deduct models

- Protrusions accounted for 8% to 24% of total length of segments, yet 18%to 59% of the penalized length
- For each project, the effect of each protrusion was calculated to be 10 in/mi
- Additional data needed from suitable rehabilitation/preservation projects

Proposed Specifications
ΔIRI

$$ImproveMRI = \frac{MRIbefore - MRIafter}{MRIbefore}$$

- Road category (***ROADCLASS***)
  - Interstate (***1***),
  - Non-Interstate divided (***2***),
  - and Undivided (***3***)
- Project Length in centerlane-miles (***LENGTH***)
- Age at construction in years (***AGEPAVE***)
- Treatment depth in inches (***DEPTH***):

Road Class	**1 (Interstates)**	**2 (Secondary Divided)**	**3 (Undivided)**
Number of Projects	14	14	31
Years	2015, 2016, 2017	2015,2016, 2017	2017
Total Length	64.5	31.1	84
Age per Project [years], min/median/max	7.0/ 9.1/ 15.0	8.0/ 15.0/ 19.0	10.5/ 17.4/ 24.0
Length per Project [mi] , min/median/max	0.3/ 5.2/ 7.3	0.4/ 2.0/ 5.6	0.5/ 2.6/ 7.6
Depth per Project [in] min/median/max	0.75/ 1.00/ 3.00	1.00/ 2.00/ 3.00	1.00/ 2.00/ 2.00
MRI Before [in/mi], min/median/max	64/ 82/ 146	83/ 123/ 155	127/ 172/ 336
MRI after [in/mi], min/median/max	42/ 57/ 102	58/ 80/ 107	69/ 93/ 130

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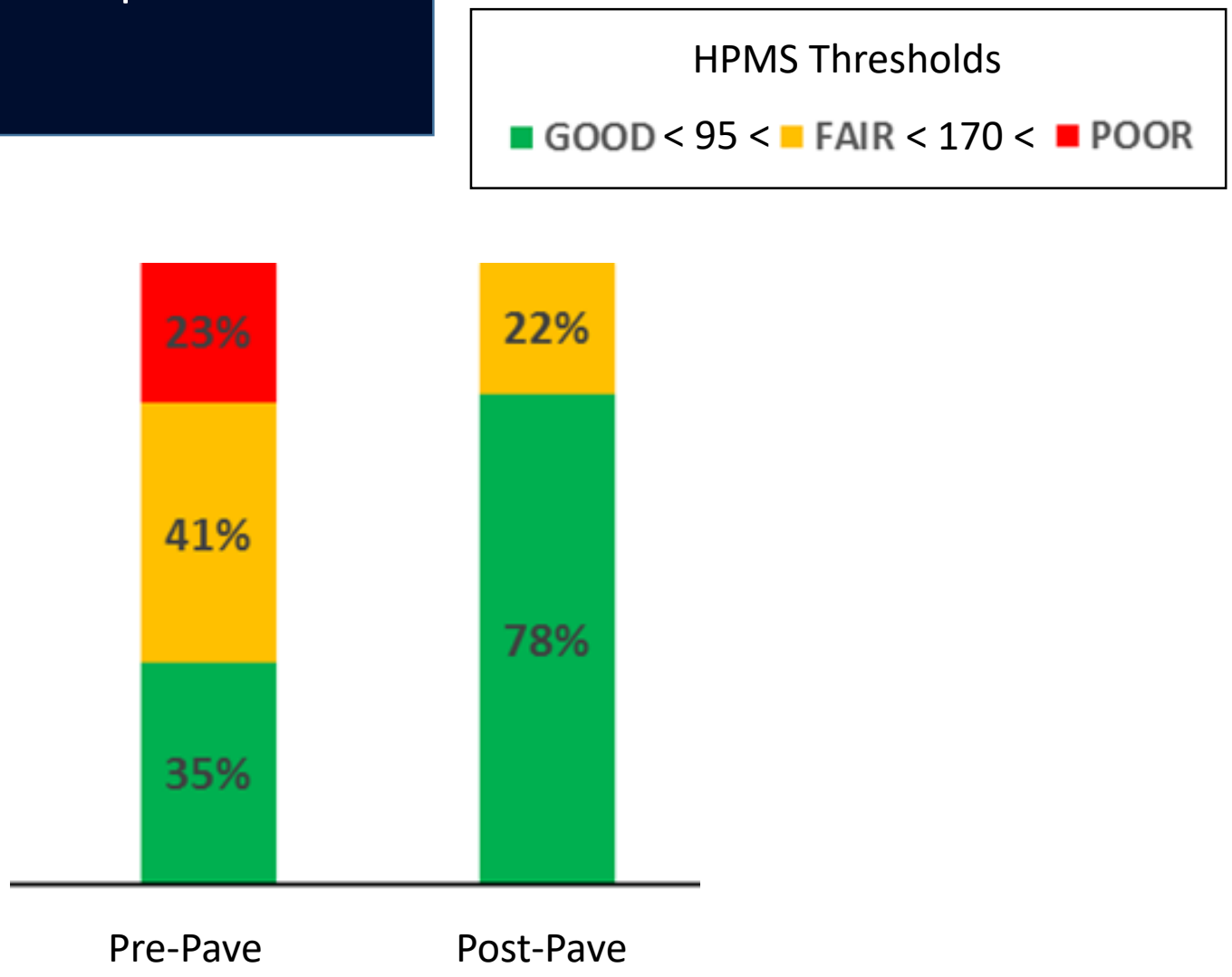
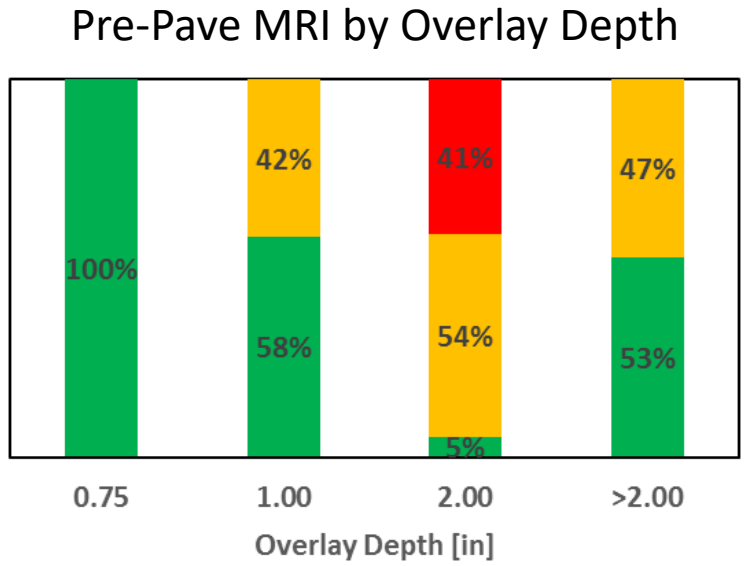
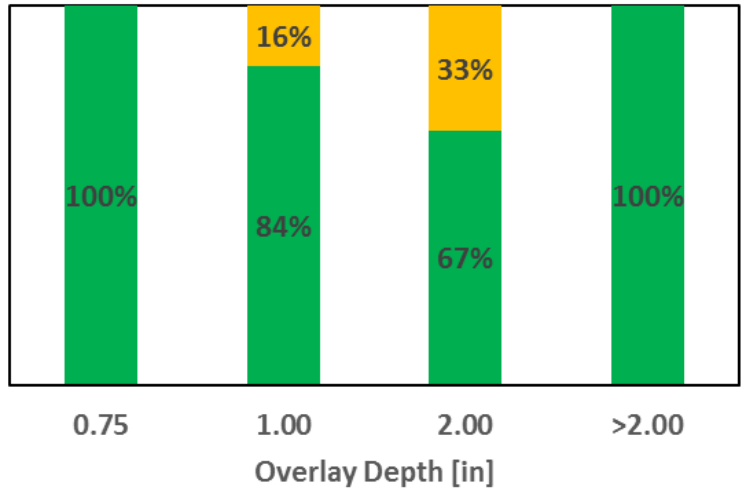
Proposed Specifications
ΔIRI







Proposed Specifications
ΔIRI

	ΔMRI Equations	Pay Factor
A	$MRI \leq 33.5+0.3xMRI_{initial}-2.7x(Length)-7.1x(Depth)$	+10
B	$33.5+0.3xMRI_{initial}-2.7x(Length)-7.1x(Depth) < MRI \leq 44.8+0.3xMRI_{initial}-2.7x(Length)-7.1x(Depth)$	3%
C	$44.8+0.3xMRI_{initial}-2.7x(Length)-7.1x(Depth) < MRI \leq 67.4+0.3xMRI_{initial}-2.7x(Length)-7.1x(Depth)$	0
D	$67.4+0.3xMRI_{initial}-2.7x(Length)-7.1x(Depth) < MRI \leq 78.7+0.3xMRI_{initial}-2.7x(Length)-7.1x(Depth)$	-3%
E	$MRI > 78.7+0.3xMRI_{initial}-2.7x(Length)-7.1x(Depth)$	-10%

Model ID	> 2" (Multiple Lifts)
Equation for model mean	MRI_{final} = 56.1+ 0.3*$MRI_{initial}$-2.7*LENGTH -7.1*DEPTH
R-Sq.	74%
RMSE	11.3
F (model)	51.5
p-value	0.0000

Proposed Specifications
ΔIRI

	ΔMRI Equations	Pay Factor
A	$\Delta MRI \geq (-)6.7+0.1xMRI_{initial}+7.8x(Depth)$	+10%
B	$(-)6.7+0.1xMRI_{initial}+7.8x(Depth) \leq \Delta MRI < 1.5+0.1xMRI_{initial}+7.8x(Depth)$	+3%
C	$1.5+0.1xMRI_{initial}+7.8x(Depth) \leq \Delta MRI < 17.9+0.1xMRI_{initial}+7.8x(Depth)$	0%
D	$17.9+0.1xMRI_{initial}+7.8x(Depth) \leq \Delta MRI < 26.1+0.1xMRI_{initial}+7.8x(Depth)$	-3%
E	$\Delta MRI < 26.1+0.1xMRI_{initial}+7.8x(Depth)$	-10%

Model ID	< 2" (Thin Lifts)
Equation for model mean	ImproveMRI = 9.7 + 0.1* MRIBefore + 7.8*DEPTH
R-Sq.	54%
RMSE	8.2
F (model)	33.33
p-value	0.0000

Thank you!