SAFER-LC WORKSHOP 2
Tuesday 27 March 2018

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Level Crossing Research
at NURail Universities

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The NURail Center

The National University Rail (NURail) Center is a consortium of seven partner colleges and universities offering an unparalleled combination of strengths in railway transportation engineering research and education in North America.

Highway-Rail Grade Crossings

- Over 200,000 level crossings in the US alone
- Hundreds of fatal accidents
- Rough crossings result in delays, vehicle damage, discomfort
- Huge maintenance issue for RR and DOT alike

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Outline of This Presentation

- Work of 4 NURail universities (9 projects)
- Common goal of improving safety
- Three general themes
  - human factors
  - risk analysis
  - infrastructure assessment

Michigan Tech

UIC UNIVERSITY OF ILLINOIS AT CHICAGO

ILLINOIS UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

UK UNIVERSITY OF KENTUCKY

Human Factors

Risk Analysis

Infra-structure

#1 Warning

#2 Driver

#3 Peds

#4 Derail

#5 Models

#6 3D

#7 Dymanic

#8 Index

#9 Hump

Papers are available for all projects

Contact the speaker at Souleyrette@uky.edu

#1 Warning

Human Factors

#1 In-Vehicle Alerts; How Best to Warn Drivers?

Stimuli

31 novel auditory cues

- 9 Earcons (Beeps)
  - Varied in pitch, pulse rate, wave shape, etc.
- 6 Auditory Icons (train sounds)
  - Train horns, "track" sounds, warning bells, etc.
- 16 Verbal messages
  - 2 Genders (M, F)
  - 2 Voice types (Human, TTS)
  - 4 words (Alert, Caution, Danger, Warning)

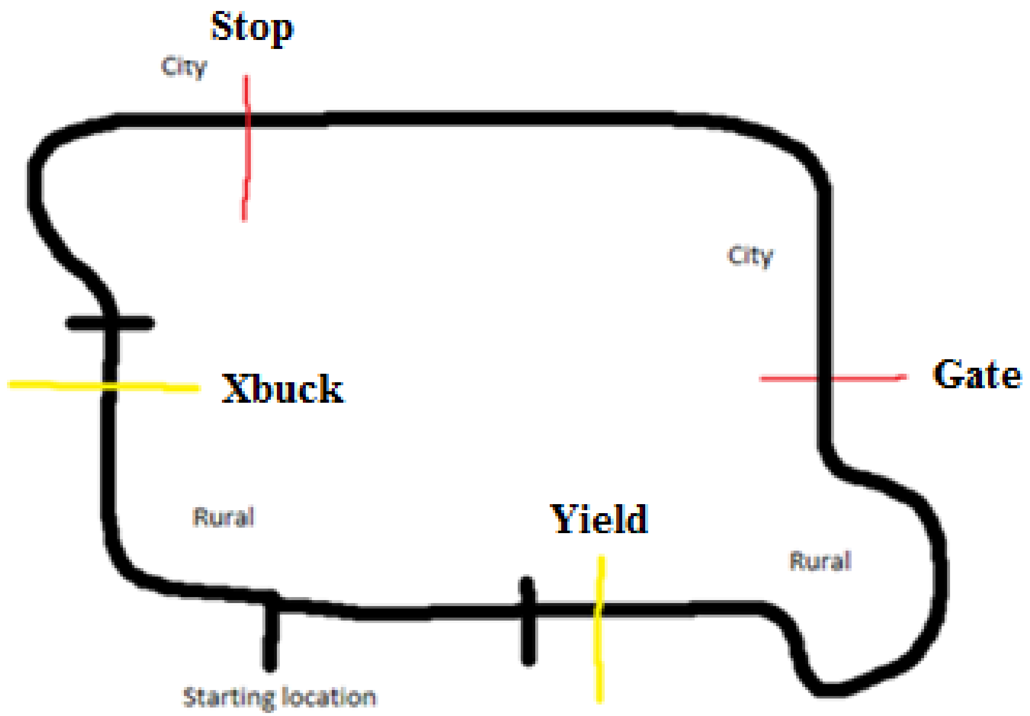
Subjective Measurements

7 psychological dimensions

- Likert scale 1-7
  - Overall Appropriateness
  - Urgency
  - Meaning
  - Discriminability
  - Annoyance
  - Startle effect
  - Natural-In-Car

Baldwin & Lewis, 2014

Experimental Design



22 minute loop, train present at 23rd crossing (gate)

#1 Warning

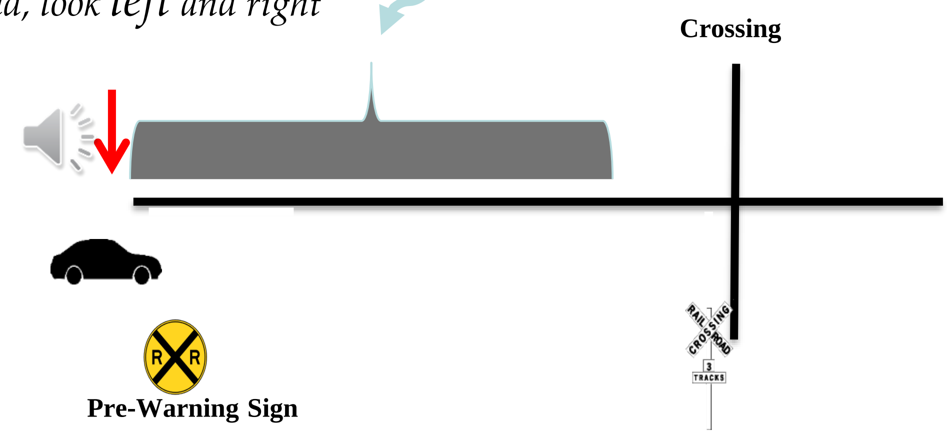
Human Factors

Evaluation Auditory Warnings using Driver Simulator

Compliance coding scheme

+ 1 for each direction looked (max 2)
+ 1 for coasting (releasing accelerator pedal)
+ 1 for slowing down (press on brake pedal)
- 1 for not coming to a complete stop (if STOP sign)

*"**ding ding**, Railroad Crossing ahead, look left and right"*



#1 Warning

Human Factors

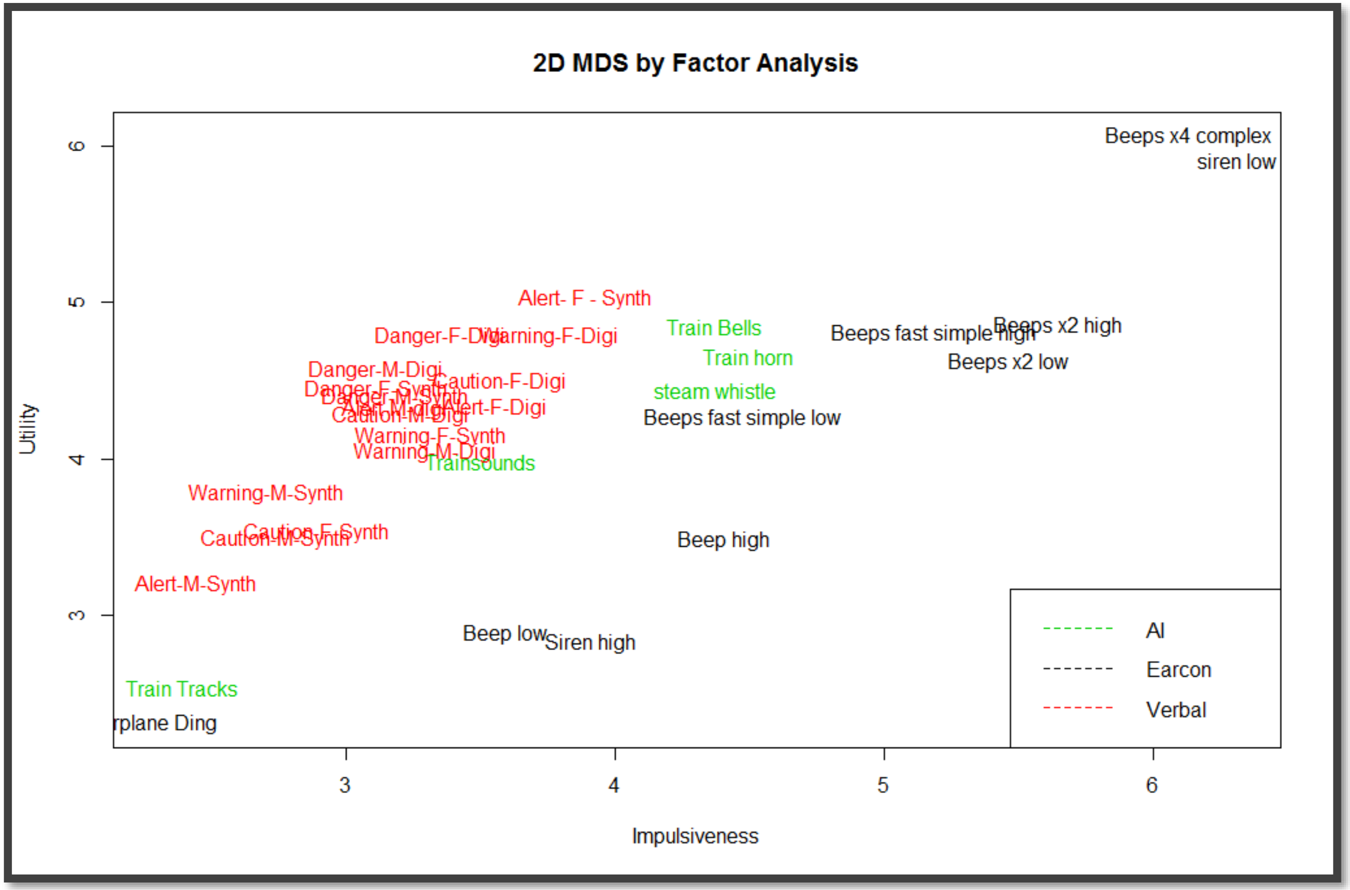
Results

Principal Component Analysis suggested two main factors (95% of variance explained across all 7 dimensions)

"Utility" – meaning & natural & urgency

"**Impulsivity"** – annoying & startle

Utility



Impulsivity

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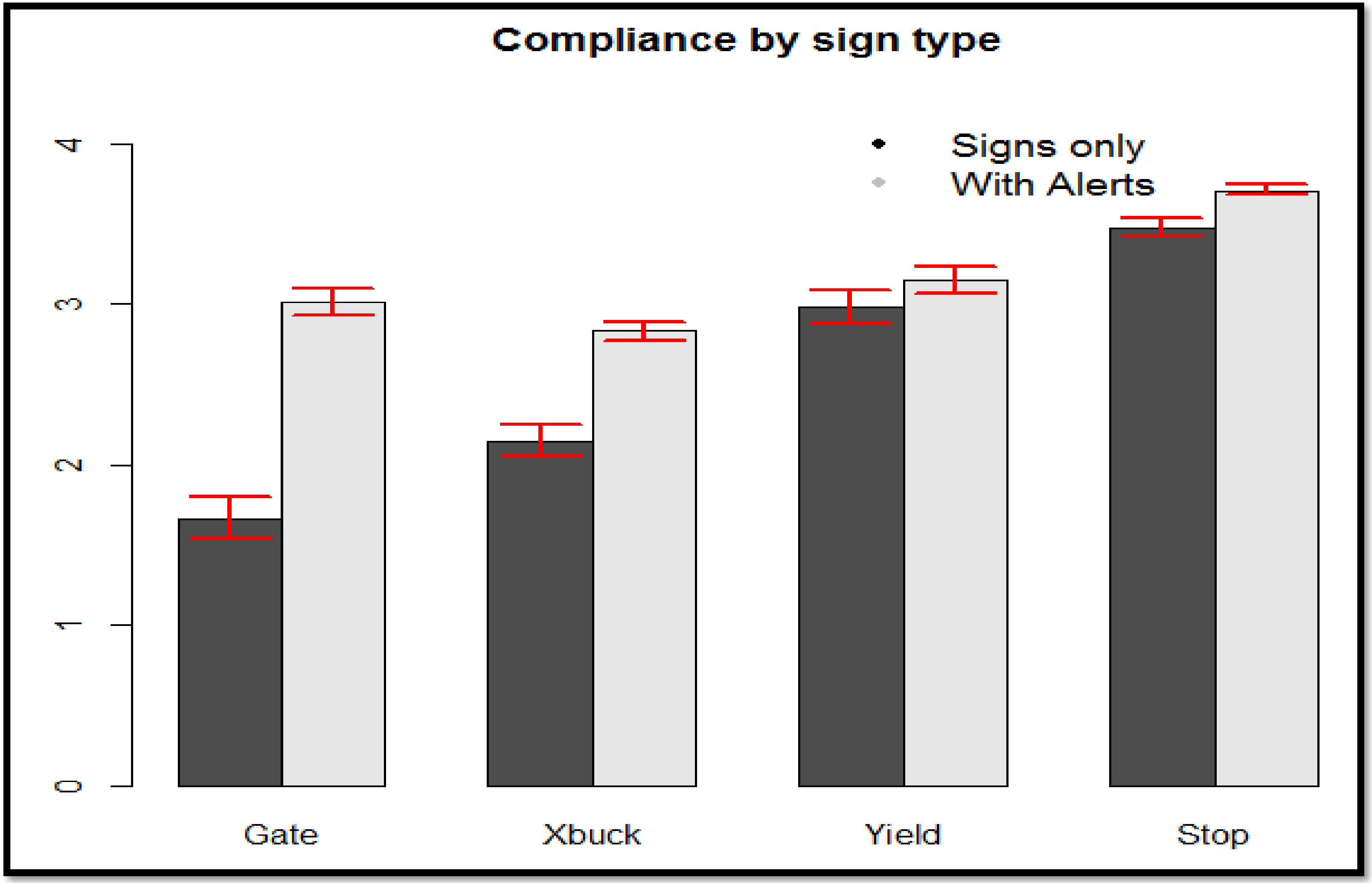
#1 Warning

Human Factors

Significance of Results



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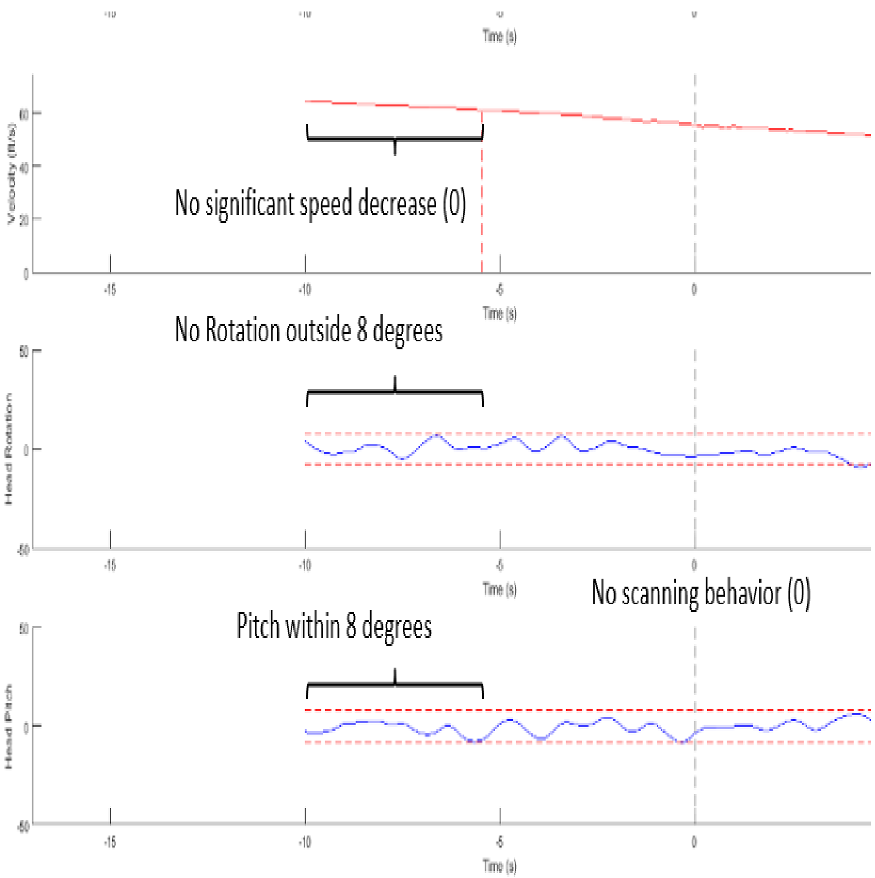
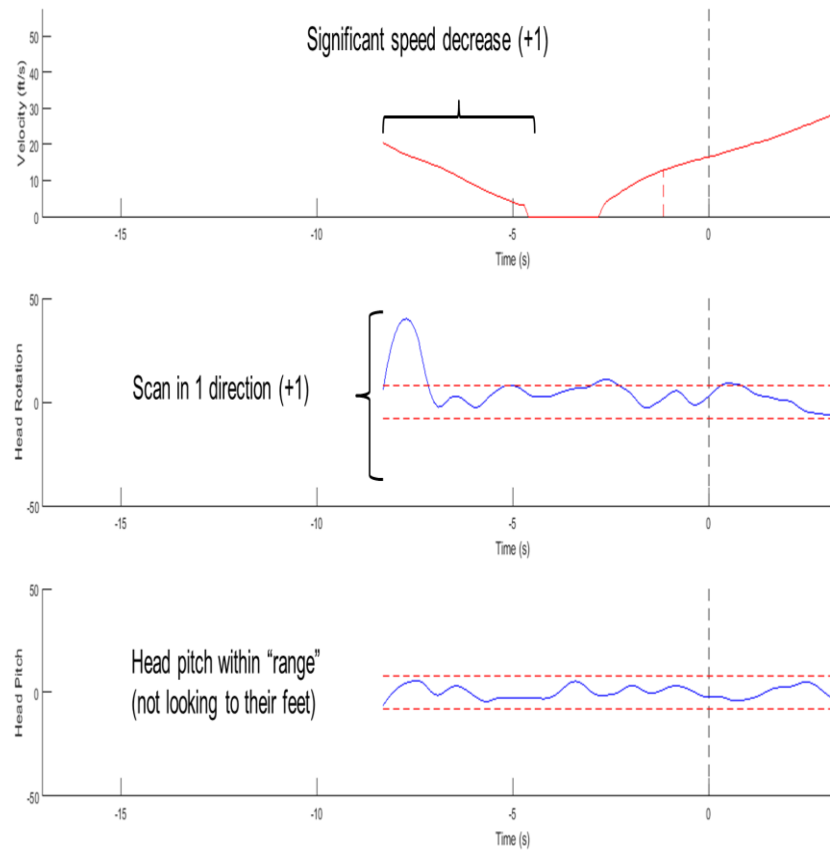
#2 Integration of Driver Simulator and NDS Data

- SHRP2-NDS (Naturalistic Driving Study)
  - Data were live recorded in-vehicle
  - Behavior very similar to the natural environment
  - Expensive and difficult to set up
  - Data collected between 2011 and 2013
  - 3,500 Vehicles in 6 Regions: FL, IN, NY, NC, PA, WA
  - More than five million trips and over 1,000 crossings involved
  - Data used to analyze driver behavior at grade crossings, ***primarily in non-accident situations***

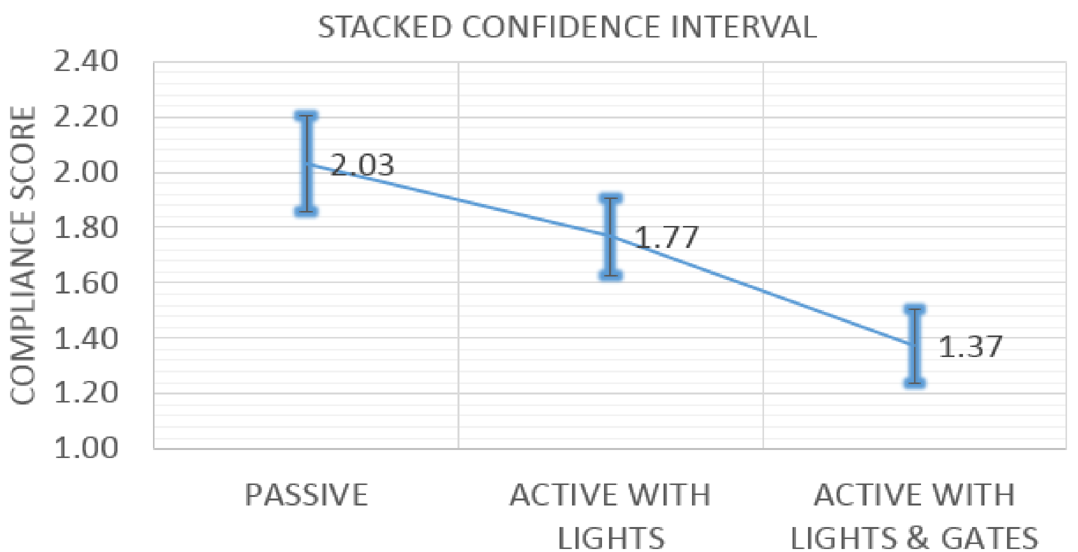
Data analysis





Scores - Crossing Type

- Clusters are based on :
  - Traffic control devices (passive, active w/ lights, active w/ lights&gates)
  - Angle of the crossing
  - Total trains per day
  - Highway maximum speed

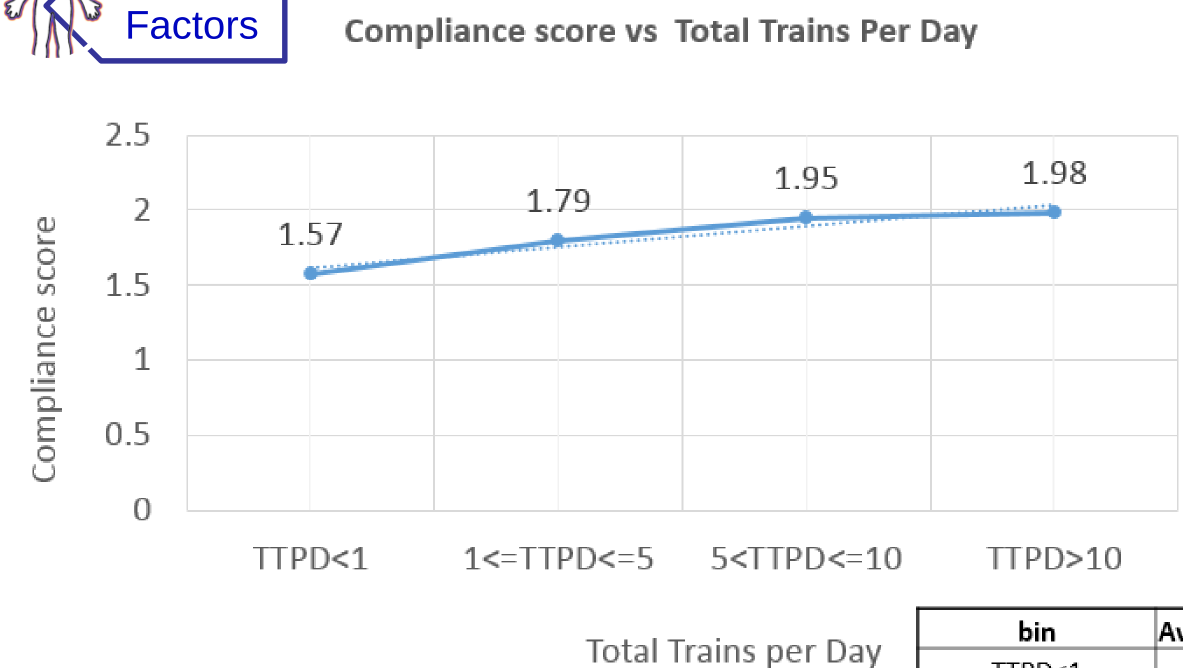


- Scanning vs. speed reduction behavior offers similar trending with all main TCDs

#2 Driver

Human Factors

Correlation analysis



bin	Average score	std	Current n	Required n
TTPD<1	1.57	0.73	84	64
1<=TTPD<=5	1.79	0.61	37	44
5<TTPD<=10	1.95	0.55	22	36
TTPD>10	1.98	0.50	5	30

- Initial results show drivers display more compliant behaviors as the number of trains per day increases
- More data are needed in some of the clusters to reach a 90% confidence with 5% standard error

#2
Driver

Human
Factors

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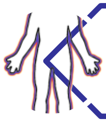
Next Steps

- Simulate a variety of observed sites
- Calibrate driver simulator with NDS data
- Provide warnings in similar circumstances to test improvement

#2 Driver



Human Factors

Application

Auditory warning of approaching crossing…

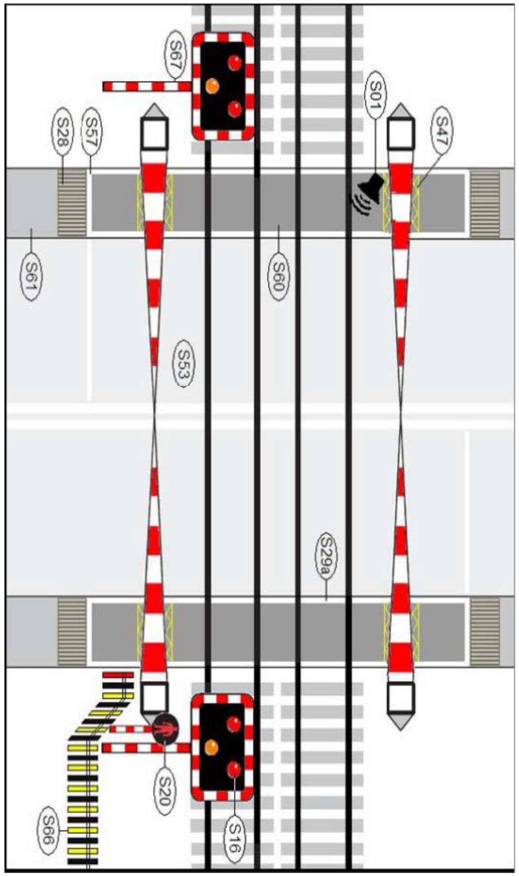
- Requires GPS + crossing location database
- No vehicle-train communication necessary (not “Active” from the RR perspective)
- Increases saliency, especially at passive crossings
- Reminds drivers to comply (and *how to* comply)

#3 Peds

Risk Analysis

#3 Grade Crossing Pedestrian Safety

- Interviews with experts
  - Lower priority unless adjacent to highway crossing
  - Lack of tools, cost data, uniformity
  - Distraction the big problem
- Survey of users
  - Younger users notice active, old notice passive
  - Regular users & females more safety conscious
- Video
  - Larger groups more likely to violate



#4
Derail

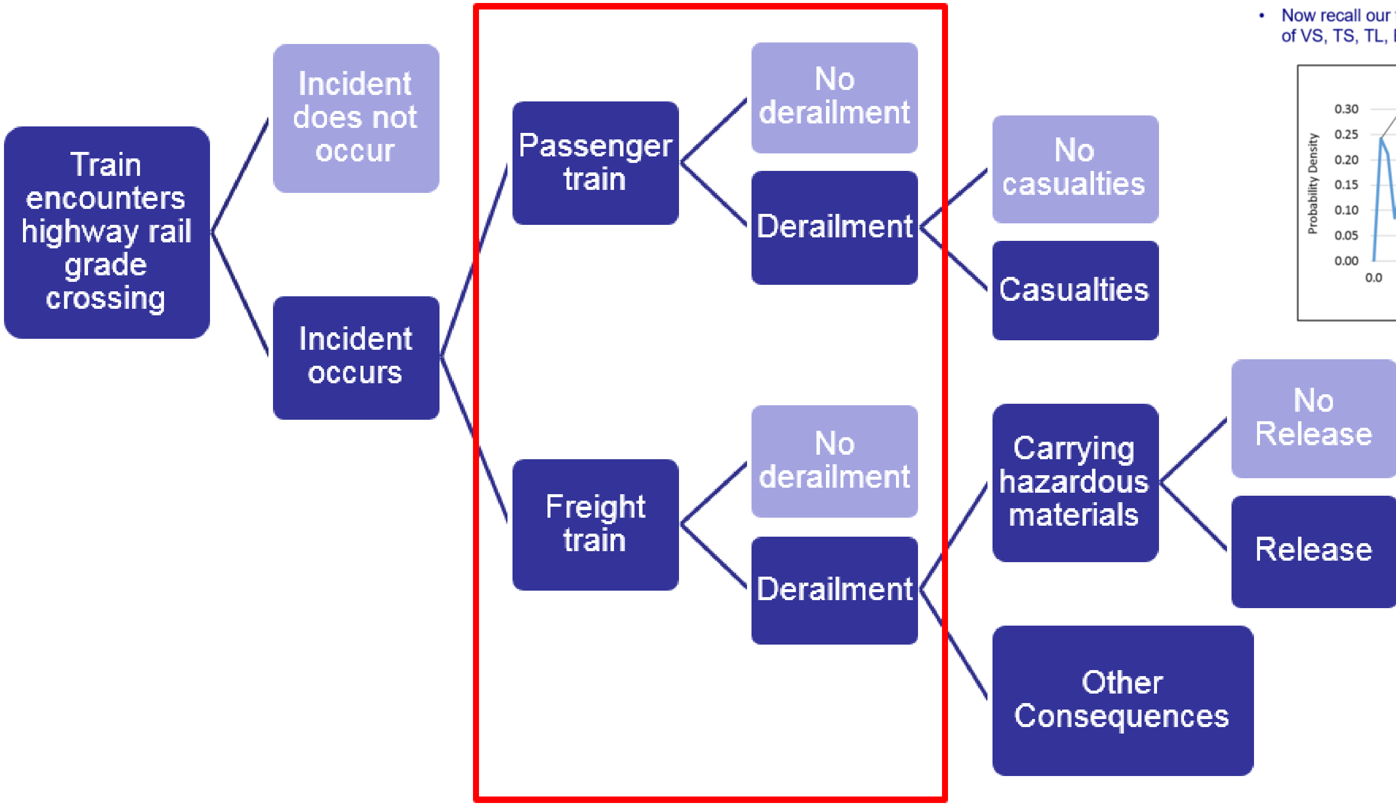
Risk
Analysis

Quantitative Analysis of Train Derailments Due to Highway-Rail Grade Crossing Incidents

#4
Derail

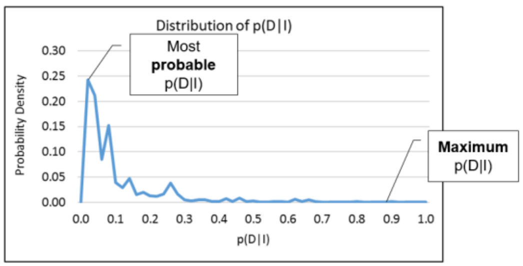
Risk
Analysis

Probabilistic Risk Assessment



Derailment Likelihood Calculator – p(D|I) curve

- Now recall our function $p(D|I) = \frac{1}{e^{-x}+1}$ which is a function of VS, TS, TL, EC, IT, LV



Incident Probability **p(D|I) Calculator** **Consequences**

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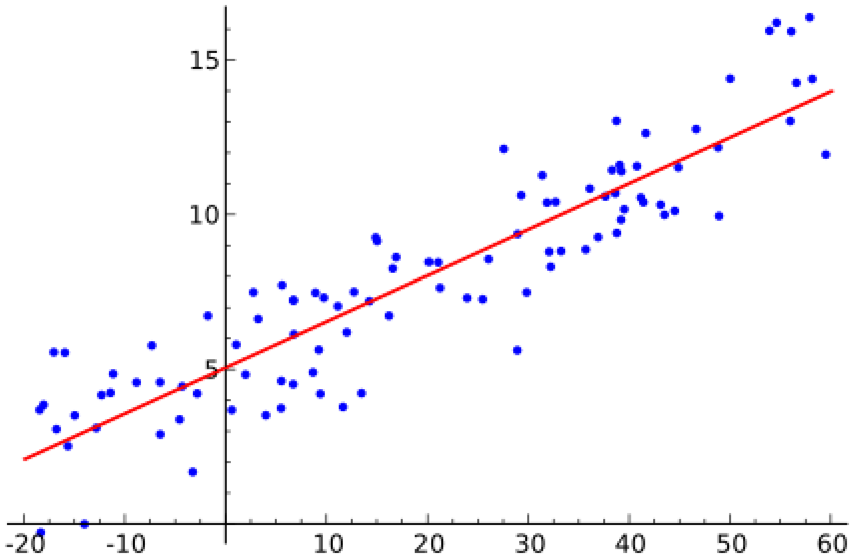
Key Findings

- Speed and weight of highway and rail vehicles important
- **Regression models** calculate probability of derailment based on physical factors
- **Easy-to-use calculator** for use by practitioners (ranking tool)



#4 Derail

Risk Analysis

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Key Findings (cont)

- **Case study** on how results can be used with existing metrics
- Combining consequence data, incident likelihood, derailment likelihood helps decide **<u>which crossings to upgrade</u>**

Crossing	Warning Device	Highway Class	Pax Trains	All Trains	Timetable Speed	Track Class	Expected Value		95th Percentile		WBAPS Prediction		$p(D\|I)_{exp}*f(I)$		$p(D\|I)_{95}*f(I)$	
							$p(D\|I)_{exp}$	Rank	$p(D\|I)_{95}$	Rank	f(I)	Rank	$f(D)_{exp}$	Rank	$f(D)_{95}$	Rank
4U	O. Active	UA	0	2	30	3	0.03689	1	0.22442	1	0.02110	4	0.00078	3	0.00473	3
4V	Passive	UL	0	2	30	3	0.03373	2	0.19140	4	0.00252	22	0.00009	23	0.00048	23
4W	Passive	UL	0	2	30	3	0.03373	2	0.19140	4	0.04836	2	0.00163	1	0.00926	2
4T	O. Active	UC	0	2	30	3	0.03348	3	0.19416	3	0.00877	16	0.00029	9	0.00170	12
4K	O. Active	UA	0	4	10	1	0.02570	4	0.19882	2	0.01293	9	0.00033	6	0.00257	7
4N	O. Active	UA	0	4	10	1	0.02570	4	0.19882	2	0.02149	3	0.00055	4	0.00427	4
4R	O. Active	UA	0	4	10	1	0.02570	4	0.19882	2	0.02092	5	0.00054	5	0.00416	5
4S	O. Active	UA	0	4	10	1	0.02570	4	0.19882	2	0.05827	1	0.00150	2	0.01158	1
4C	O. Active	UC	0	4	10	1	0.02230	5	0.16090	5	0.00671	19	0.00015	20	0.00108	20
4E	O. Active	UC	0	6	10	1	0.02230	5	0.16090	5	0.01311	8	0.00029	10	0.00211	9
4F	O. Active	UC	0	4	10	1	0.02230	5	0.16090	5	0.00898	15	0.00020	17	0.00144	17
4H	O. Active	UC	0	4	10	1	0.02230	5	0.16090	5	0.01011	12	0.00023	13	0.00163	13
4I	O. Active	UC	0	4	10	1	0.02230	5	0.16090	5	0.00962	14	0.00021	15	0.00155	15
4O	O. Active	UC	0	4	10	1	0.02230	5	0.16090	5	0.01270	10	0.00028	11	0.00204	10
4P	O. Active	UC	0	4	10	1	0.02230	5	0.16090	5	0.01201	11	0.00027	12	0.00193	11
4A	O. Active	UL	0	4	10	1	0.02154	6	0.15518	6	0.01003	13	0.00022	14	0.00156	14
4B	O. Active	UL	0	4	10	1	0.02154	6	0.15518	6	0.01440	7	0.00031	8	0.00223	8
4G	O. Active	UL	0	4	10	1	0.02154	6	0.15518	6	0.00773	18	0.00017	19	0.00120	19
4J	O. Active	UL	0	4	10	1	0.02154	6	0.15518	6	0.00589	21	0.00013	22	0.00091	22
4L	O. Active	UL	0	4	10	1	0.02154	6	0.15518	6	0.00630	20	0.00014	21	0.00098	21
4M	O. Active	UL	0	4	10	1	0.02154	6	0.15518	6	0.00823	17	0.00018	18	0.00128	18
4Q	O. Active	UL	0	4	10	1	0.02154	6	0.15518	6	0.00962	14	0.00021	16	0.00149	16
4D	Gates	UA	0	4	10	1	0.01666	7	0.14098	7	0.01983	6	0.00033	7	0.00280	6
							Corridor 4 Incident Total:			**f(I)**	**0.34961**	**$f(D)_{exp}$**	**0.00901**	**$f(D)_{95}$**	**0.06299**	

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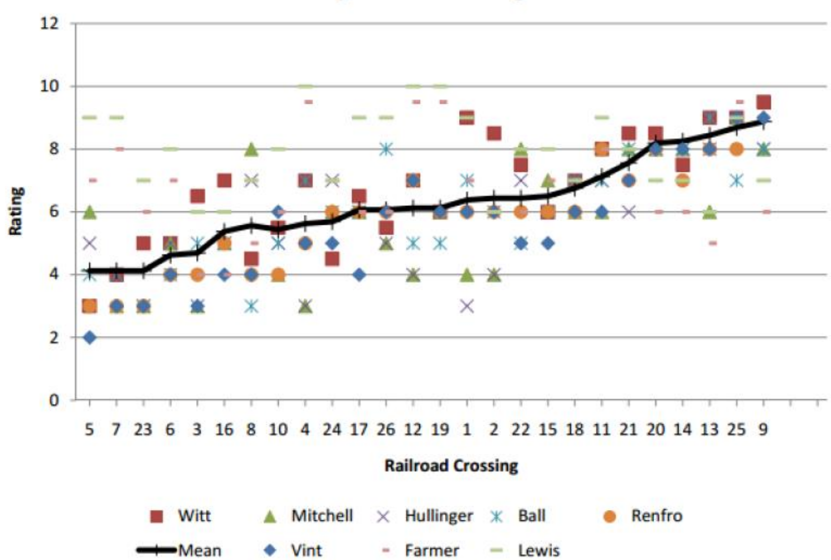
Combination of Micro and Macro Models for Risk Assessment

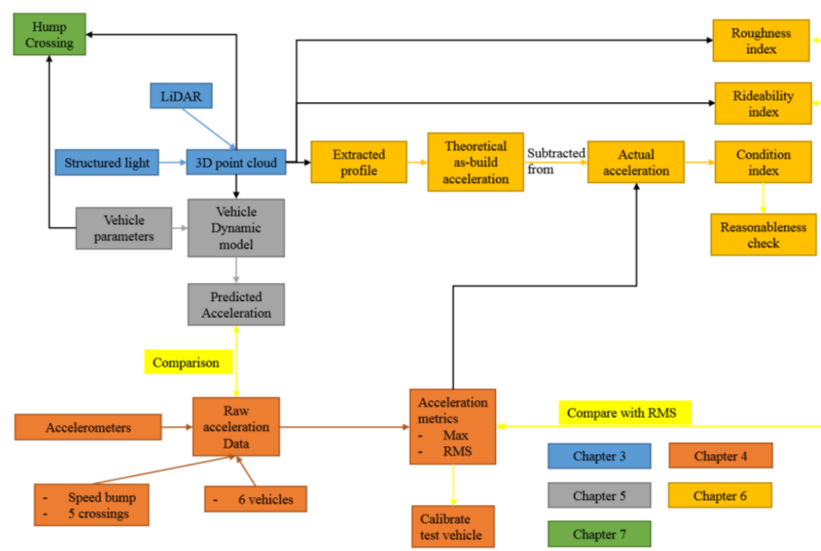
- **Macroscopic** models derived from entire state or country
  - Correlation between **crossing characteristics** and past accident frequency
  - E.g., **US DOT** Accident Prediction Formula.
- Microscopic perspective: **individual characteristics** of accidents and crossings
  - Discover **local trends**
- **Combined** micro and macro model development
  - **Compared** results to US DOT APF

#6 3D

Infra-
structure

Quantifying Condition





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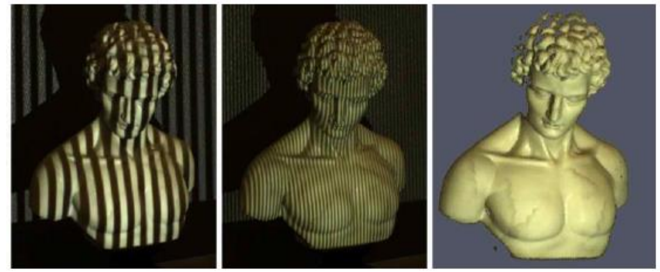
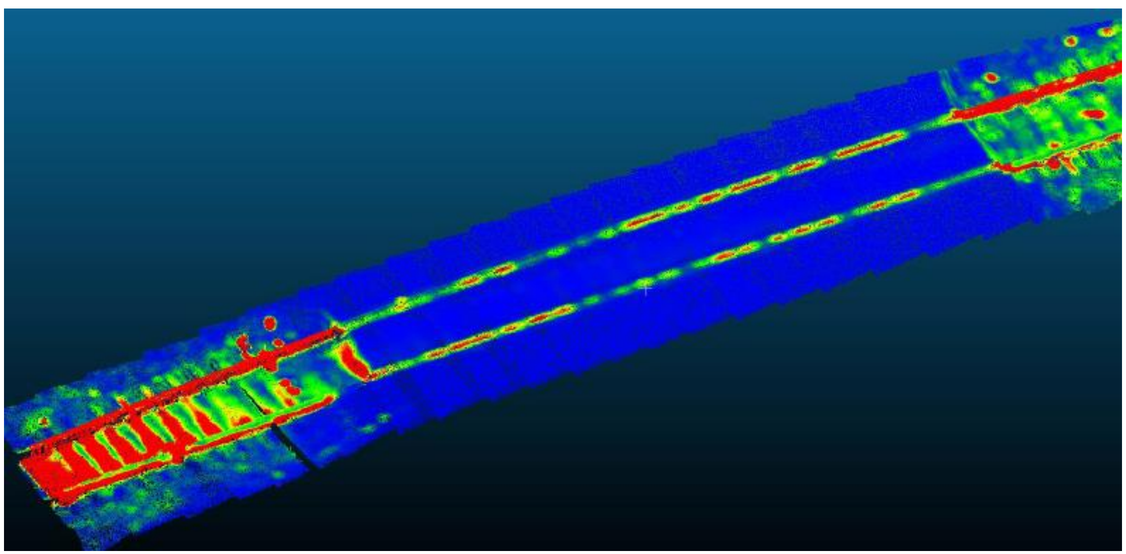
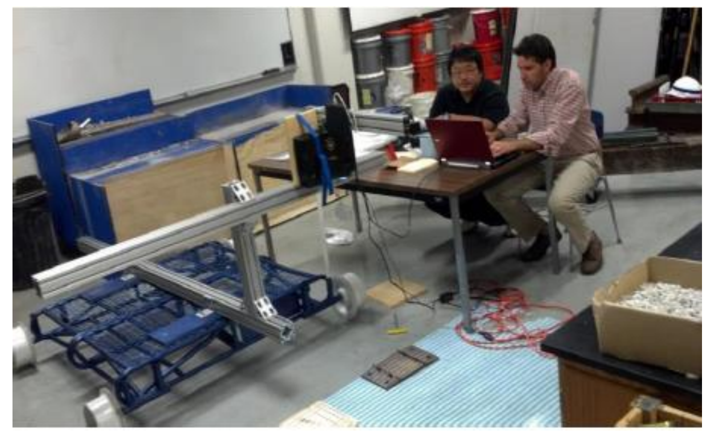
Structured-light Sensor





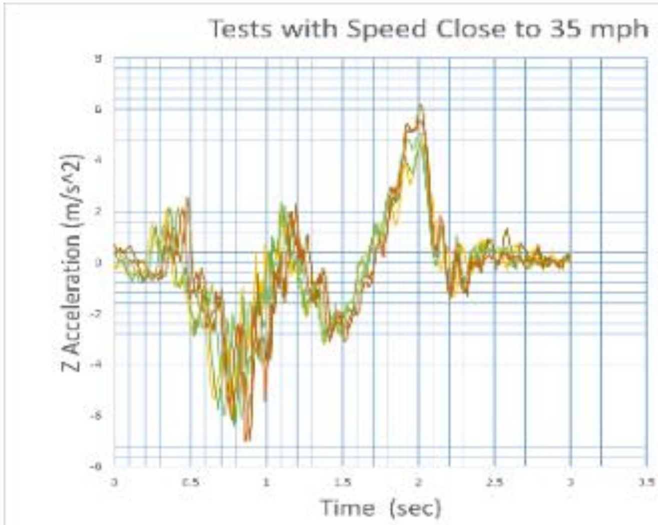


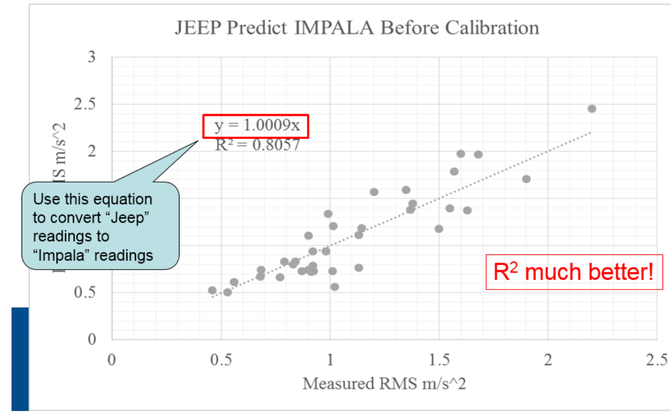
Physical model

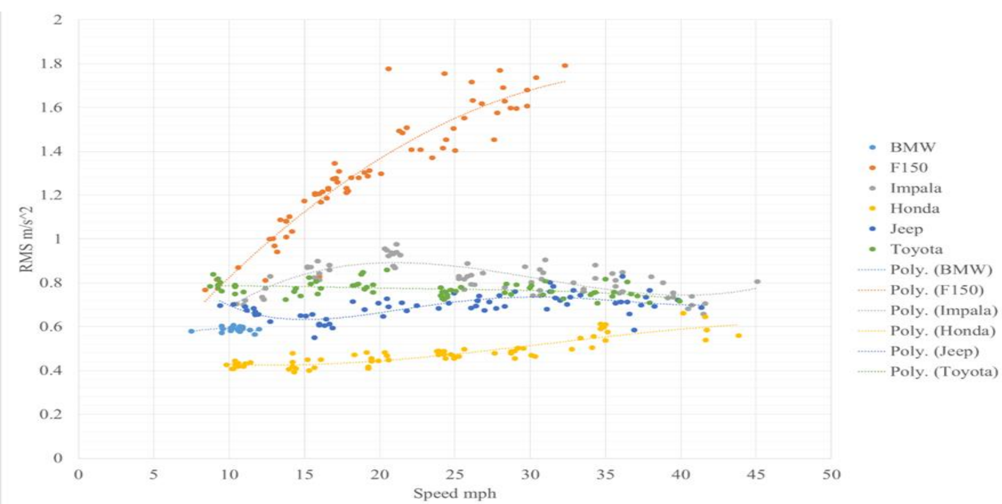
#6 3D

Infra-
structure

Accelerometer Application







Sensitivity of Crossing Ranking using RMS of Various Vehicles

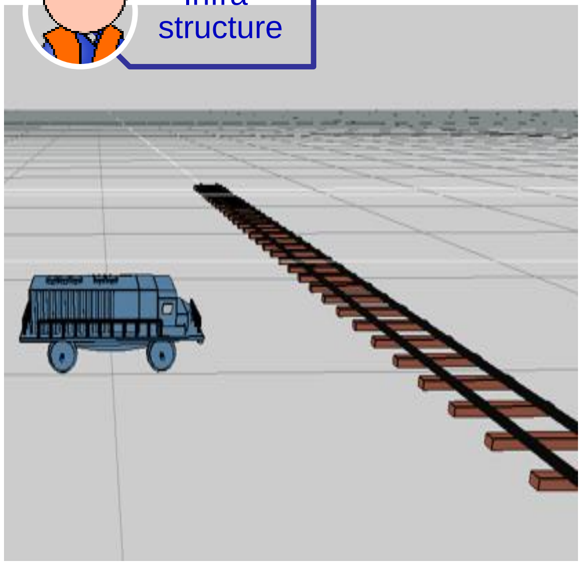
Crossing	Posted Speed	Ave. RMS	Rank based on Ave. RMS	Rank based on F150	Rank based on IMPALA	Rank based on JEEP	Rank based on HONDA	Rank based on TOYOTA	Rank based on BMW
Bryan Station	30	0.67	5	5	5	4	4	5	5
Briar Hill	35	1.74	1	1	1	1	1	1	1
Hatton	20	0.99	3	3	3	3	3	2	3
Bridgeport-Benson	25	1.09	2	2	2	2	2	3	2
Devil's Hollow	35	0.71	4	4	4	5	5	4	4

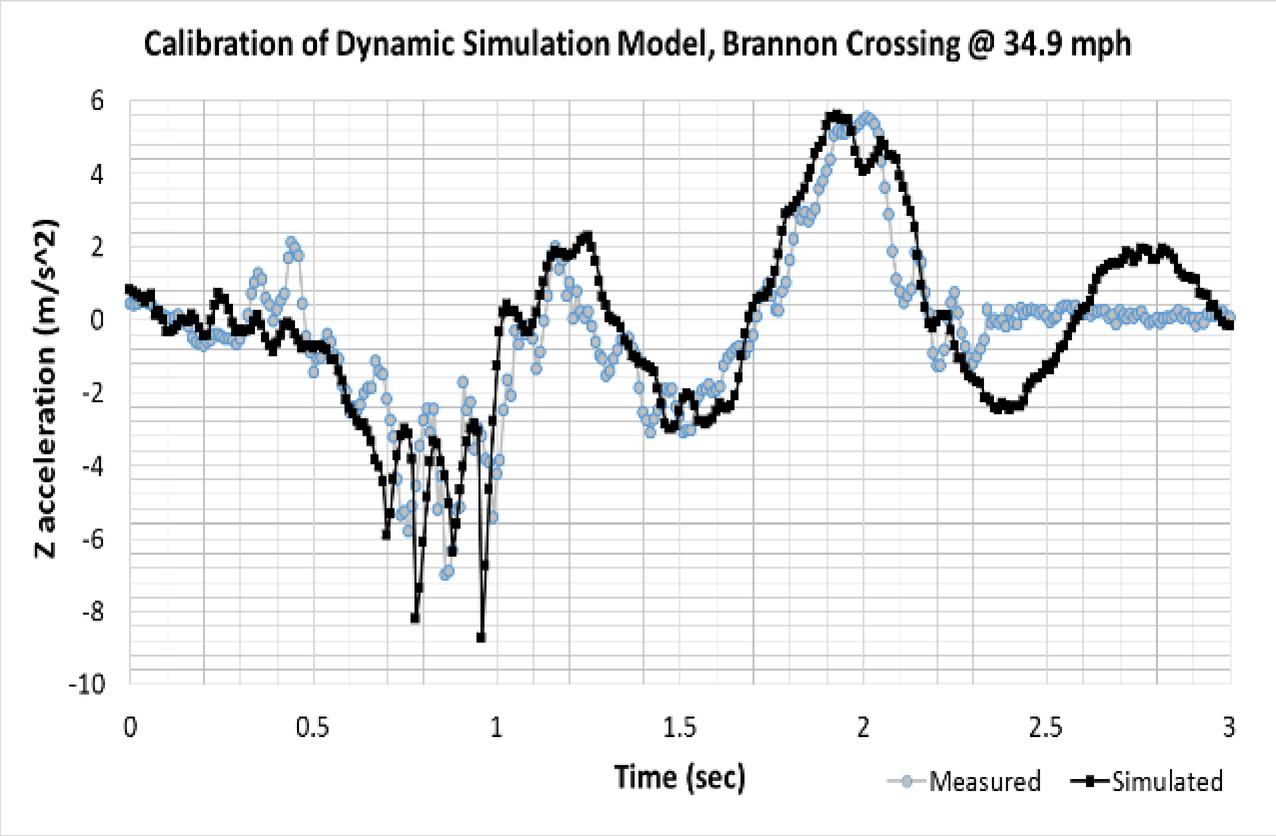
Performance

A Vehicle Dynamic Model

#7 Dymanic

Infra-structure





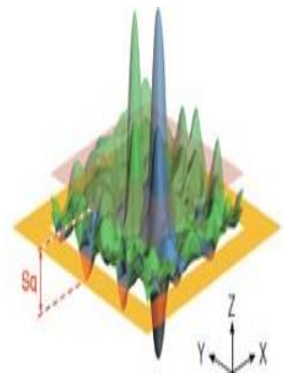
Do we need to go to the field?

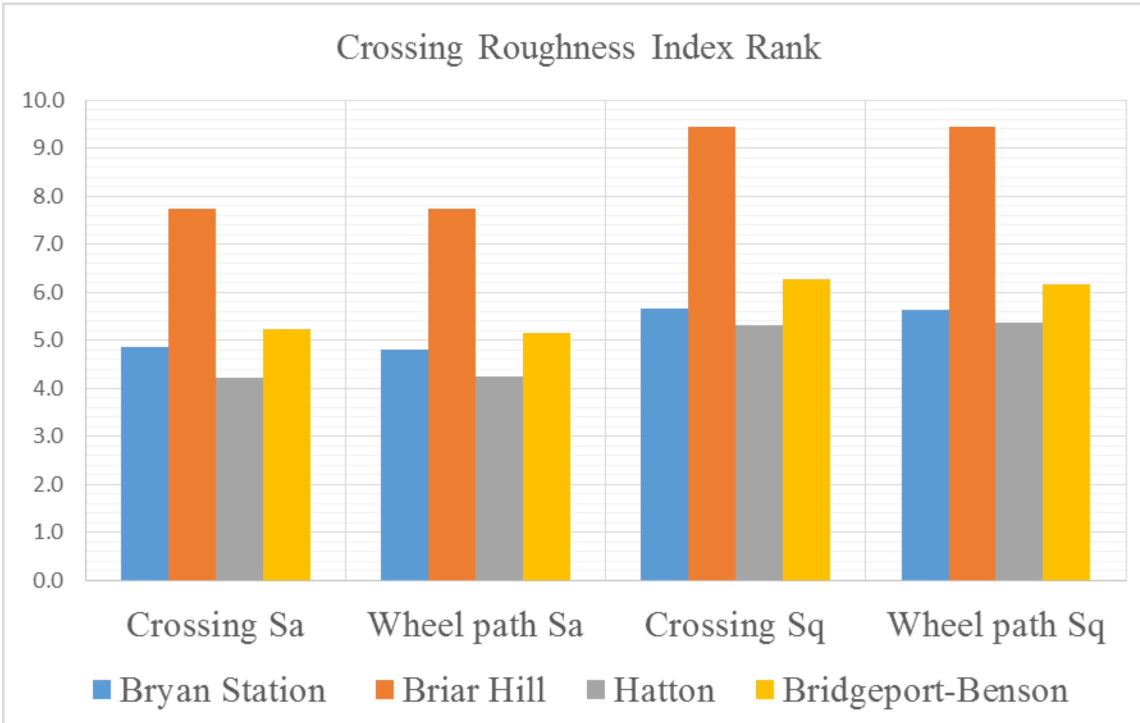
Physical model ⇨ **Performance**

#8 Index

Infra-structure

Rail Crossing Condition Index

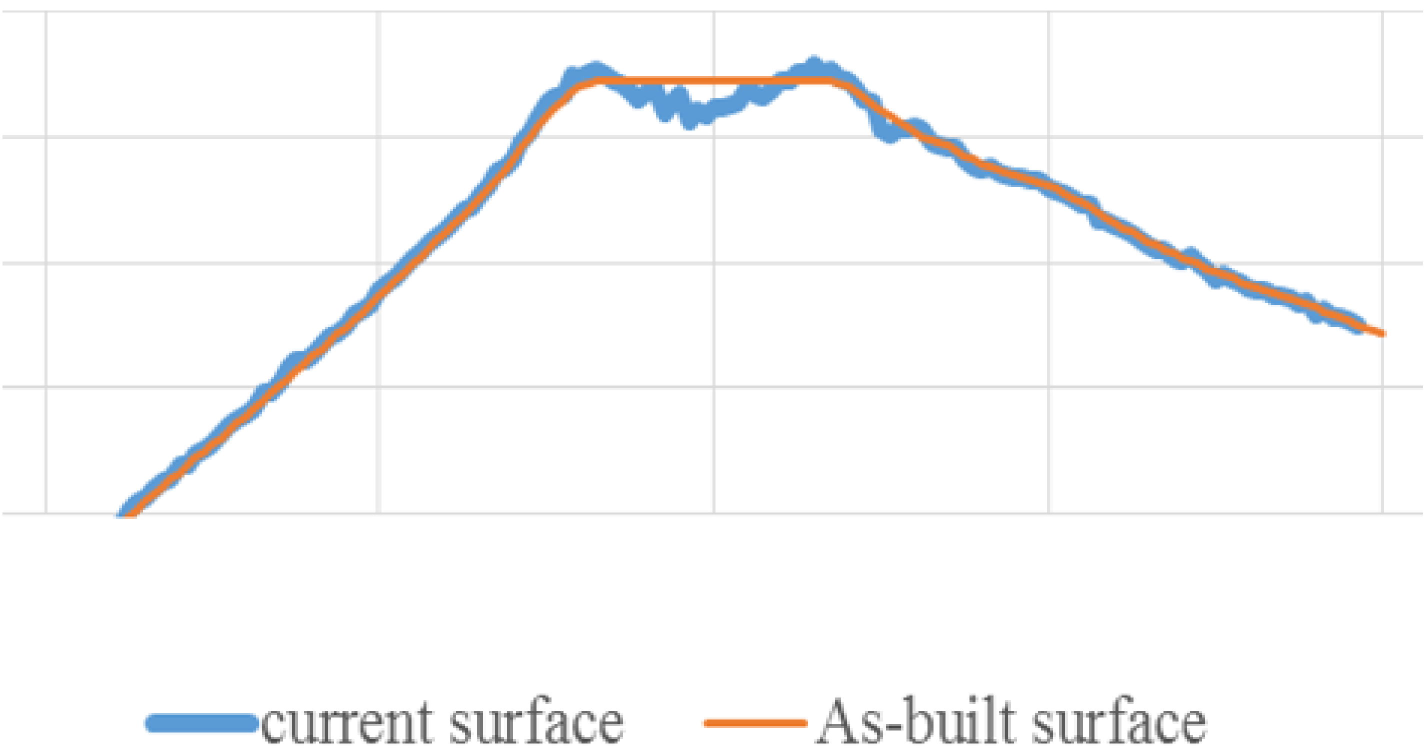




$$S_a = \frac{1}{MN}\sum_{j=1}^{N}\sum_{i=1}^{M}\left|z(x_i, y_j)\right| \qquad S_q = \sqrt{\frac{1}{MN}\sum_{j=1}^{N}\sum_{i=1}^{M} z^2(x_i, y_j)}$$

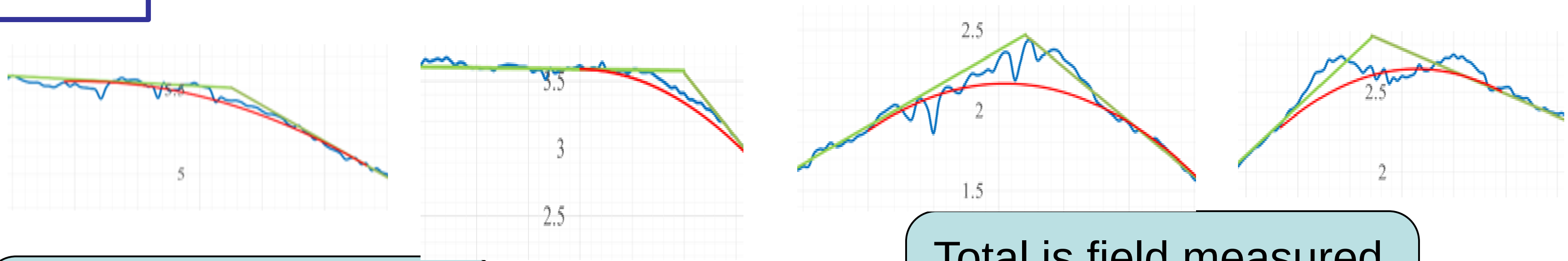
Can we separate the effects of original design from effects of poor surface condition?

Can we separate the effects of original design from effects of poor surface condition?



Two components of crossing rideability

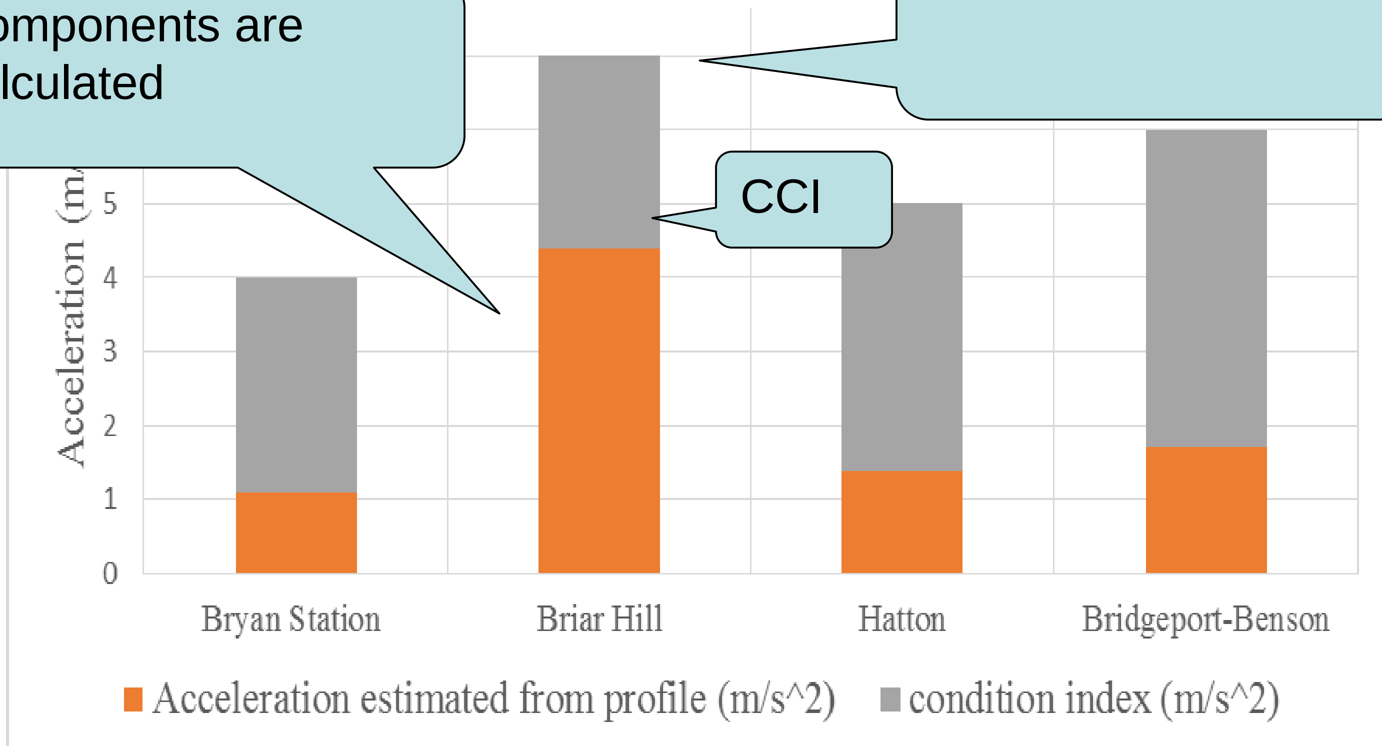
UNIVERSITY OF KENTUCKY



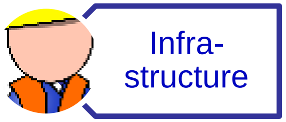
Components are calculated

Total is field measured

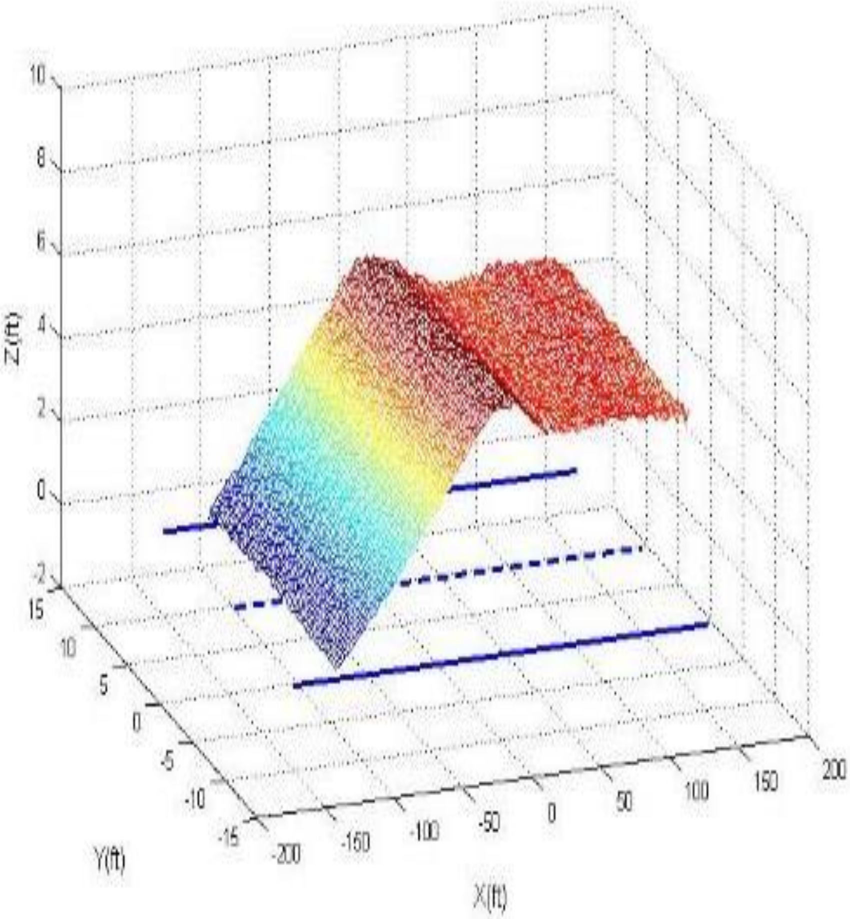
CCI



Hump Crossings



Hump? … More that just a "yes or no" question



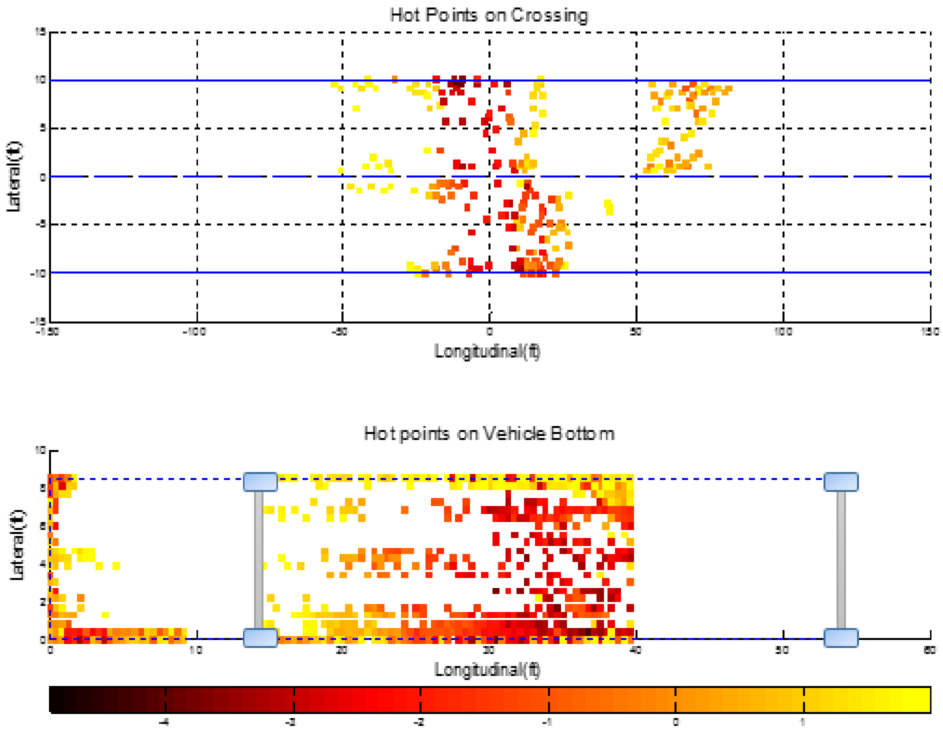


Figure.9 Car Carrier Trailer pass KY-57 Briar Hill Army Depot

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Validation

	KY-57 Bryan Station (A)			Brannon Rd (B)			KY-57 Briar Hill Army Depot (C)		
Veh. type	Wheel base	Front Over hang	Rear Over hang	Wheel base	Front Over hang	Rear Over hang	Wheel base	Front Over hang	Rear Over hang
1	L1	-	L1.	L1	-	L1	L1.	-	L1
2	L1	L1	L1	L1	L1	L5	L1	L1	L1
3	L1	L1	L1	L2	L3	L4	L1	L1	L1
4	L1	-	L1	L2	-	L3	L1	-	L1
5	L3	-	-	L5	-	-	L4	-	-
6	L4	-	L1	L5	-	L5	L5	-	L3
7	L2	-	-	L4	-	-	L2	-	-

Level 1: $\delta_{min} > 2$ inch

Level 2: $2\ inch \geq \delta_{min} > 0\ inch$

Level 3: $0\ inch \geq \delta_{min} > -1\ inch$

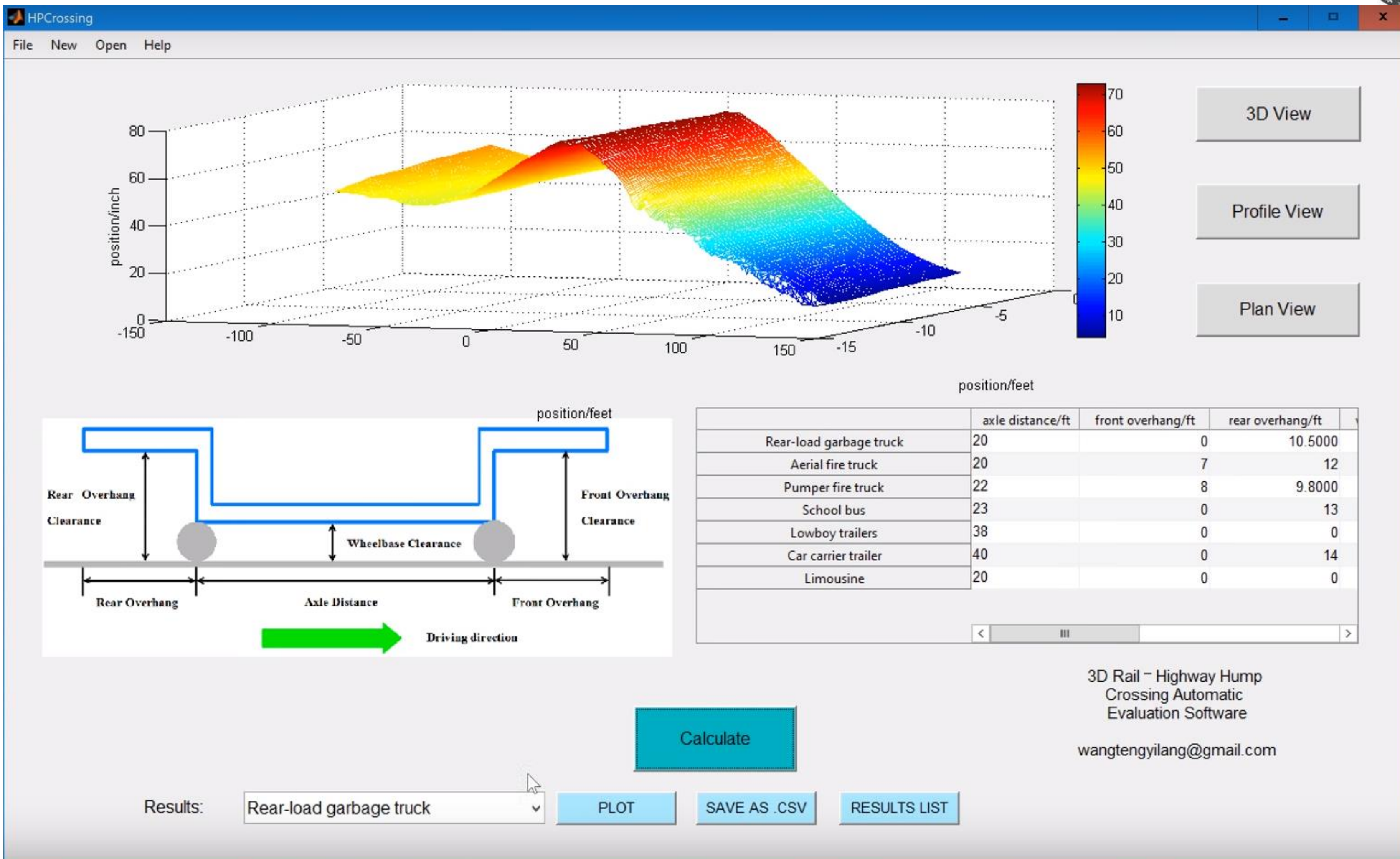
Level 4: $-1\ inch \geq \delta_{min} > -2\ inch$

Level 5: $\delta_{min} \leq -2\ inch$

#9
Hump

Infra-
structure

3D Rail-highway hump crossing automatic evaluation software GUI

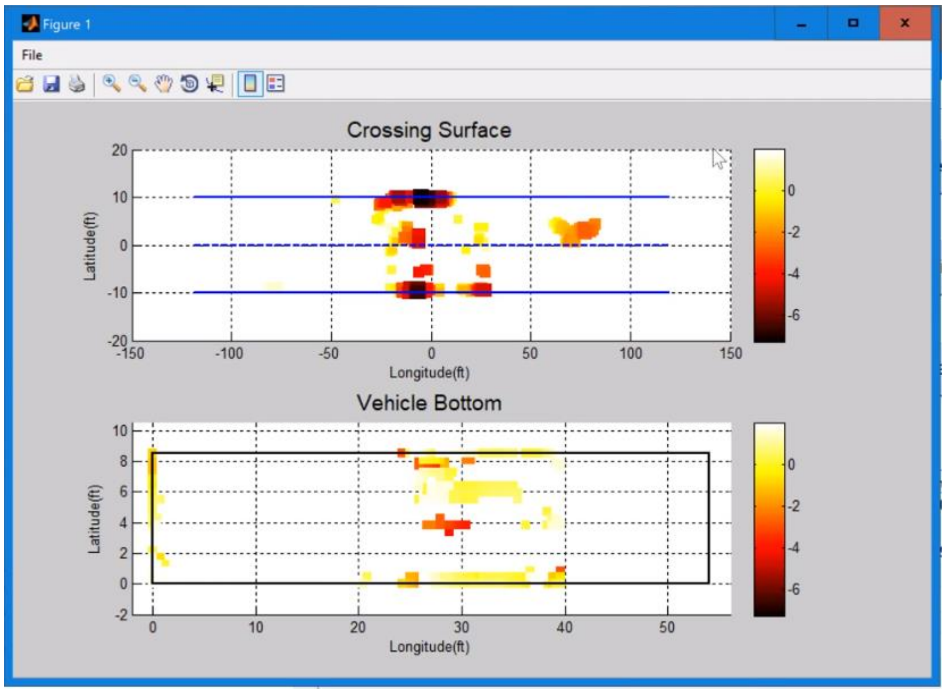


Software Demo Video: https://youtu.be/EwEpXB4Zq2U

#9 Hump

Infra-structure

3D Rail-highway hump crossing automatic evaluation software result output



Brannon Rd 0.05_Car carrier

	Road_Surf_Longitudinal	Road_Surf_Lateral	Contact_Index	Car_Base_Longitudinal	Car_Base_Lateral
2	4.973	-2.788	0.050603947	0.127	0
3	7.513	-2.918	0.05060301	8.001	0.13
4	-24.872	-2.658	0.05059141	0	0.39
5	-14.498	2.918	0.050548678	11.303	0
6	-14.498	2.918	0.050428728	11.557	0.13
7	7.513	-2.918	0.049546246	8.001	0
8	4.973	-2.918	0.049066676	0.127	0
9	8.529	-0.188	0.048656385	8.636	2.6
10	8.529	-0.188	0.048290749	8.509	2.6
11	-4.846	2.398	0.048131177	0	0.39
12	-23.475	-2.658	0.048118439	0	0.39
13	-5.735	0.318	0.048077325	7.747	2.6
14	-23.983	-2.658	0.047961646	0.127	0.39
15	-6.116	2.528	0.047760134	0.254	0.26
16	-23.221	-2.658	0.047712527	0	0.39
17	-23.602	-2.658	0.047702935	0	0.39
18	-7.005	2.398	0.047617553	0	0.39
19	-6.584	-0.448	0.047566416	12.065	2.6
20	-23.729	-2.658	0.04756486	0	0.39
21	-6.116	2.528	0.047278892	0.508	0.26
22	-14.498	2.918	0.047151711	11.43	0
23	-6.116	1.098	0.046818828	8.001	1.69
24	-24.999	-2.658	0.046768698	0	0.39
25	4.973	-2.788	0.046671245	0	0
26	-5.862	0.448	0.046604578	7.874	2.6
27	-6.116	1.098	0.045925356	8.255	1.95
28	8.529	-0.188	0.045414963	8.763	2.6
29	7.513	-2.918	0.044494299	8.128	0
30	-23.856	-2.658	0.044337768	0	0.39
31	-6.116	1.098	0.044262588	8.128	1.69
32	-14.498	2.918	0.044143409	11.303	0.13
33	-25.126	-2.658	0.043872367	0	0.39

Brannon Rd 0.05_Car carrier tra

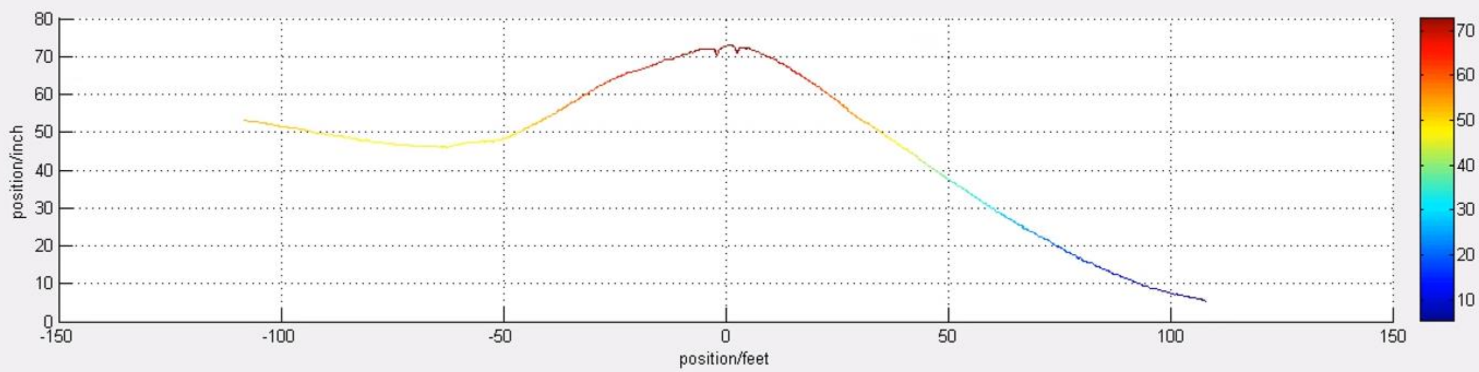
#9 Hump

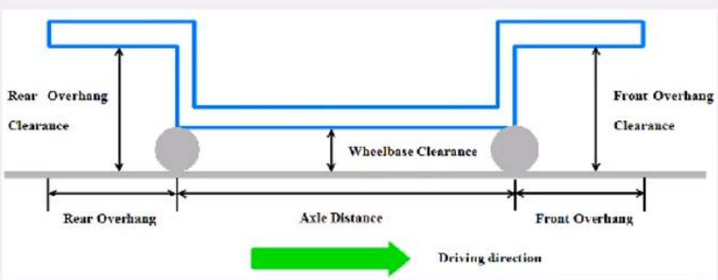
Infra-structure

2D Rail-highway hump crossing automatic evaluation software GUI

HPCrossing

File New Open Help





	axle distance/ft	front overhang/ft	rear overhang/ft
Rear-load garbage truck	20	0	10.5000
Aerial fire truck	20	7	12
Pumper fire truck	22	8	9.8000
School bus	23	0	13
Lowboy trailers	38	0	0
Car carrier trailer	40	0	14
Limousine	20	0	0

2D Rail – Highway Hump Crossing Automatic Evaluation Software

wangtengyilang@gmail.com

Calculate

Results: PLOT SAVE AS .CSV RESULTS LIST

Software Demo Video: https://youtu.be/EwEpXB4Zq2U

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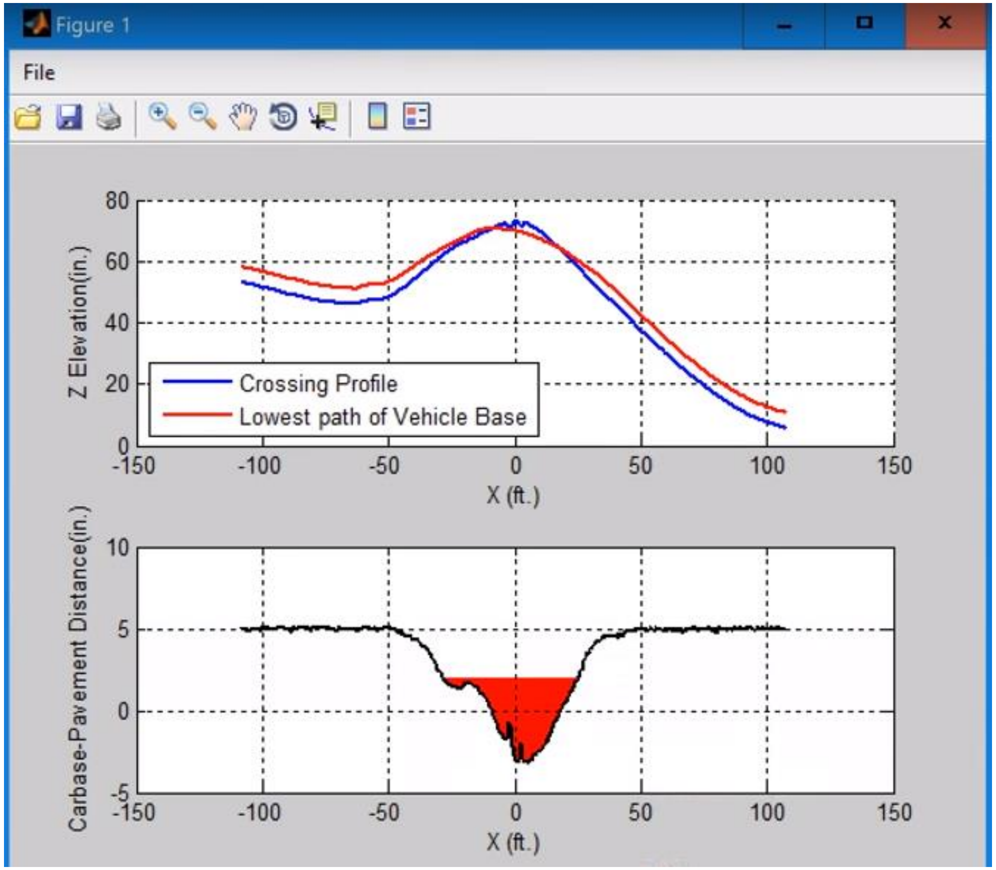
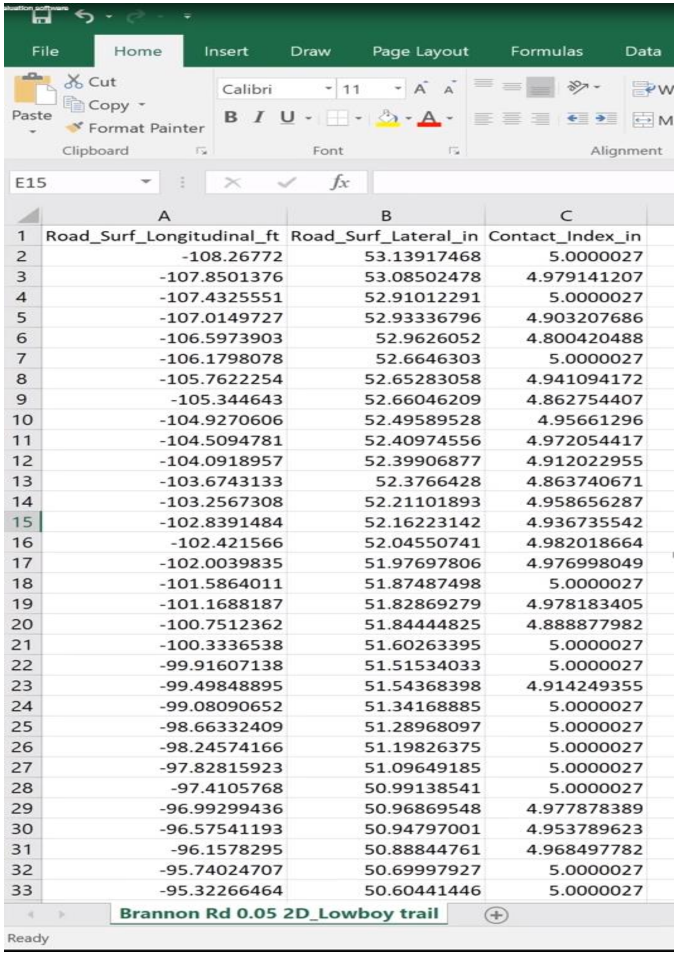
#9 Hump

Infra-structure

2D Rail-highway hump crossing automatic evaluation software result output





	A	B	C
1	Road_Surf_Longitudinal_ft	Road_Surf_Lateral_in	Contact_Index_in
2	-108.26772	53.13917468	5.0000027
3	-107.8501376	53.08502478	4.979141207
4	-107.4325551	52.91012291	5.0000027
5	-107.0149727	52.93336796	4.903207686
6	-106.5973903	52.9626052	4.800420488
7	-106.1798078	52.6646303	5.0000027
8	-105.7622254	52.65283058	4.941094172
9	-105.344643	52.66046209	4.862754407
10	-104.9270606	52.49589528	4.95661296
11	-104.5094781	52.40974556	4.972054417
12	-104.0918957	52.39906877	4.912022955
13	-103.6743133	52.3766428	4.863740671
14	-103.2567308	52.21101893	4.958656287
15	-102.8391484	52.16223142	4.936735542
16	-102.421566	52.04550741	4.982018664
17	-102.0039835	51.97697806	4.976998049
18	-101.5864011	51.87487498	5.0000027
19	-101.1688187	51.82869279	4.978183405
20	-100.7512362	51.84444825	4.888877982
21	-100.3336538	51.60263395	5.0000027
22	-99.91607138	51.51534033	5.0000027
23	-99.49848895	51.54368398	4.914249355
24	-99.08090652	51.34168885	5.0000027
25	-98.66332409	51.28968097	5.0000027
26	-98.24574166	51.19826375	5.0000027
27	-97.82815923	51.09649185	5.0000027
28	-97.4105768	50.99138541	5.0000027
29	-96.99299436	50.96869548	4.977878389
30	-96.57541193	50.94797001	4.953789623
31	-96.1578295	50.88844761	4.968497782
32	-95.74024707	50.69997927	5.0000027
33	-95.32266464	50.60441446	5.0000027

Thanks:
SAFER-LC, Elias Kassa, Marie-Hélène Bonneau

- Questions?
  - Souleyrette@uky.edu
- Reports and more information:
  - http://www.nurailcenter.org/

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