Combination of Microscopic and Macroscopic Models for Analysis of Accidents at Railroad Grade Crossings

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Background

- Grade crossings accidents are often predicted based on models developed on national/state level trends (macro model)

- Current state-of-practice is using the U.S. DOT accident model:

(FRA's Web Accident Prediction System – WBAPS)

- Useful tool that may provide acceptable results

- Are WBAPS estimates accurate enough? Can we do better?

Background

- Two modeling options:

  - Micro scale: Detail analysis of contributing factors at high accident crossings
  - Macro scale: Models built on national/state level trends and contributing factors

- Each option has usefulness and limitations
- Goal is to combine results from micro and macro analysis
- Illinois data is used to illustrate potential benefits of combined method

A Micro Approach

- Micro-level approach is being developed

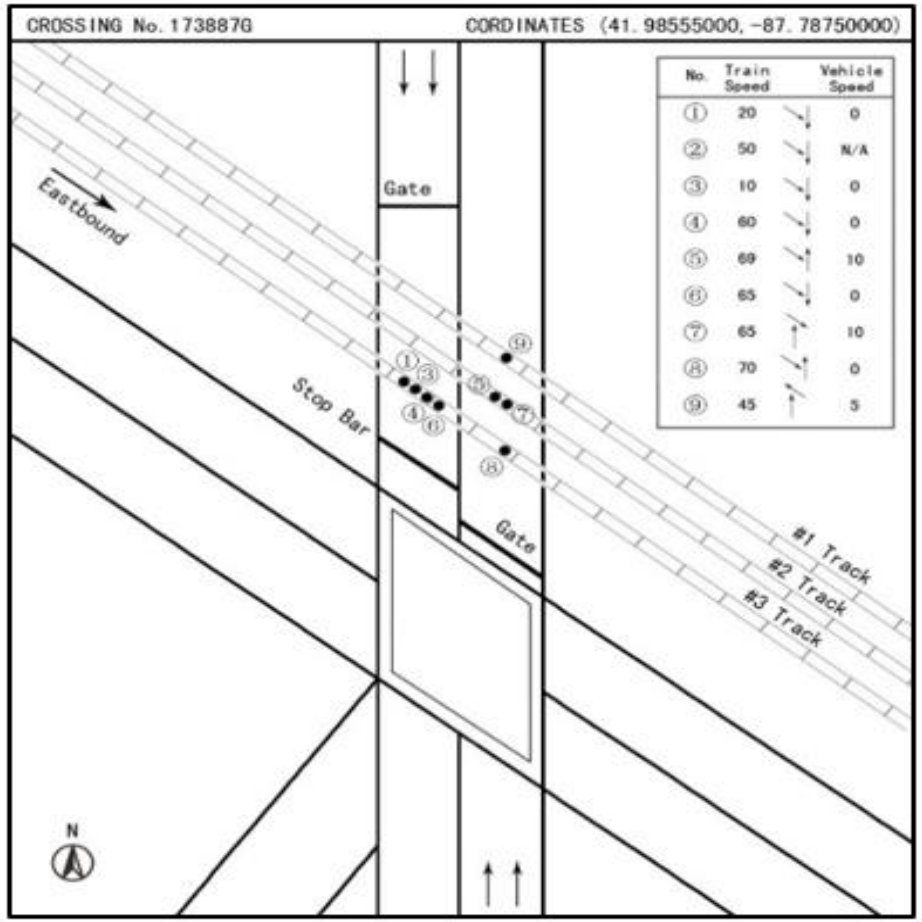
- The main goal is to spot local trends/contributing factors

- Simple, easy-to-use, complements info for site inspections and prelim analysis

- <u>3 steps so far</u>:
  - Sketch of crossings with key info
  - Tree structure to spot trends (dynamic structure is under development)
  - Additional information (e.g. surroundings, land use, nearby ramps)

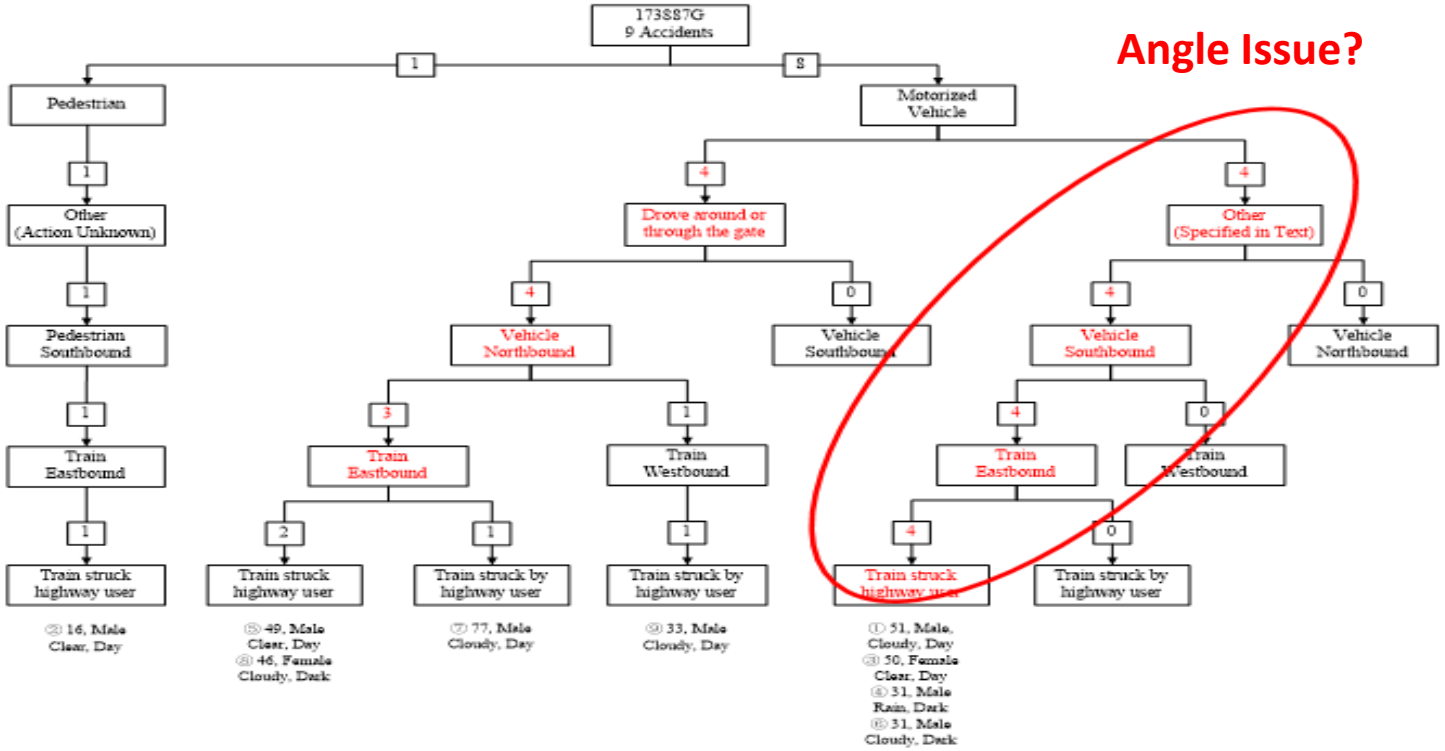
A Micro Approach

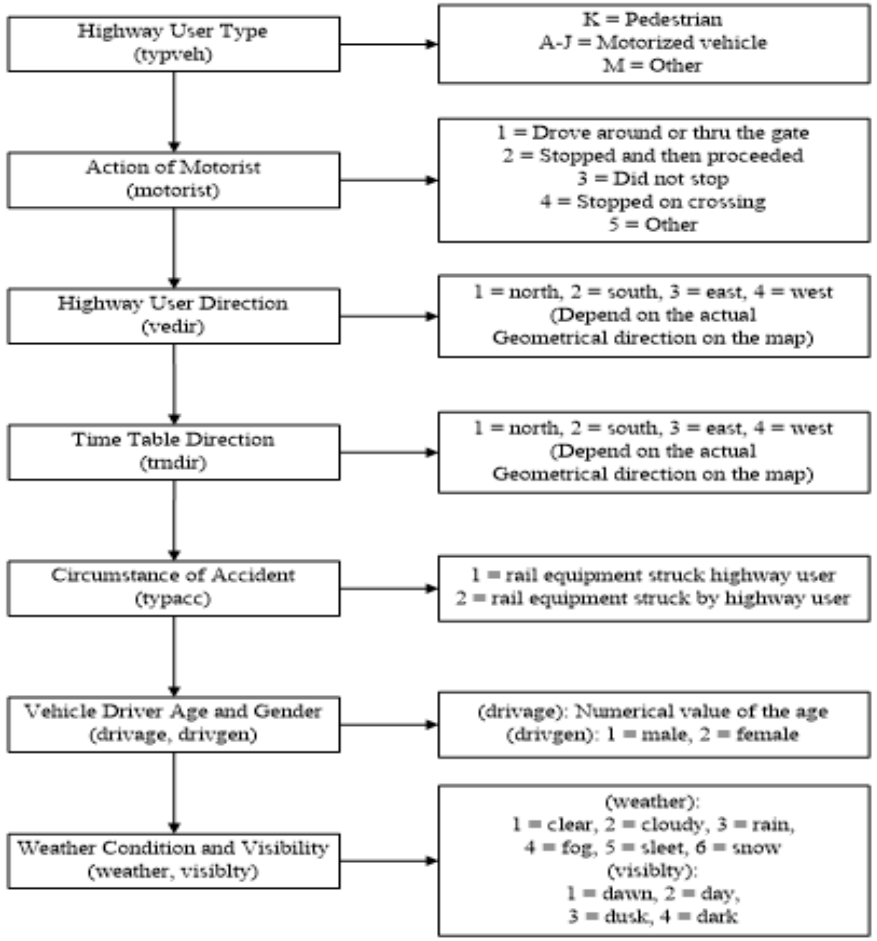
- Sketch of crossings with key info:



A Micro Approach

- Tree structure to visualize trends: A first example



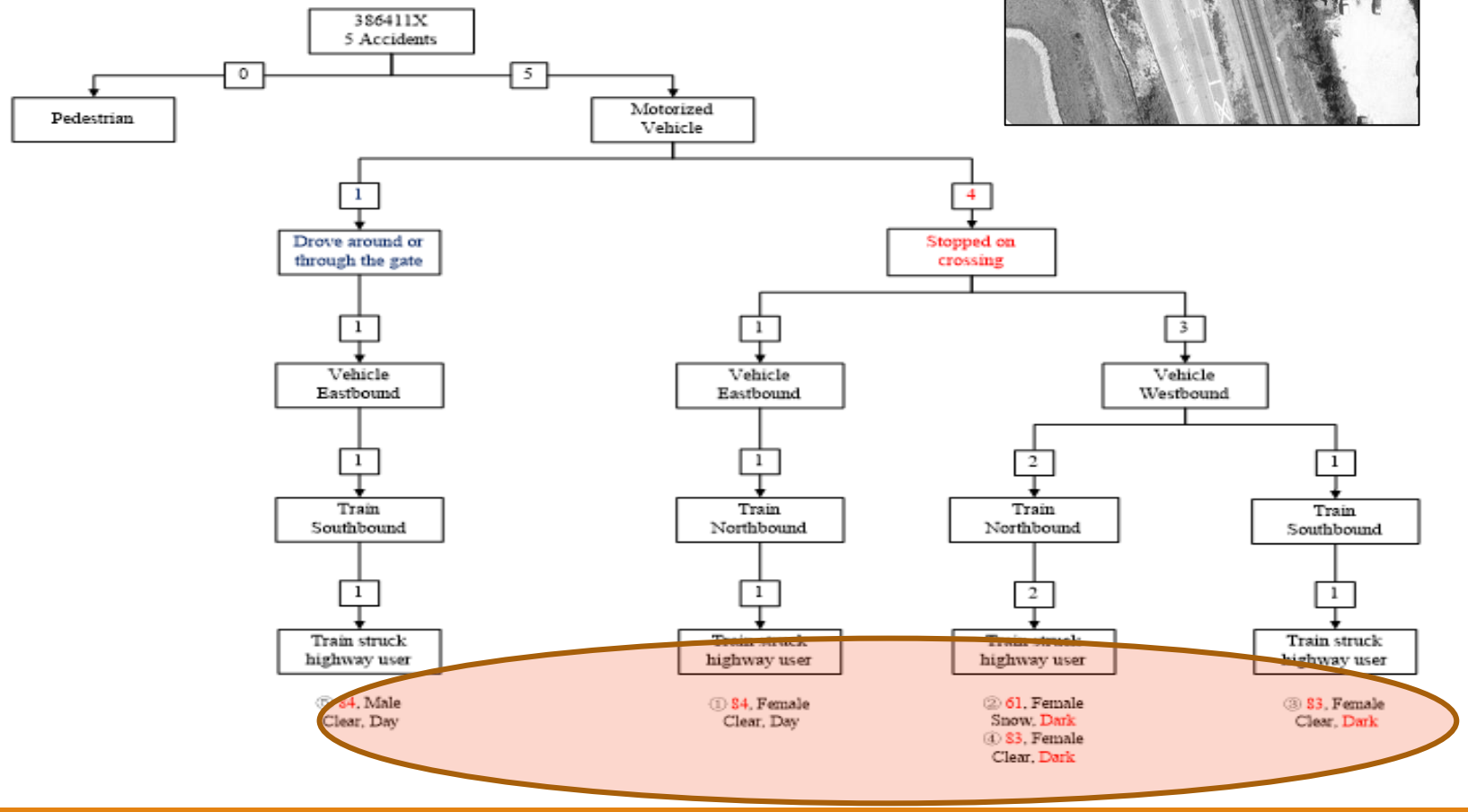


A Micro Approach

<u>A Second example:</u>

Unusual trend spotted at the bottom of the tree:

- 4 of 5 accidents involved drivers older than 80
- The remaining driver was 61 years old



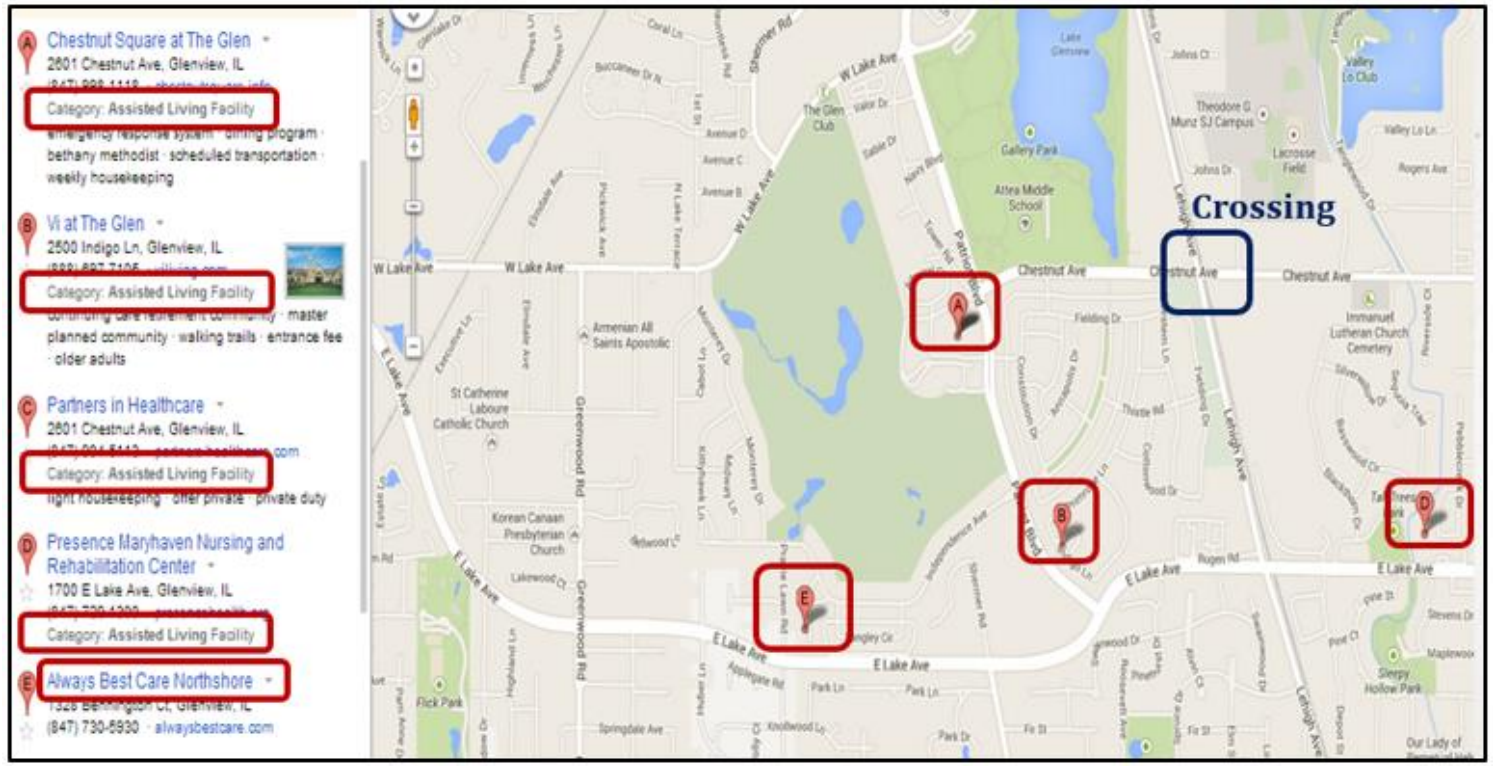
A Micro Approach

A Second example (Cont…)

- Crossing surroundings indicated high concentration of assisted living communities

- Countermeasures should incorporate population type

- Should aspects like this be included at macro level?



A Combined Macro Model

- Combination of micro results into improved macro models currently under study

- Variables such as crossing angle can be tested and added to improve accuracy

- Example to compare U.S. DOT model and a combined model based on:

  - The overall accident predictions (absolute predictions)
  - Ranking high-accident locations

The U.S. DOT Model

- Initial collision model was developed based on the data from 1975 database

- Most coefficients remain unchanged since 1980
  - (“Rail-Highway Crossing Hazard Prediction – Research Results”)

- A new term is added to reflect frequency of accidents in recent years

- Weighted average of the initial and new terms is computed

- To compute the predicted No. of accidents: the predicted value is multiplied by a constant that changes by the device type and year

Three Main Steps in U.S. DOT Model

1. Initial collision prediction (*a*) = $K \times EI \times MT \times DT \times HP \times MS \times HT \times HL$

Example for Flashing Lights:

Crossing Category	Formula Constant K	Exposure Index Factor EI	Main Tracks Factor MT	Day Thru Trains Factor DT	Highway Paved Factor HP	Maximum Speed Factor MS	Highway Type Factor HT	Highway Lanes Factor HL
Flashing Lights	0.003646	$\left(\frac{e \times t + 0.2}{0.2}\right)^{0.2953}$	$e^{0.1088mt}$	$\left(\frac{d + 0.2}{0.2}\right)^{0.0470}$	1.0	1.0	1.0	$e^{0.1380(hl-1)}$

Source: *U.S. DOT and Federal Highway Administration. Railroad-highway Grade Crossing Handbook. Washington D.C., 2007*

Three Main Steps in U.S. DOT Model

2. Second collision prediction (*B*) = $\frac{T_0}{T_0 + T}(a) + \frac{T}{T_0 + T}\left(\frac{N}{T}\right)$

Accident history
(N accidents in T years)

$$T_0 = \frac{1.0}{(0.05 + a)}$$

3. Final collision prediction (*A*) = B * Normalizing Constant

WARNING DEVICE GROUPS	NEW	PRIOR YEAR CONSTANTS							
	2010	2007	2005	2003	1998	1992	1990	1988	1986
(2) Flashing Lights	**.2918**	.4605	.5233	.5001	.5292	.6935	.8345	.8013	.8887

Source: *Accident Prediction and Resource Allocation Procedure Normalizing Constants. 2010*

Observations on the U.S. DOT Model

- Does not provide relevant information about local contributing factors

- Final prediction is mostly based on past history:

$$\frac{T_0}{T_0 + T}(a) + \frac{T}{T_0 + T}\left(\frac{N}{T}\right)$$

For a 5-year analysis: $T_0 \geq T$ if $a < 0.15$

For most high accident locations $a > 0.15$

Example: AADT=3000, Trains=50, 3 lanes, 3 tracks → *a=0.22*

- In summary, prediction similar to past history for high accident locations, limited role of ***a***

A Combined Macro Model

- Using data from Illinois, we tested different regression models, found good fit for:
  - Zero-inflated negative binomial (ZINB)
- 5 years of data (2003-2007) used for model building
- 5 years for data (2008-2012) used for evaluation/validation of the model
- ZINB models created for the same warning device categories as U.S. DOT formula

A Combined Macro Model

- Significant contributing variables (ZINB Models) – example active warning devices:

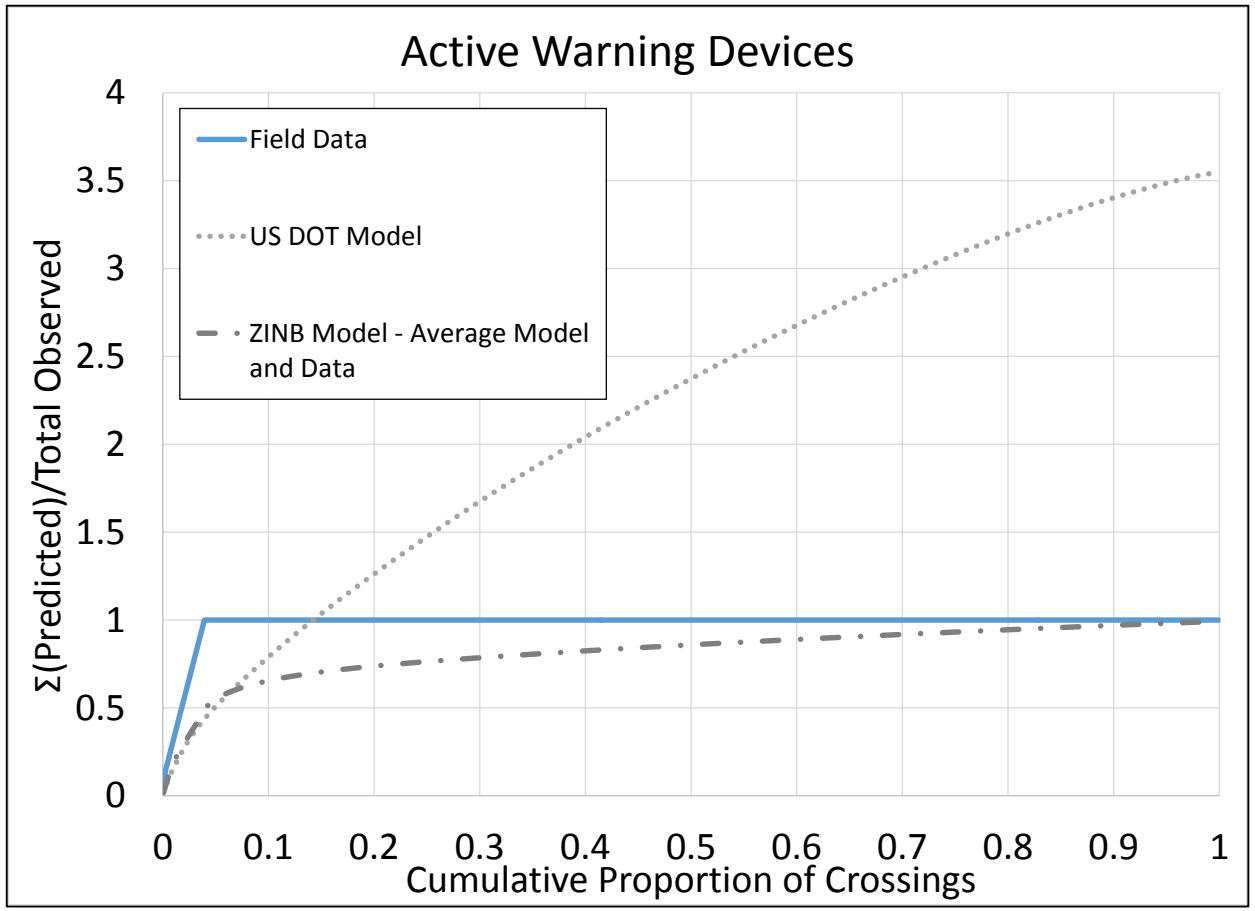
Variable	Category	Active Warning Devices	
		Selected for Final Model	Pvalue
Intercept	-	✓	< 0.0001
aadt	-	✓	0.0089
total_train	-	✓	0.0226
cross angle	1 (0°-29°)	✓	0.0746
	2 (30°-59°)		0.0667
	3 (60°-90°)		-
total_tracks	-	x	N/A
traf_lanes	-	✓	0.0044
hwy_near	1 (0-200ft)	x	N/A
	2 (>200ft)		
Intercept (zero model)	-	✓	0.0438
total_train (zero model)	-	✓	0.0275

Accuracy of Combined Macro Model

Overall absolute predictions:

- ZINB Model

- Adjustment based on accident history (similar to *B* in U.S. DOT model)



Accuracy of Combined Macro Model

- Ranking of high-accident locations:

Warning Device	Ranking Method	Number of crashes predicted in top locations		
		Top 10	Top 20	Top 50
Active	Data (observed)	16	26	56
	US DOT Formula	8	13	26
	ZINB - Average model and data	11	19	35

Conclusions

- Improvements for state-of-practice in accident prediction *are needed*:
  - Accuracy of predictions
  - Understanding contributing factors, finding countermeasures
- Micro approach finds contributing factors that data aggregation may mask:
  - We got positive feedback from practitioners
  - Future developments are promising
- Combination of macro and micro analysis showed accident prediction can be improved

Conclusions

- US DOT Model trends from case study:
  - Initial underestimation of accidents (a), then almost complete reliance of history (B)
  - Significant overestimation of absolute predictions
- Macro regression models using recent data provided improvements:
  - Better accuracy, more reliable results (based on current data)
  - Basis for justify rankings, absolute predictions are sound
- Future activities:
  - Improve the accident predictions based on the combination approach
  - Develop probabilistic analysis, and dynamic tree

Thanks!

Questions?

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