



INTRODUCTION

- Wrong-Way Driving (WWD) is the act of driving against the legal direction of traffic flow, inadvertently or deliberately, on a controlled access highway
- In the United States, WWD crashes result in 300 to 400 fatalities per year
- Entering controlled access highways through an exit ramp is the primary origin of most WWD events
- However, there is no mathematical models available to identify the exit ramp terminals with high risk of WWD entry
- Therefore, this study focuses on developing mathematical model to predict the probability of wrong-way (WW) entry at the exit ramp terminals of full diamond interchanges, primarily based on geometric design features and usage of traffic control devices (TCDs)
- This mathematical model will help the state and local transportation agencies to assess the risk of WW entry at the exit ramp terminals of full diamond interchanges and prioritize the locations for applying safety countermeasures

RESEARCH OBJECTIVES

- Develop a mathematical to **predict the risk of WWD entry at the exit ramp terminals of FULL DIAMOND INTERCHANGES**
- Two important features of the developed model:

Microscopic Level Model

Predicts the risk of WWD entry on a specific exit ramp terminal

DATA COLLECTION

Identify exit ramp terminals with history of WW entry

- WWD crashes on Alabama and Illinois freeways were collected for a period of five-years (2009–2013)

Collect geometric design features and TCD information

- These data were collected for exit ramp terminals with or without history of WWD using google earth aerial and street view

Collect AADT and area type

- Using ALDOT and IDOT traffic count map
- Using census urban area map (2010)

A SNAPSHOT OF COLLECTED DATA

Variable	Category	Locations with History of WWD (n=128, 23%)		Locations without History of WWD (n=428, 77%)	
		Frequency	Percent	Frequency	Percent
Intersection Angle					
	Acute	35	27.34%	54	12.62%
	Right	41	32.03%	125	29.21%
	Obtuse	52	40.63%	249	58.18%
Median on Crossroad					
	Non-traversable	55	42.97%	277	64.72%
	Traversable	73	57.03%	151	35.28%



Fig. 1 Collected Geometric Design Features

Collected TCD Usage

- Distance of **WRONG WAY** sign from crossroad
- Use of **DO NOT ENTER** sign
- Intersection signalization (Signalized/Unsignalized?)

METHODOLOGY

- Mathematical model were developed base on Firth's Penalized Likelihood Logistic Regression
 - Minimizes the biased probability and convergent failures resulting from the maximum likelihood estimation

$$\text{logit}(p) = \ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n$$

where p is the probability of WW entry at an exit ramp terminal, $X_1, X_2, X_3, \dots, X_n$ are the predictor variables, β_0 is the intercept, and $\beta_1, \beta_2, \beta_3, \dots, \beta_n$ are the regression coefficients

MATHEMATICAL EXPRESSION OF DEVELOPED MODEL

$$\begin{aligned} \text{logit}(p) = \ln\left(\frac{p}{1-p}\right) &= -4.799 + 0.257(X_{IA1}) - 0.644(X_{IA2}) + 0.233(X_{MC}) + 1.309(X_{CR}) + 1.313(X_{WWS1}) \\ &+ 1.634(X_{WWS2}) + 1.448(X_{WWS3}) + 1.576(X_{WWS4}) - 0.305(X_{Signal}) \\ &- 0.410(X_{\log(\text{exit ramp AADT})}) + 0.832(X_{\log(\text{crossroad AADT})}) + 1.361(X_{AT}) \end{aligned}$$

$$X_{IA1} = \begin{cases} 1, & \text{if intersection angle is acute} \\ 0, & \text{otherwise} \end{cases}$$

$$X_{IA2} = \begin{cases} 1, & \text{if intersection angle is obtuse} \\ 0, & \text{otherwise} \end{cases}$$

$$X_{MC} = \begin{cases} 1, & \text{if median on crossroad is traversable} \\ 0, & \text{otherwise} \end{cases}$$

$$X_{CR} = \begin{cases} 1, & \text{if corner radius is tangent to the edge of crossroad} \\ 0, & \text{otherwise} \end{cases}$$

$$X_{WWS1} = \begin{cases} 1, & \text{if the distance of WW sign from crossroad is between 201 ft to 300 ft} \\ 0, & \text{otherwise} \end{cases}$$

$$X_{WWS2} = \begin{cases} 1, & \text{if the distance of WW sign from crossroad is between 301 ft to 400 ft} \\ 0, & \text{otherwise} \end{cases}$$

$$X_{WWS3} = \begin{cases} 1, & \text{if the distance of WW sign from crossroad is between 401 ft to 500 ft} \\ 0, & \text{otherwise} \end{cases}$$

$$X_{Signal} = \begin{cases} 1, & \text{if the exit ramp terminal is signalized} \\ 0, & \text{otherwise} \end{cases}$$

$$X_{\log(\text{exit ramp AADT})} = \text{Logarithmic value of exit ramp AADT}$$

$$X_{\log(\text{crossroad AADT})} = \text{Logarithmic value of crossroad AADT}$$

$$X_{AT} = \begin{cases} 1, & \text{if the interchange is located in urban area} \\ 0, & \text{otherwise} \end{cases}$$

$$X_{WWS4} = \begin{cases} 1, & \text{if the distance of WW sign from crossroad is more than 500 ft} \\ 0, & \text{otherwise} \end{cases}$$

SUMMARY OF FIRTH'S LOGISTIC REGRESSION

Variables	Category	Parameter Estimates	Estimated Std. Error	Chi-Square Statistics	Odds Ratio (OR)
Intersection Angle					
	Right	Reference			
	Acute	0.257	0.320	0.659	1.293
	Obtuse	-0.644	0.268	5.823	0.525
Median on Crossroad					
	Non-traversable	Reference			
	Traversable	0.233	0.304	0.597	1.262
Is Corner Radius Tangent to Crossroad Edge?					
	No	Reference			
	Yes	1.309	0.303	20.373	3.702
Distance of WW Sign from Crossroad					
	200 ft. and less	Reference			
	201 to 300 ft.	1.313	0.307	18.600	3.717
	301 to 400 ft.	1.634	0.388	17.592	5.124
	401 to 500 ft.	1.448	0.394	13.344	4.255
	More than 500 ft.	1.576	0.403	15.325	4.836
Signalized/Unsignalized?					
	Unsignalized	Reference			
	Signalized	-0.305	0.372	0.687	0.737
log(Exit Ramp AADT)					
		-0.410	0.400	1.066	0.664
log(Crossroad AADT)					
		0.832	0.435	3.883	2.298
Area Type					
	Rural	Reference			
	Urban	1.361	0.357	15.022	3.900

CONCLUSIONS & RECOMMENDATIONS

- Although a right angle is recommended by the AASHTO Green Book for connecting exit ramps to crossroads, the results show that an **obtuse-angle connection** (refer to Fig. 2) was found to have the least possibility of WW entry
- AASTHO recommendation for using **non-traversable median and angular connection between the left edge of exit ramp and right edge of crossroad** is supported by our results.
- The **first WW sign should be used within 200 feet from the crossroads**, so that these signs are clearly visible to the motorists on the crossroad
- **Signalized exit ramp terminals have lower chance of WW entry**, as they provide more regulated traffic flow
- The locations with **low exit ramp AADT and high crossroad AADT** are more prone to WW entries
- The **interchanges in urban areas** should be given higher priority for implementing safety countermeasures



Fig. 2 WW right-turning maneuvers for obtuse angle (left) and acute angle (right) connection

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