A hierarchical modeling framework for vehicle-bicycle interactions at roundabouts?

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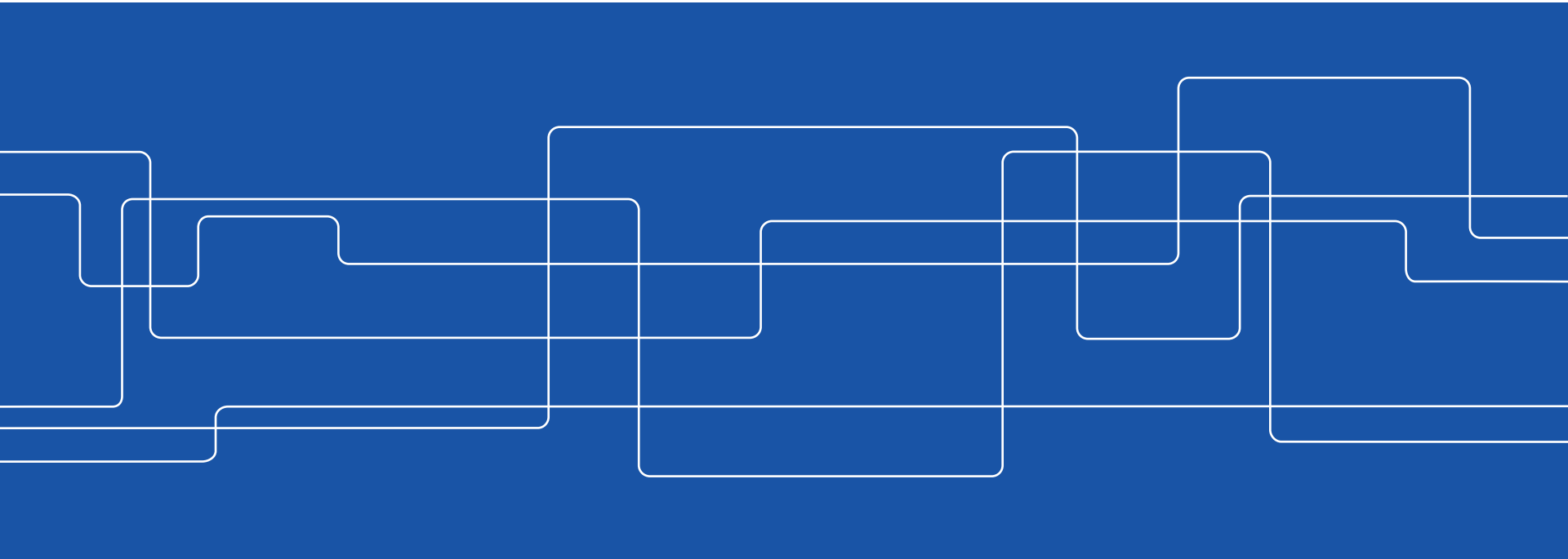


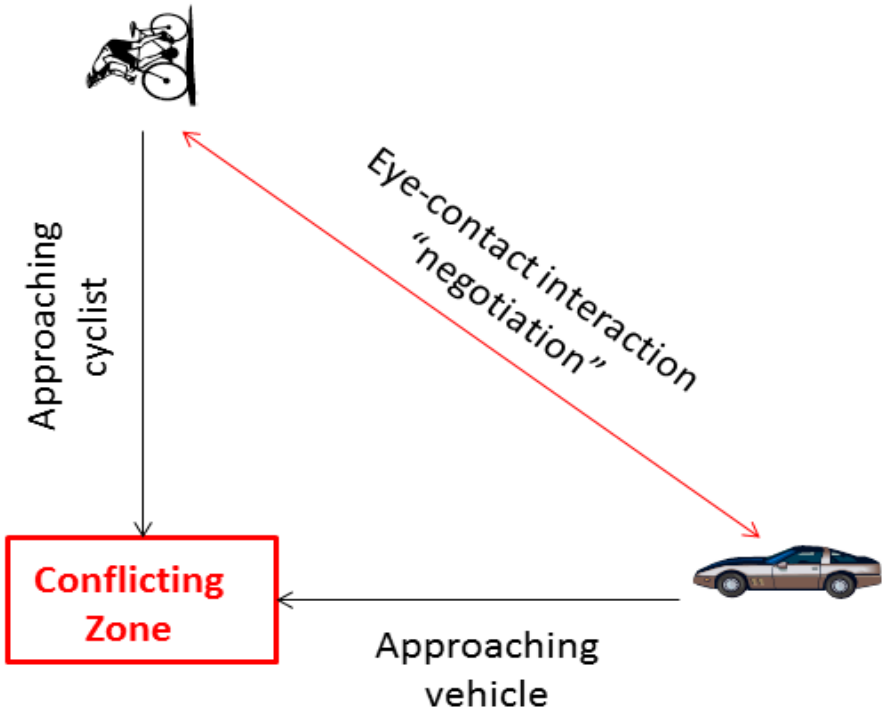
OUTLINE

- Background
- Introduction
- Objective
- Vehicle-Bicycle Interaction
- Data Collection
- Modeling Framework
- Results
- Conclusions
- Recommendations

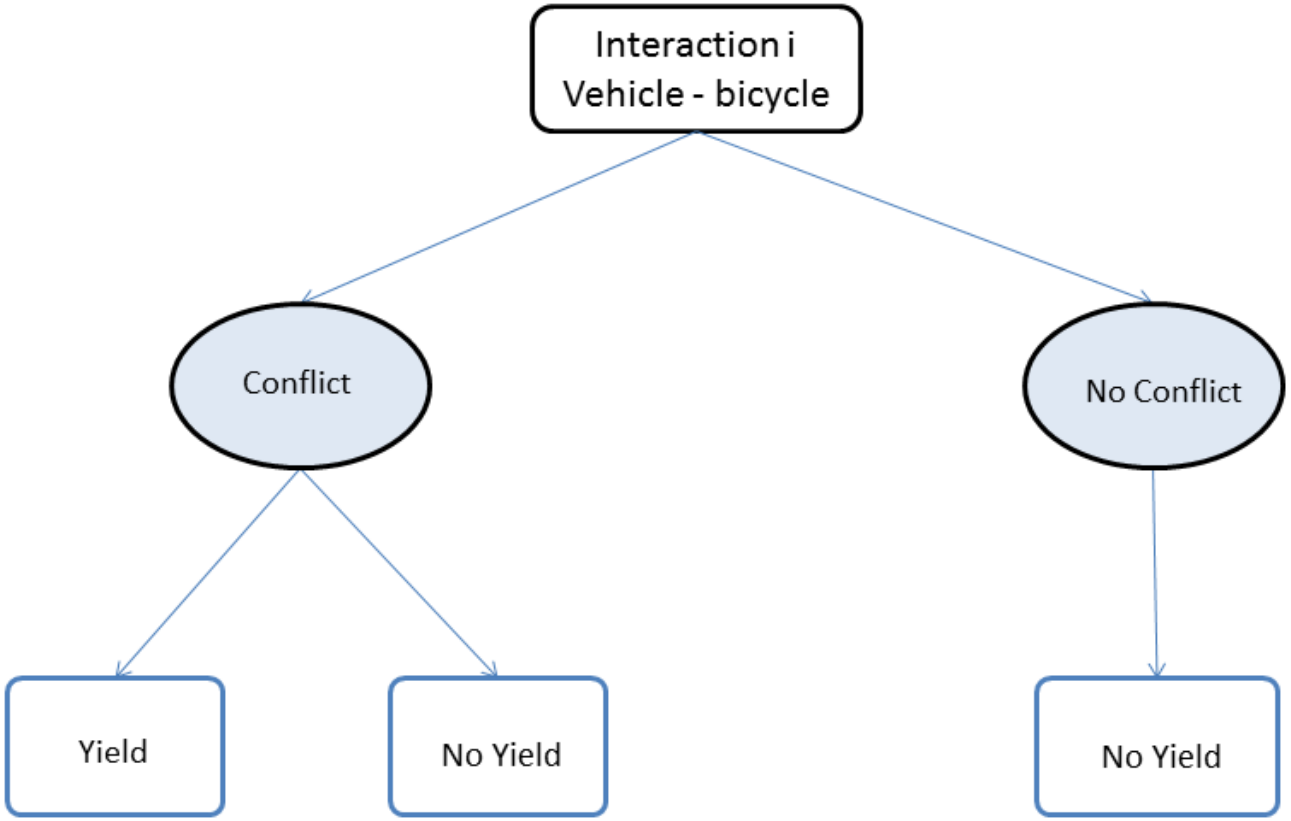
Yielding process

A conflict event (*C*) is perceived.

A yielding event (*Y*) is observed.



Hierarchical framework



Conflict (Latent)

Yielding (Observable)

Probabilities

Probability of yielding

$$P(Y_n = 1) = P(Y_n = 1, C = 1) + P(Y_n = 1, C = 0)$$

$$P(Y_n = 1) = P(Y_n = 1, C_n = 1) = P(Y_n = 1|C_n = 1) \cdot P(C_n = 1)$$

Probability of non - yielding

$$P(Y_n = 0) = P(Y_n = 0, C_n = 1) + P(Y_n = 0, C_n = 0)$$

$$P(Y_n = 0) = P(Y_n = 0|C_n = 1) \cdot P(C_n = 1) + P(C_n = 0).$$

Logit Models

Probability of Conflict:

$$P(C_n = 1) = \frac{e^{\boldsymbol{\Phi \cdot X}}}{1 + e^{\boldsymbol{\Phi \cdot X}}}$$

Probability of Yielding:

$$P(Y_n = 1 | C_n = 1) = \frac{e^{\boldsymbol{\Psi \cdot Z}}}{1 + e^{\boldsymbol{\Psi \cdot Z}}}$$

Yielding Probability of Driver y_n is:

$$P(y_n) = \big(P(y_n = 1)\big)^{y_n} \big(P(y_n = 0)\big)^{1-y_n}$$

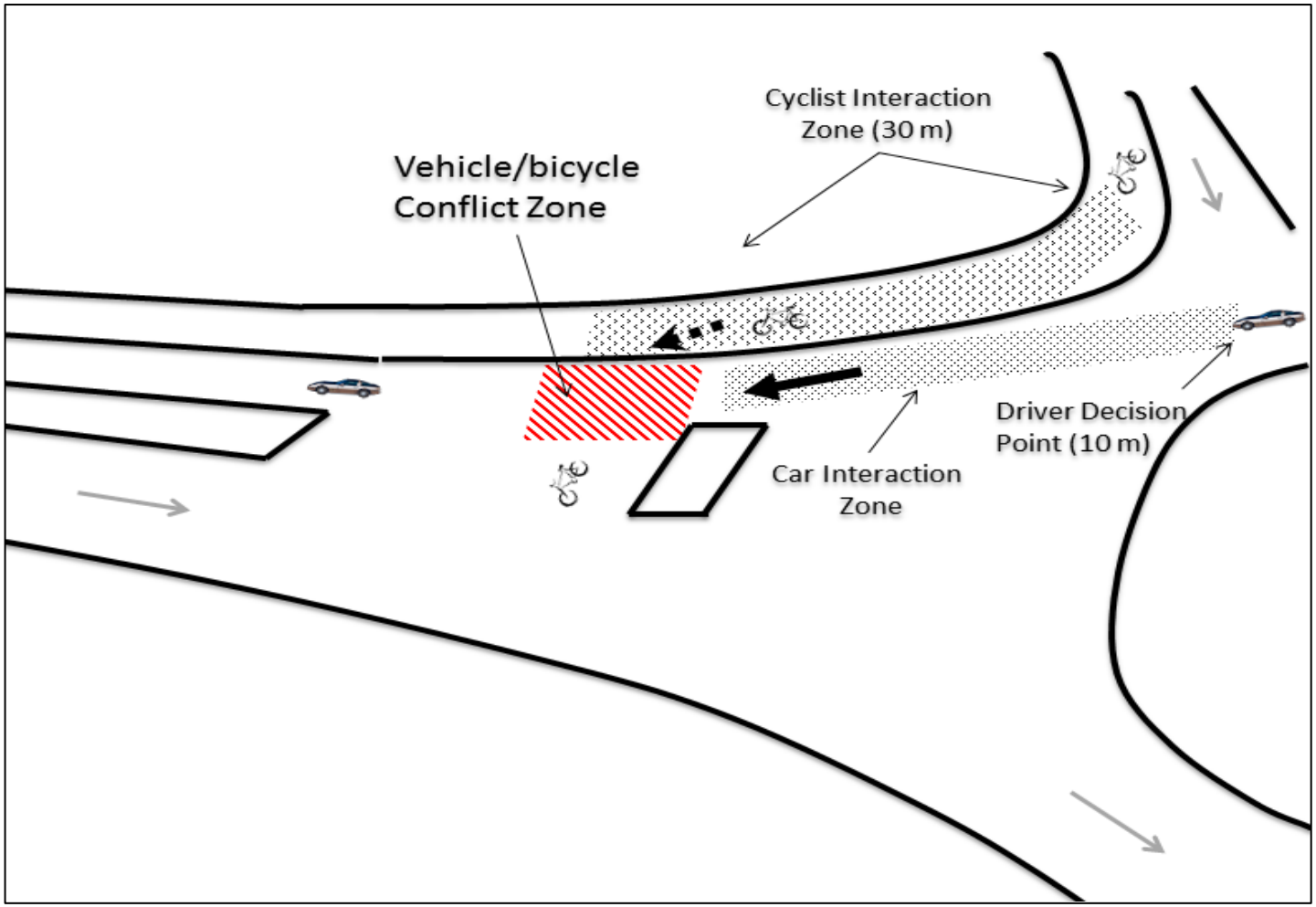
The joint probability of observing N vehicle-bicycle interactions:

$$P(y_1 \dots y_N) = \prod_{n=1}^{N} \big(P(y_n = 1)\big)^{y_n} \big(P(y_n = 0)\big)^{1-y_n}$$

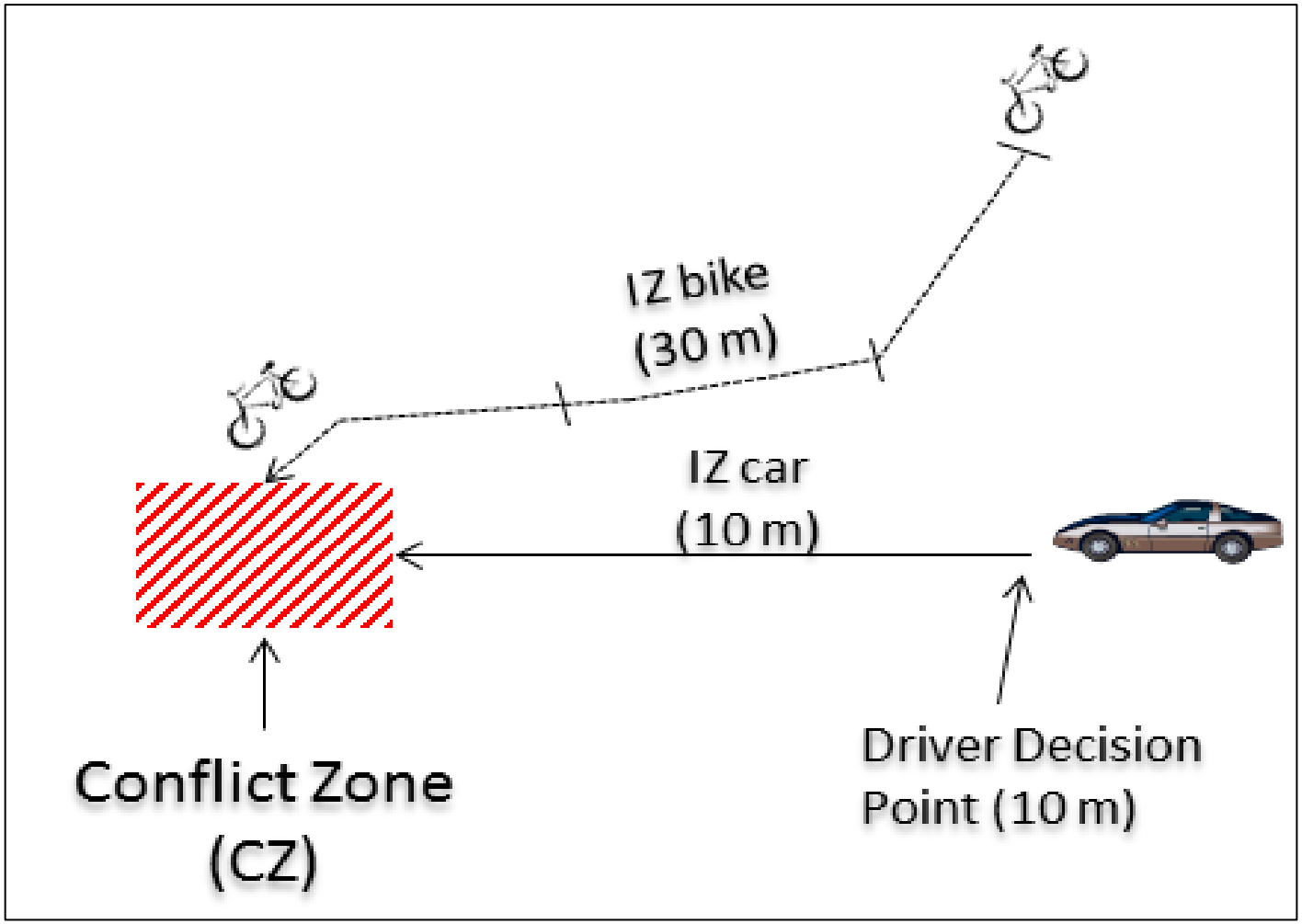
The log-likelihood replacing the logit models:

$$\mathcal{L} = \sum_{n=1}^{N} \log\left(\left\{ \frac{e^{\Psi \cdot z}}{(1 + e^{\Psi \cdot z})} \cdot \frac{e^{\Phi \cdot x}}{(1 + e^{\Phi \cdot x})} \right\}^{y_n} \left\{ \frac{1}{(1 + e^{\Psi \cdot z})} \cdot \frac{e^{\Phi \cdot x}}{(1 + e^{\Phi \cdot x})} + \frac{1}{(1 + e^{\Phi \cdot x})} \right\}^{1-y_n} \right)$$

APPLICATION



INTERACTION ZONES



Conflict Probability

Parameter	Variable	Unit	Description
ϕ_0	-	-	Constant
ϕ_1	χ_1^{ATD}	Sec	Arrival time difference when bicycle arrives first.
ϕ_2	χ_2^{ATD}	Sec	Arrival time difference when car arrives first

$$V_{conf} = \Phi \cdot X = \phi_0 + \phi_1 \chi_1^{ATD} + \phi_2 \chi_2^{ATD}$$

Yielding Probability

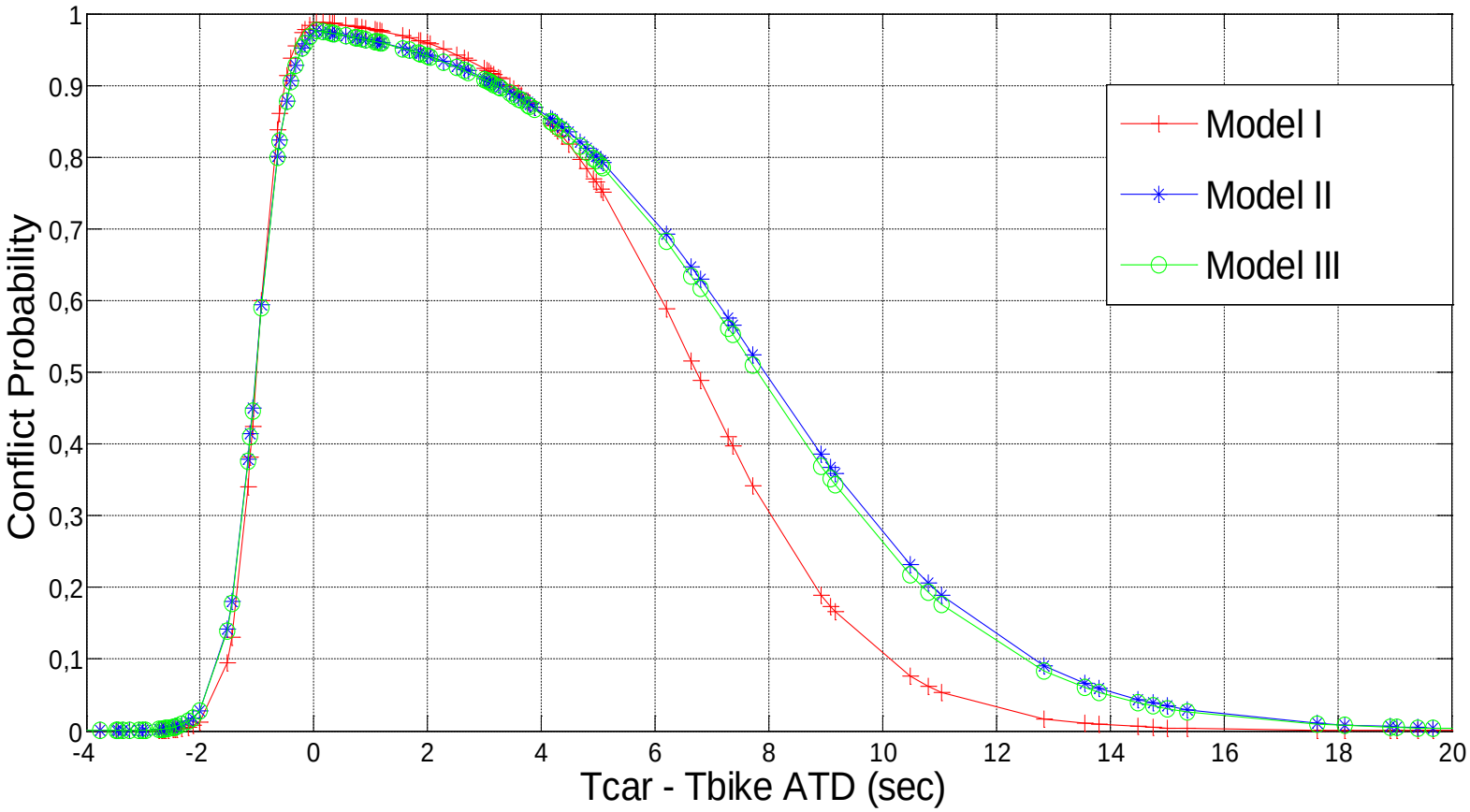
Parameter	Variable	Unit	Description
ψ_0	-	-	Constant
ψ_1	V_{car}	Km/h	Instantaneous speed of a vehicle at the start of the IZ zone
ψ_2	R_1	dummy	1 if the bike is in Region 1 (0-10 m) when the car arrives at decision point, else 0
ψ_3	R_2	dummy	1 if the bike is in Region 2 (11-20 m) when the car arrives at decision point, else 0
ψ_4	R_3	dummy	1 if the bike is in Region 3 (21-30 m) when the car arrives at decision point, else 0
ψ_5	V_{bike}	Km/h	Bicycle velocity measured with reference to the car at 10 m away from conflict zone

$$V_{yield} = \Psi \cdot Z = \psi_0 + \psi_1 z_1 \cdots \cdots + \psi_5 z_5$$

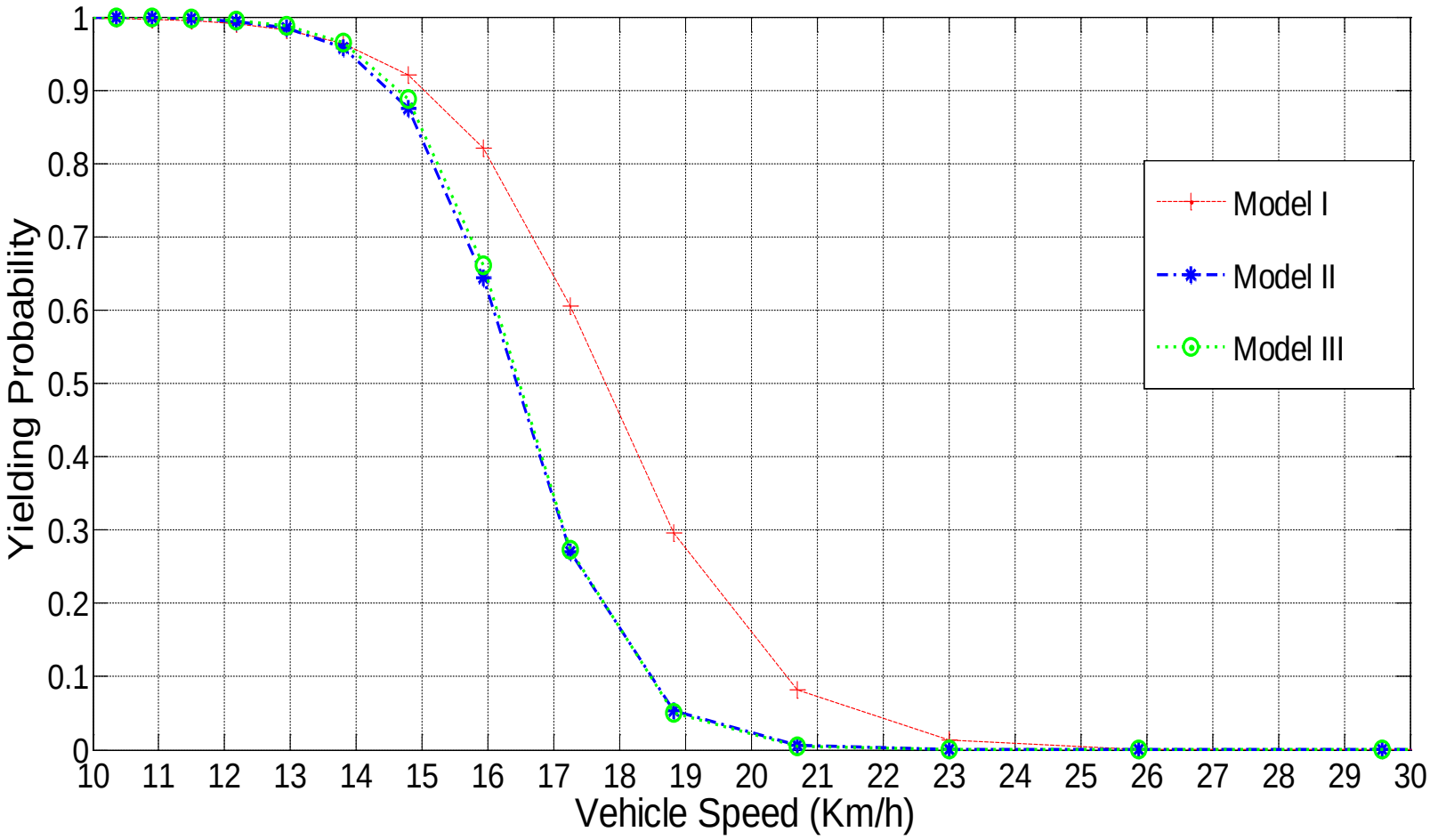
RESULTS

Parameters		MODEL I		MODEL II		MODEL III	
		Estimate	(t-value)	Estimate	(t-value)	Estimate	(t-value)
CONFLICT PROBABILITY							
Constant	ϕ_0	4.480**	(3.39)	3.721**	(2.70)	3.720**	(2.77)
χ_1^{ATD}	ϕ_1	-0.665**	(-2.33)	-0.469	(-1.12)	-0.477**	(-1.20)
χ_2^{ATD}	ϕ_2	4.432**	(2.49)	3.633*	(1.94)	3.646**	(1.99)
YIELDING PROBABILITY							
Constant	ψ_0	14.639**	(3.37)	19.634*	(1.72)	20.411*	(1.72)
V_{car}	ψ_1	-0.824**	(-3.48)	-1.196*	(-1.85)	-1.240*	(-1.84)
R_1	ψ_2	-	-	5.220*	(1.76)	3.298	(0.27)
R_2	ψ_3	-	-	2.911	(1,32)	0.851	(0.06)
R_3	ψ_4	-	-	0.143	(0.07)	-1.997	(-0.15)
V_{bike}	ψ_5	-	-	-	-	0.130	(0.16)
$LL(\beta)$		-27.761		-22.121		-22.107	
Likelihood ratio index(corrected ρ^2)		0.6531		0.6811		0.6706	
Cox & Snell (R^2)		0.5155		0.5443		0.5444	
$LL(0)$		-94.445					
No. of observation		184					
Yielding events		37					

Conflict Estimates



Yielding Estimates



CONCLUSSIONS

- ✓ most important factors influencing drivers' yielding decisions
  - o Speed of the vehicle and
  - o Relative position of the cyclist to the *CZ*.

- ✓ The conflict probability depends on whether the driver or the cyclist arrives first at the *IZ* zones.

THANKS

Q & A