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Calibrating Car-following Models For Chinese Drivers Using Naturalistic Driving Data From Urban Expressways

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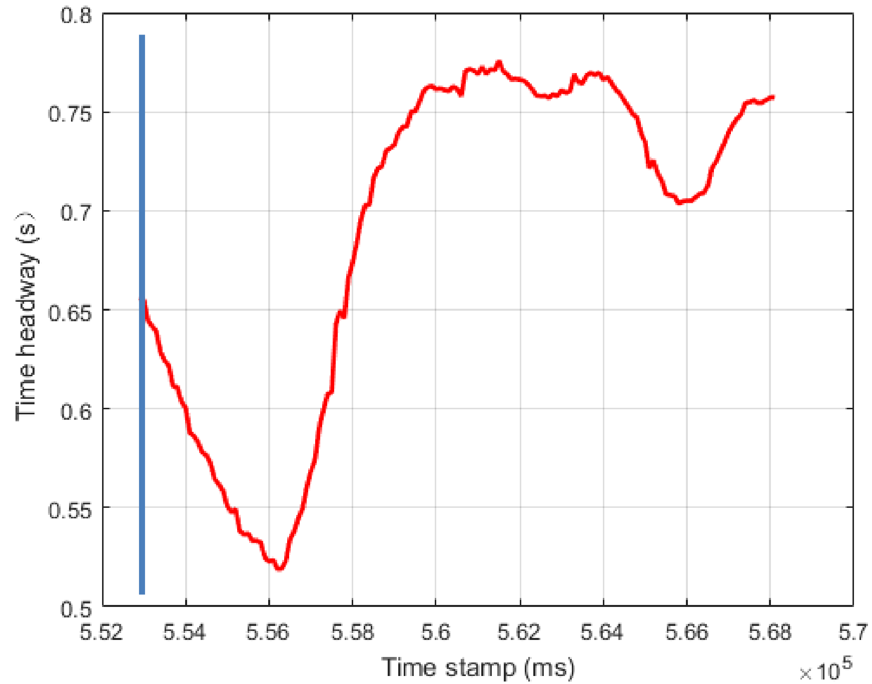
Introduction

■ Car-following model

- Cornerstone for microscopic traffic simulation and intelligent vehilcle;
- The development and investigation of these models have been almost entirely based on experiments conducted in Western countries;
- Different driving styles, types of vehicles, traffic regulations as well as cultural environments (Lindgren et al., 2008b) may result in **considerable differences in driving behavior and traffic operation**.

Introduction

■ Short-following example of Chinese driver



- A car-following model performing well in Western countries may perform poorly in developing countries.

Introduction

■Motivation

- How well are the existing models able to model Chinese drivers' car-following behavior?
- What are the main disparities between car-following behavior in China and that in the US?

Data Preparation

■ Shanghai Naturalistic Driving Study (SH-NDS)

- From 2012 to 2015;
- Five vehicles with SHRP2 NextGen data acquisition systems
- Each participant drives the vehicle for 2 months;
- Sixty drivers' data, with a total mileage of 161,055 km, have been collected.

Data Preparation

■ Data items

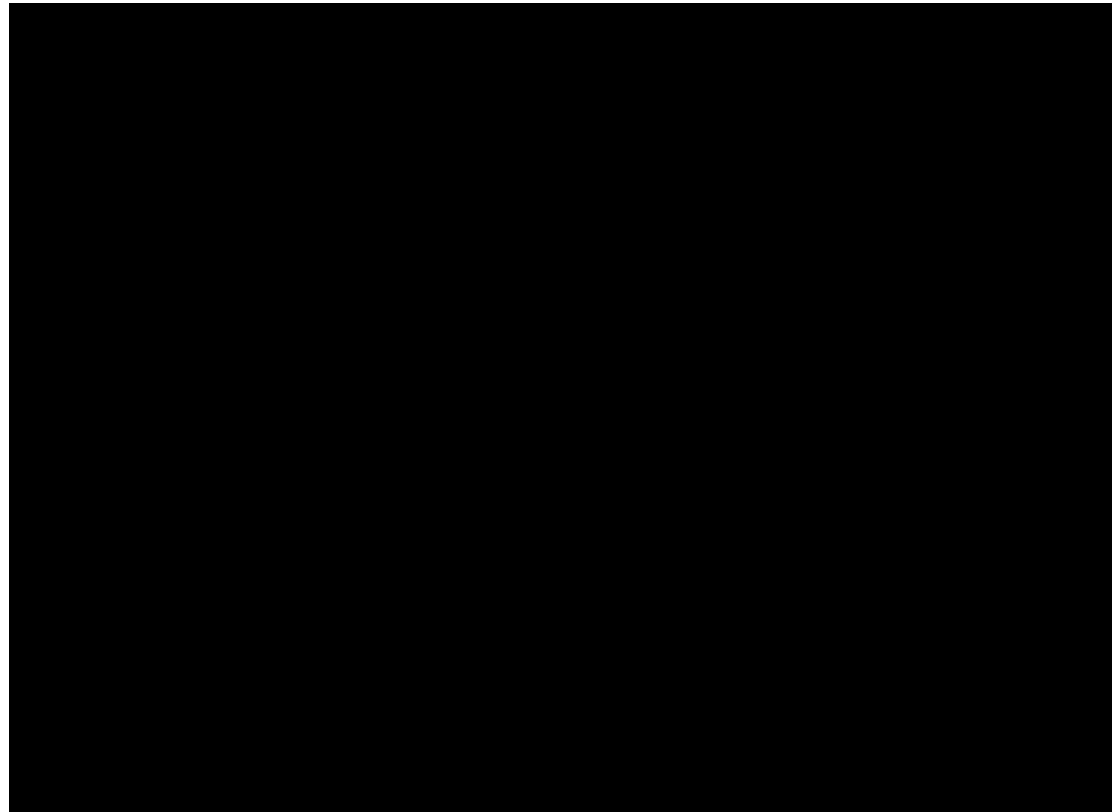
- Forward radar data
- Vehicle network data
- GPS data
- Accelerometer data
- Four synchronized camera views
- Collection frequency: 10-50 Hz

Four camera views from the SH-NDS

Data Preparation

■ Forward radar data

- Track, at most, 8 vehicles simultaneously
- T0 to T7
- Unique target ID
- X and Y positions
- X and Y velocities

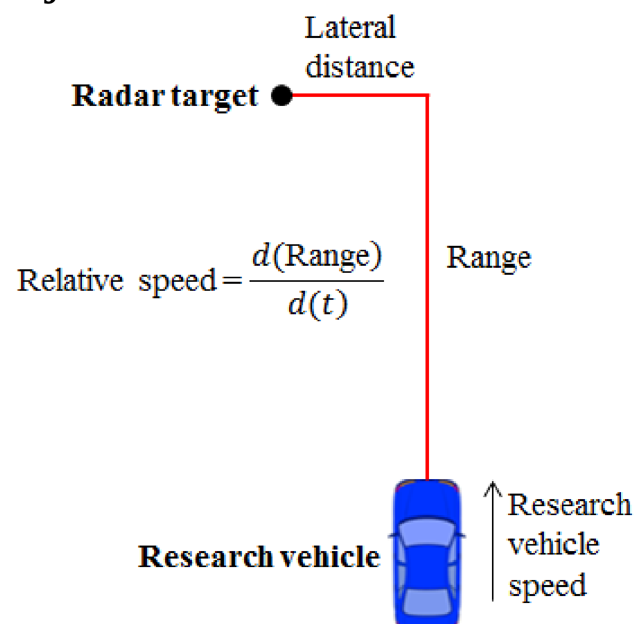


Front video   Radar target map

Data Preparation

■ Car-following periods extraction

- Initial criteria followed Ervin et al. (2005) and Higgs and Abbas (2013);
- Iterative adjustment:
  - ➢ Extract potential car-following periods;
  - ➢ Review corresponding video material to adjust the criteria.
- Final criteria:
  - ➢ Radar target's identification remained constant;
  - ➢ 7m<range<120m, and speed of the research vehicle>5m/s;
  - ➢ −2.5m<lateral distance<2.5m;
  - ➢ −2.5m/s<relative speed<2.5m/s;
  - ➢ Length >15s.



Data Preparation

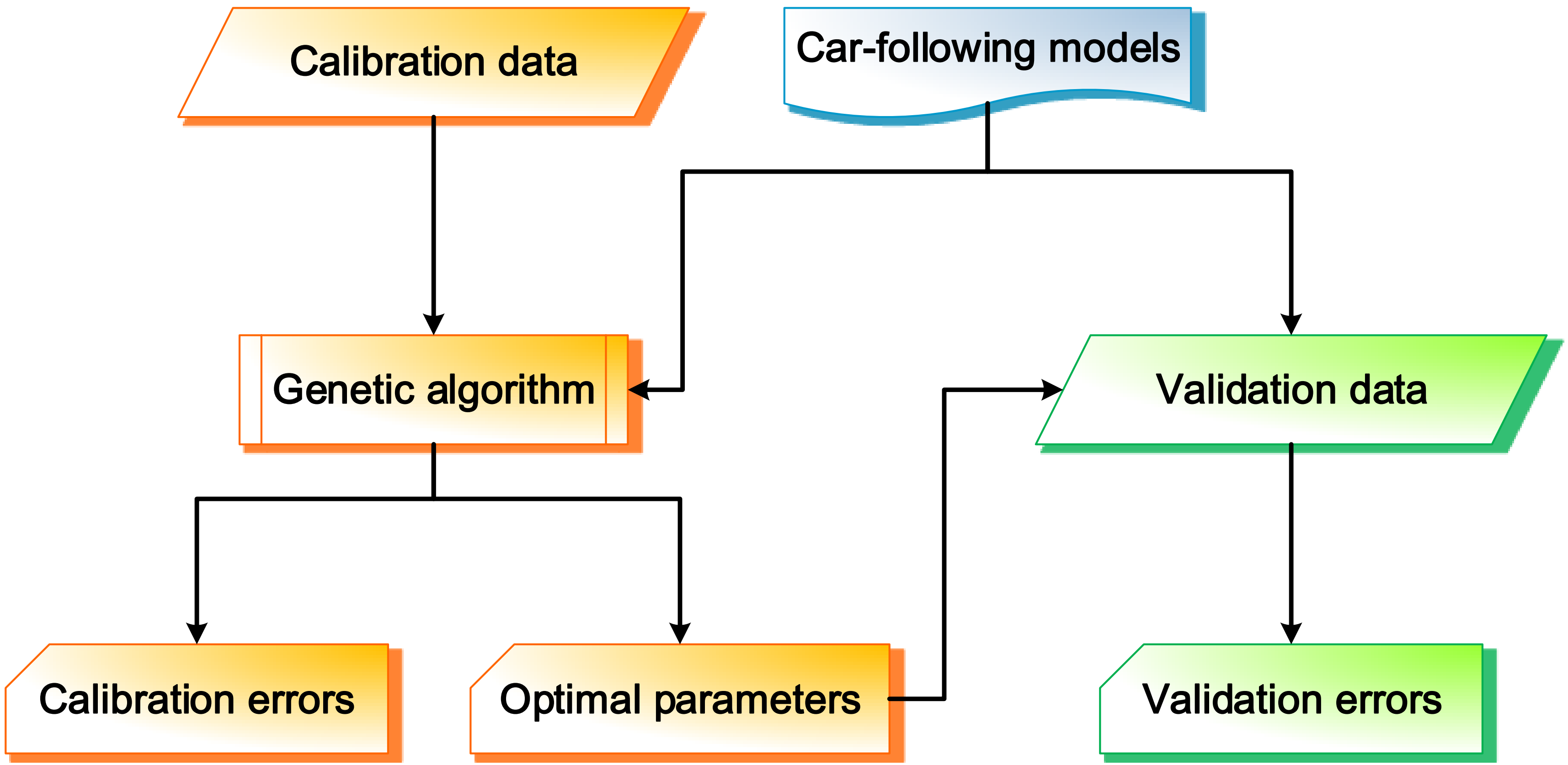
■ Car-following periods analyzed

- Focusing on car-following periods on urban expressways

Road type	Urban expressway
Num. of drivers	42
Num. of periods each driver	50 in total, 40 for calibration and 10 for validation
Total car-following periods	2,100
Cumulative time length	863 minutes

Model Calibration and Validation

■Procedure



Model Calibration and Validation

■ Car-following models investigated

- Five represtantive car-following models

a) Gaxis-Herman-Rothery (GHR) model: stimulus-based model

b) Gipps model: safety-distance model

c) Intelligent Driver Model (IDM): desired measures model

d) Full Velocity Difference (FVD) model: optimal velocity model

e) Wiedemann car-following model: psycho-physical model

Model Calibration and Validation

■ Genetic algorithm: objective function

- Calibration based on spacing is more robust and efficient than speed or acceleration (Punzo and Montanino, 2016).
- Root mean square percentage errors (RMSPE) of spacing:

$$RMSPE = \sqrt{\frac{\sum_{i=1}^{N}(S_i^{sim} - S_i^{obs})^2}{\sum_{i=1}^{N}(S_i^{obs})^2}}$$

i: observation

S_i^{sim}: the ith modeled spacing

S_i^{obs}: the ith observed spacing

N: is the number of observations

Model Calibration and Validation

■ Genetic algorithm: implementation

- The Genetic Algorithm Toolbox in MATLAB® was used;
- Optimization repeated 12 times for each driver, minimum error (i.e., RMSPE) was selected;
- Tested with synthetic data:

➢ Set the GHR parameters as:
$\tau_n = 1$, $\alpha = 1$, $\beta = 1$, and $\gamma = 1$

➢ Generate synthetic car-following data were generated.

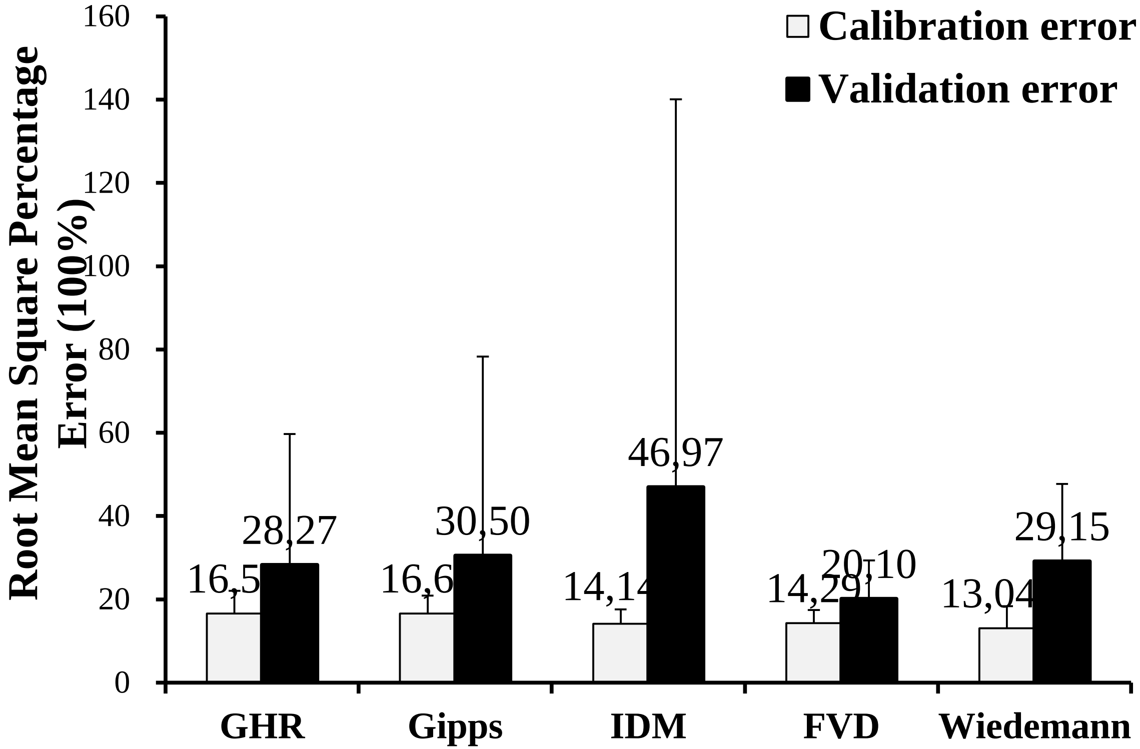
➢ Calibration result: RMSPE=0.003

$\tau_n = 1.00$, $\alpha = 1.19$, $\beta = 0.90$, and $\gamma = 0.99$

Algorithm setting	Method used
Population size	300 (500 for Wiedemann)
Maximum num. of generations	300 (1300 for Wiedemann)
Stall generations	100 (150 for Wiedemann)
Convergence tolerance	10^{-6}
Fitness scaling	Rank
Parent selection	Stochastic uniform
Children reproduction	Elite, crossover and mutation
Mutation	Gaussian
Crossover	Scatter

Model Calibration and Validation

■ Calibration and validation errors



The FVD performed best:

1) second lowest calibration error and lowest validation error;

2) smallest standard deviation of error;

3) no occurrences of collision or backward movement.

US and China Comparison

■ Description of the two studies

Item	**Current study**	**Sangster et al. (2013)**
Database	Shanghai Naturalistic Driving Study (SH-NDS)	VTTI 100-car Naturalistic Driving Study (VTTI 100-Car)
Num. of car-following periods	2100	More than 2000
Num. of drivers	42	8
Road	Inner Ring, Middle Ring, and Outer Ring expressways, Shanghai	Dulles Airport Access Road, multilane expressways, near Washington, D.C.
Objective function	RMSPE of space	RMSPE of space and speed
Optimization method	Genetic algorithm	Genetic algorithm, the maximum acceleration and comfort deceleration were observed from data

US and China Comparison

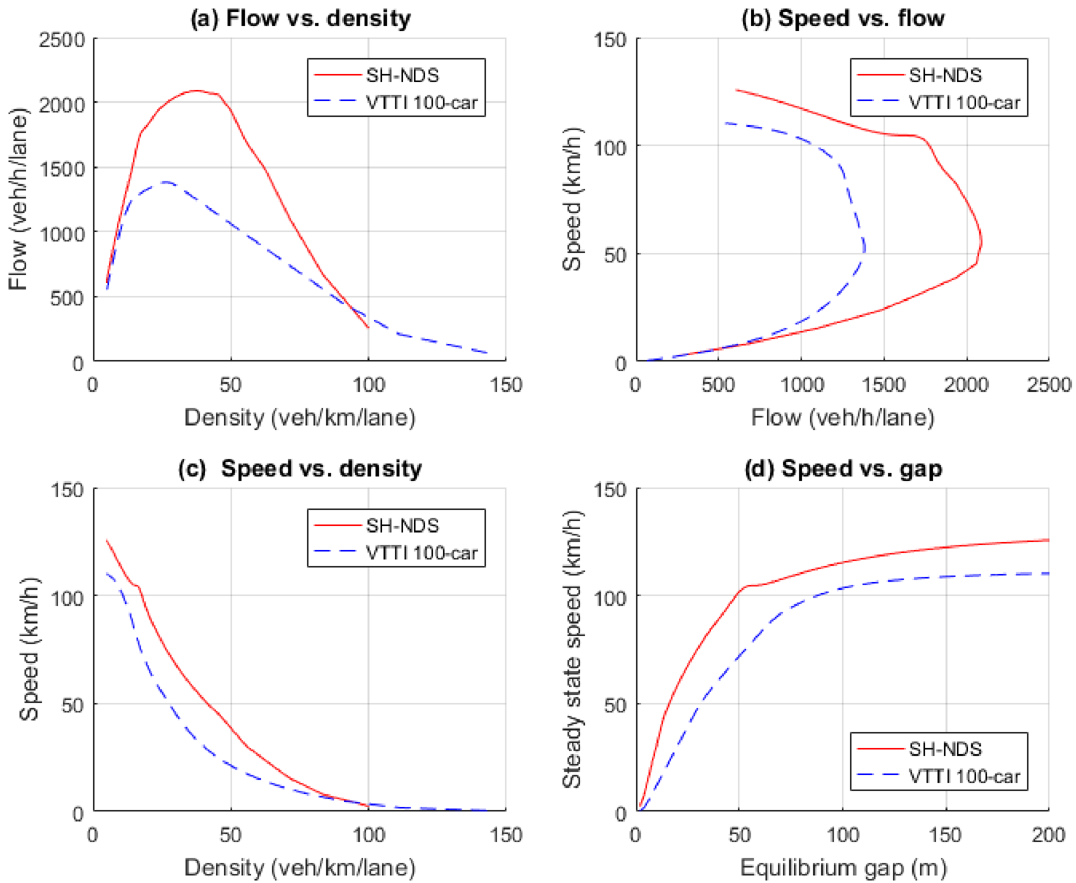
■ Parameters of the IDM model

- Desired time headway one second shorter than that of VTTI 100-Car Study; the most influential IDM parameter (Punzo et al., 2015)

Name	SH-NDS	VTTI 100-Car	t value	p value
	Mean	Mean		
Desired speed (km/h)	108.0	101.9	0.16	0.8734
Desired time headway (s)	**0.8416**	**1.72**	-7.53	**0.0001**
Maximum acceleration (m/s^2)	0.6747	5.948	-6.57	**0.0003**
Comfortable deceleration (m/s^2)	0.9198	5.961	-6.76	**0.0002**
Acceleration exponent	7.8837	16.79	-2.56	0.0276
Standstill gap (m)	3.0912	2.3713	2.29	0.0355

US and China Comparison

■ Fundamental Diagram derived by the IDM model



$$s_e = \frac{s_{jam} + v\tilde{T}}{\sqrt{1-(\frac{v_e}{\tilde{v}})^{\beta}}}$$

$$Q = \frac{v}{s+l}$$

$$\rho = \frac{1}{s+l}$$

s_e : equilibrium gap

v_e : equilibrium gap

s_{jam} : standstill gap

$\tilde{T}$: desired time headway

β : acceleration exponent

$\tilde{v}$: desired spee

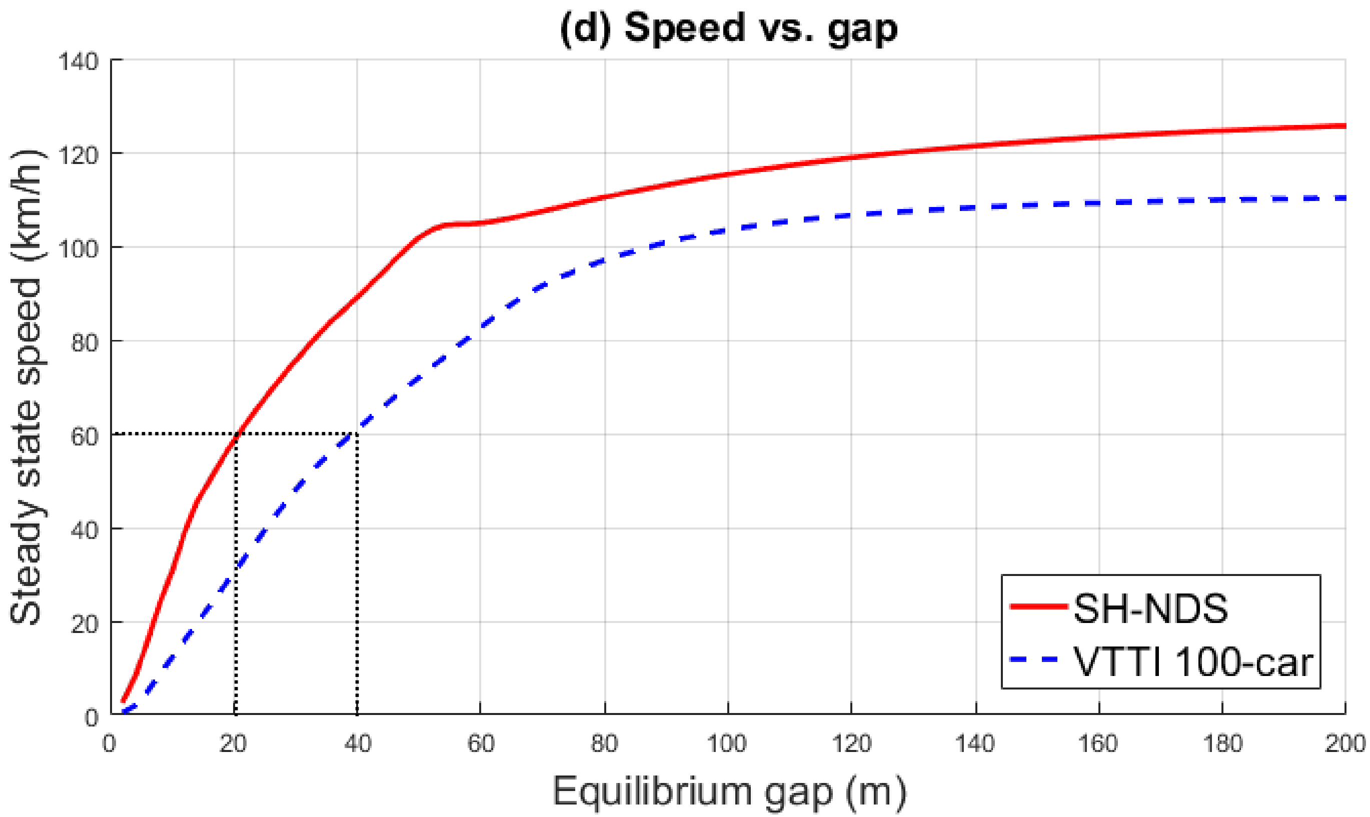
l: the vehicle length, 5m

s: following gap

US and China Comparison

■ Fundamental Diagram derived by the IDM model

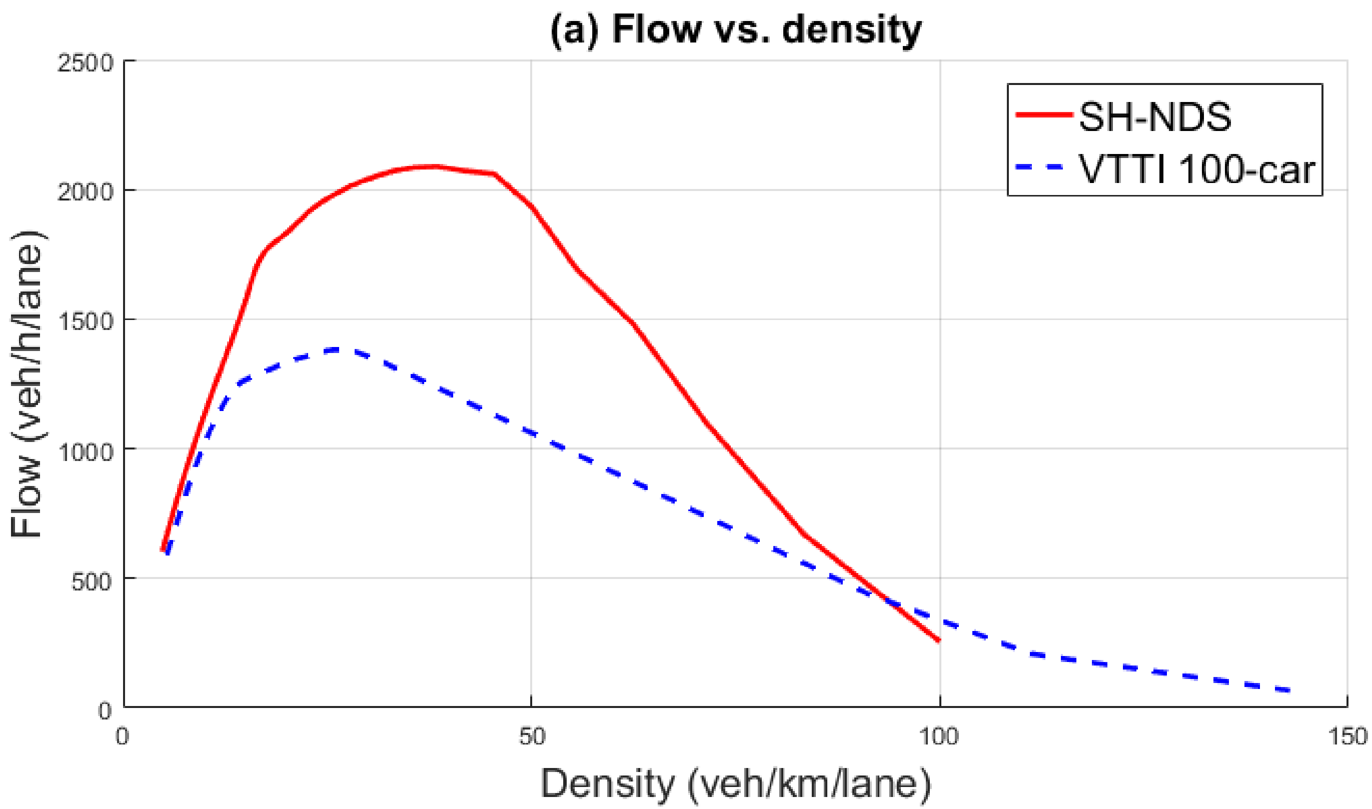
- Shoter following gap



US and China Comparison

■Fundamental Diagram derived by the IDM model

- Larger capacity



Discussion

■ Better car-following models for simulation in China

- The Wiedemann model is used by the most popular microscopic traffic simulation tool in China—VISSIM®.
- Compared to the Wiedemann, the FVD model showed:
  - ➢ Higer performance
  - ➢ More stable performance
  - ➢ More easily to calibrate: number of parameters 5 vs. 13
- The FVD may be more suitable than Wiedemann to be applied for microscopic traffic simulation in China.

Discussion

■ Why Chinese drivers following tightly

- Aggressive: lower perception of risk?
- Cultural environment: in a rush?
- Avoiding cut-in?

Conclusions

- The full velocity difference (FVD) model performed best in modeling Chinese drivers' behavior compared to the GHR, Gipps, IDM, and Wiedemann models.
- According to the IDM model, Chinese drivers adopt shorter desired time headways and following gaps than US drivers.
- Simulation models and components of intelligent vehicles must be calibrated to Chinese conditions before used in China.

THANKS

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