Linking Roadway and Naturalistic Data to Study Driver Route Choice and Car-following Behavior

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Funded:
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Modeling Driver Heterogeneity in Route Choice Behavior Based on a Real-Life Naturalistic Driving Experiment

Co-authors: Aly Tawfik, Ph.D. and Jianhe Du, Ph.D.

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Motivation

- **Equilibrium:** Nakayama et al ('01), "Drivers do not become homogeneous and rational, as equilibrium analyses presuppose; rather, there are fewer rational drivers even after a long process of learning, and heterogeneous drivers make up the system"
- **Driver Rationality:** Bogers et al ('05), "studies that focus only on a rather rational description of day-to-day learning cover only a limited part of the way route choices are made over time"
- **Driver Heterogeneity:** Iida et al ('92), "it is desirable to develop a model which is disaggregated by a type of driver because the route choice behavior varies by individual"
- **Experiment Medium:** Prato ('09) and Papinski ('11) "four main challenge areas : i) experiment medium, …"

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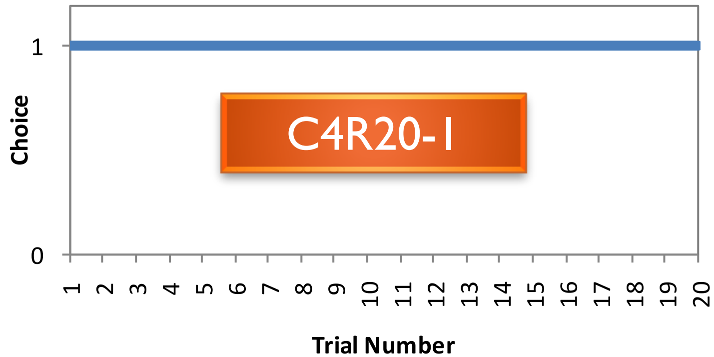
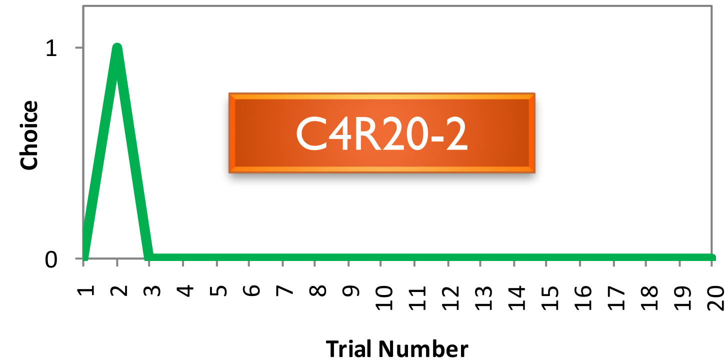
100-Car Naturalistic Driving Data

- Geocoded home and work address in ArcGIS
- Identified commuting trips by comparing the O-D with home/work locations
- Exported route maps and removed drivers without regular commuting behavior
- Sample
  - 39 Drivers with a total of 68 choice situations and an average 85 Trials
- Procedure
  - Pre-task questionnaires, 1-Year real-life data, and Personality Inventory

Disaggregate Findings



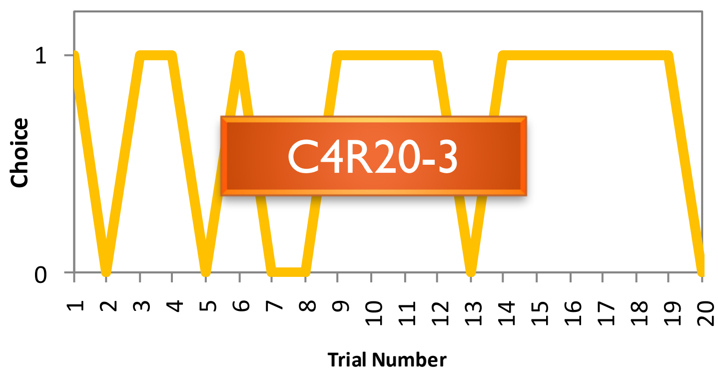


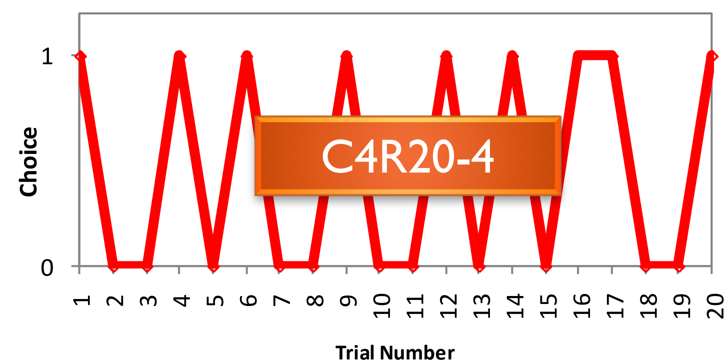
Pattern1: No Route Trials **14%**

16% Pattern2: Single Route Trials

Pattern3: Variable Route Trials **38%**

32% Pattern4: Continuous Route Trials





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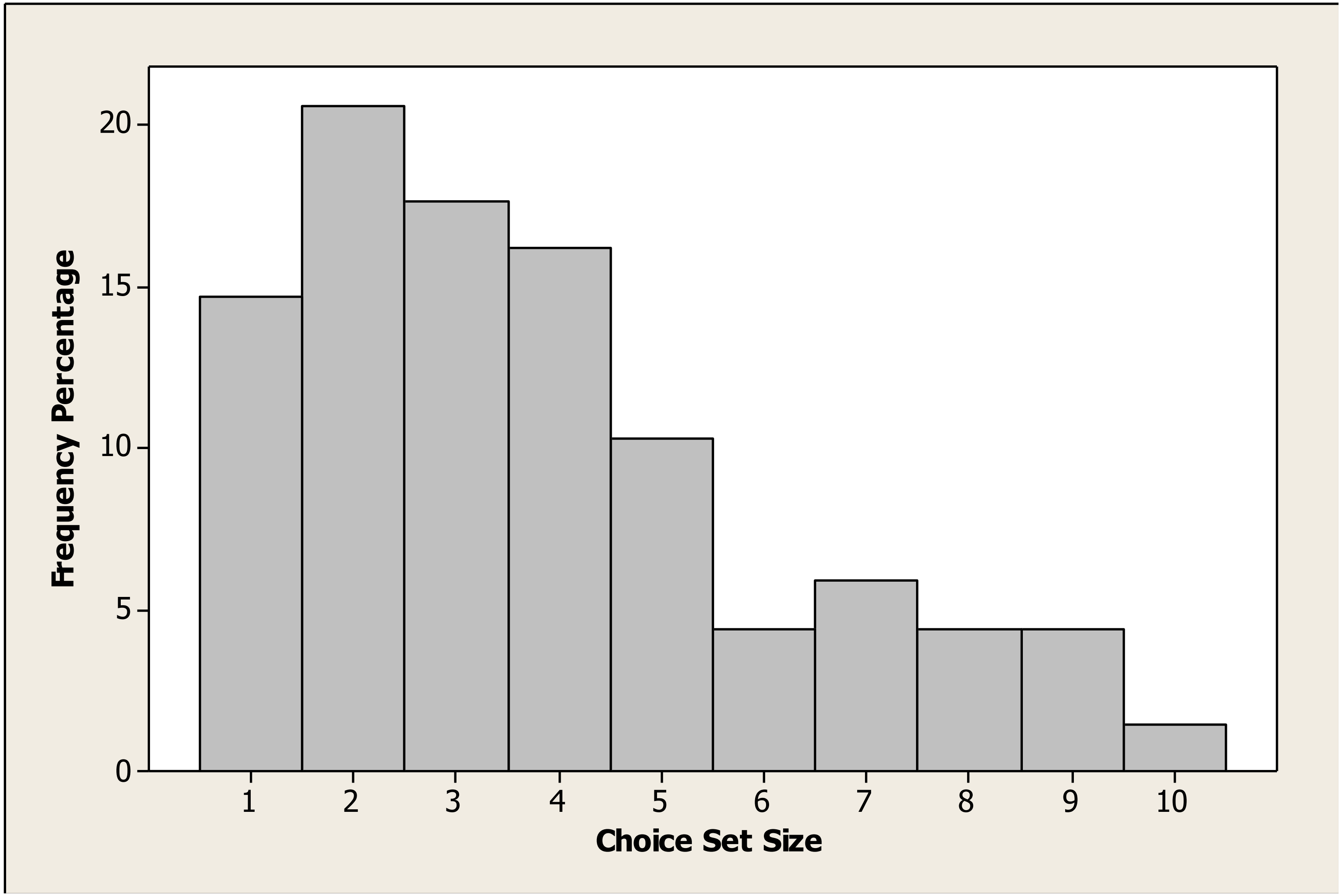
Driver Choice Set



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Variables Considered

#	Variable Name	Variable Description	Variable Values
Variables of Driver Demographics			
1	Age_i	Age of driver i	19 to 57
2	$Gender_i$	Gender of driver i	F or M*
3	$Ethnicity_i$	Ethnicity of driver i	W or NW*
4	$Education_i$	Education level of driver i	G or NG*
7	$Dr\ Years_i$	Number of years driver i has been licensed to driver	2 to 42
6	$Dr\ Miles_i$	Number of miles driver i drives per year (in thousands)	15 to 40
Variables of Driver Personality Traits			
1	N_i	Neuroticism of driver i	7 to 75
2	E_i	Extraversion of driver i	17 to 66
3	O_i	Openness to experience of driver i	14 to 53
4	A_i	Agreeableness of driver i	12 to 66
5	C_i	Conscientiousness of driver i	19 to 62
Variables of Choice Situation			
1	TT_c	Expected travel time of choice situation c (in minutes)	8 to 95
2	TS_c	Expected travel speed of choice situation c (in km/h)	24 to 90
3	TD_c	Expected travel distance of choice situation c (in km)	6 to 108
Variables of Driver-Choice Combination			
4	Obs_{ic}	Number of trips observed for driver i in choice situation c	25 to 216

* **M: male, F: female, W: white, NW: non-white, NG: no post-graduate degree, G: have a post-graduate degree**

Driver Choice Set and Switching

Significant Variables	Route Switching Model (Beta)	Choice Set Size Model * (Gamma)
(Intercept)	-1.38	– 0.284
University Education	-0.81	– 0.098
Driven Miles	-0.30	n/s
Neuroticism	n/s	0.049
Extraversion	0.56	n/s
Openness to Experience	-0.97	– 0.25
Conscientiousness	0.46	0.079
Expected Travel Time	0.35	n/s
Expected Travel Speed	-0.55	– 0.058
Number of Observations	n/s	0.001

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Findings

- Choice Set
  - Smaller choice set:
    - Drivers without post-graduate degrees and higher scores of openness to experience
  - Larger choice set:
    - Higher values of neuroticism and conscientiousness, lower travel speeds
    - Finally, it is satisfying that the number of observations was found to marginally increase the choice set size.
- Route Switching
  - Personality trait variables seem were as important as variables of travel experience (travel speed).
    - Drivers' openness to experience was the most important variable

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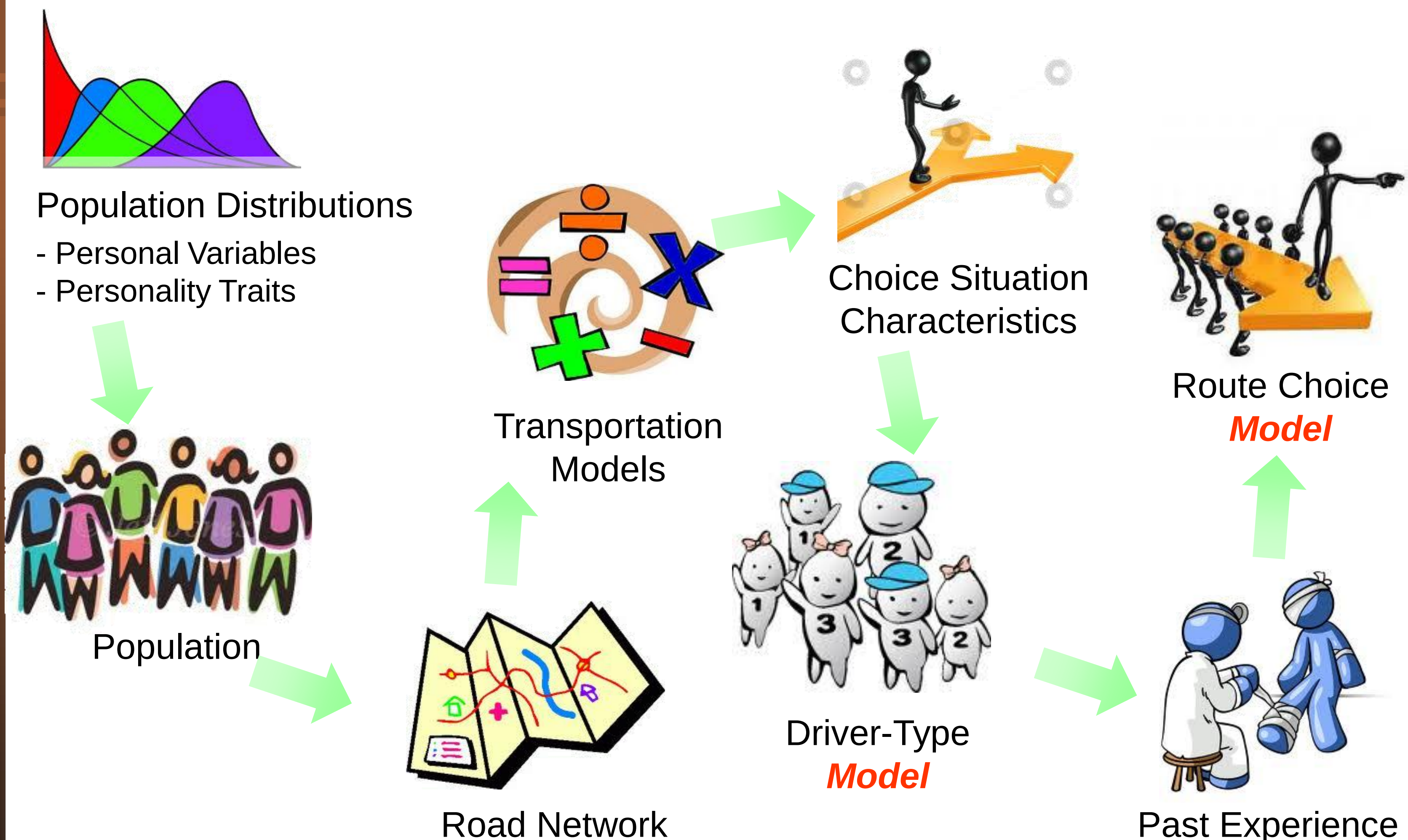
Application



Modeling Driver Car-following Behavior using Naturalistic Driving Data

Co-authors: John Sangster, MS and Jianhe Du, Ph.D.

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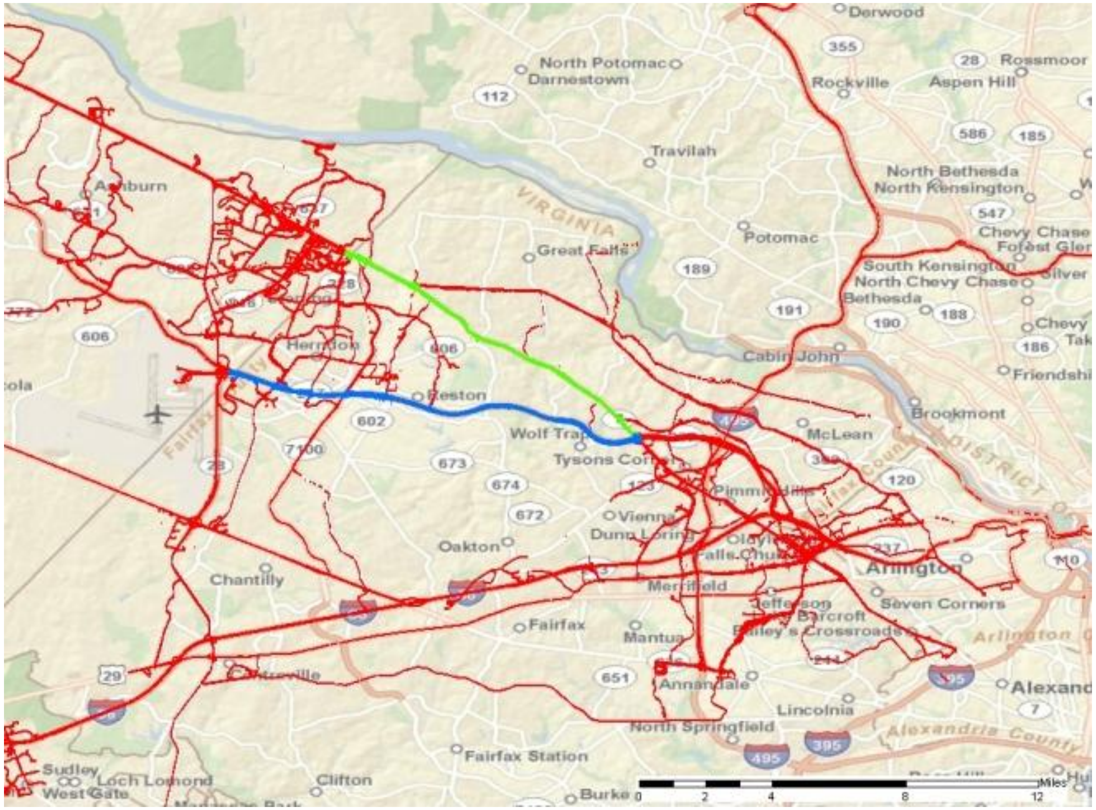
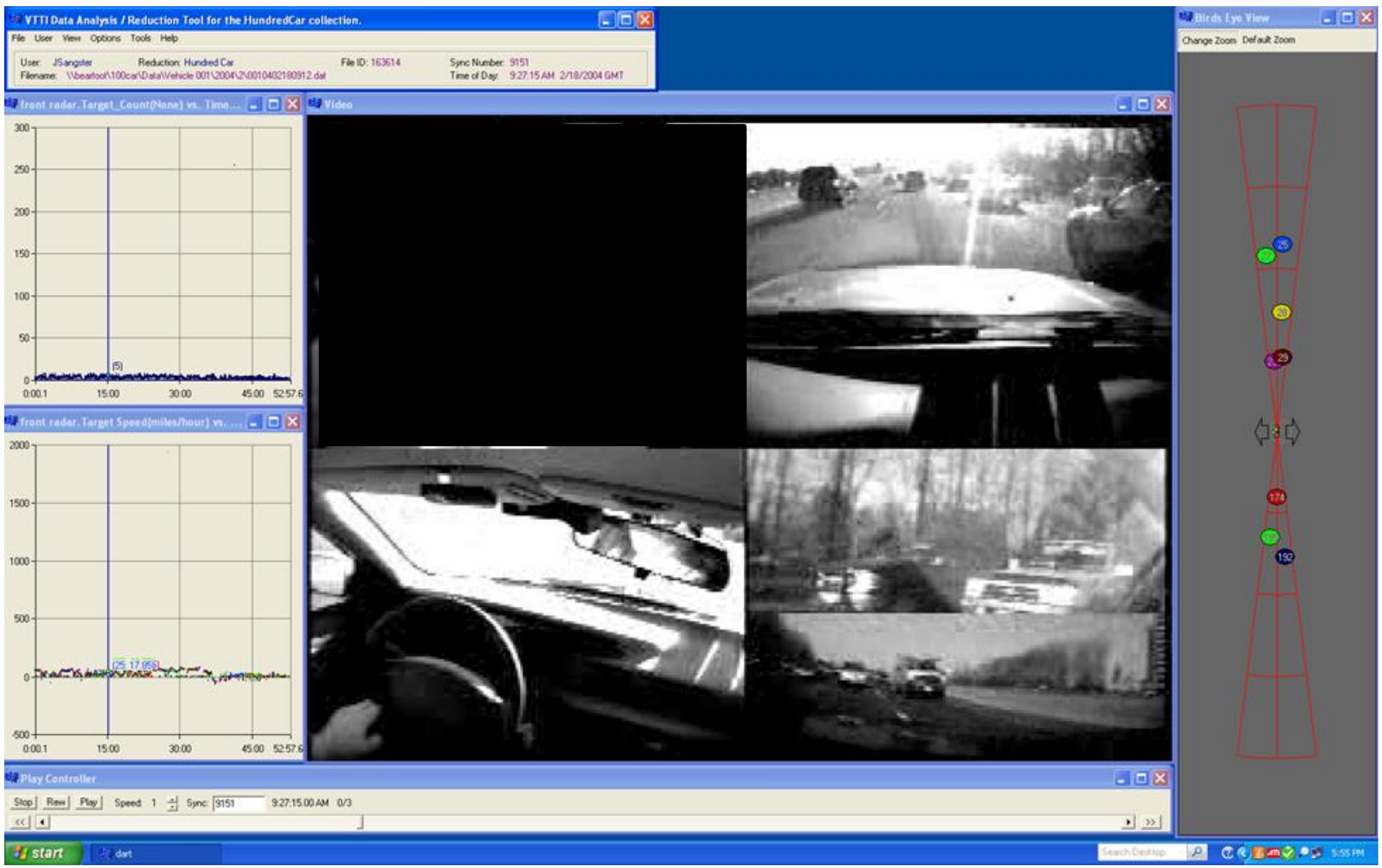
Data Reduction

- Multiple drivers identified using GIS; homogeneous roadway segment.



Data Reduction

- Car-following events verified visually



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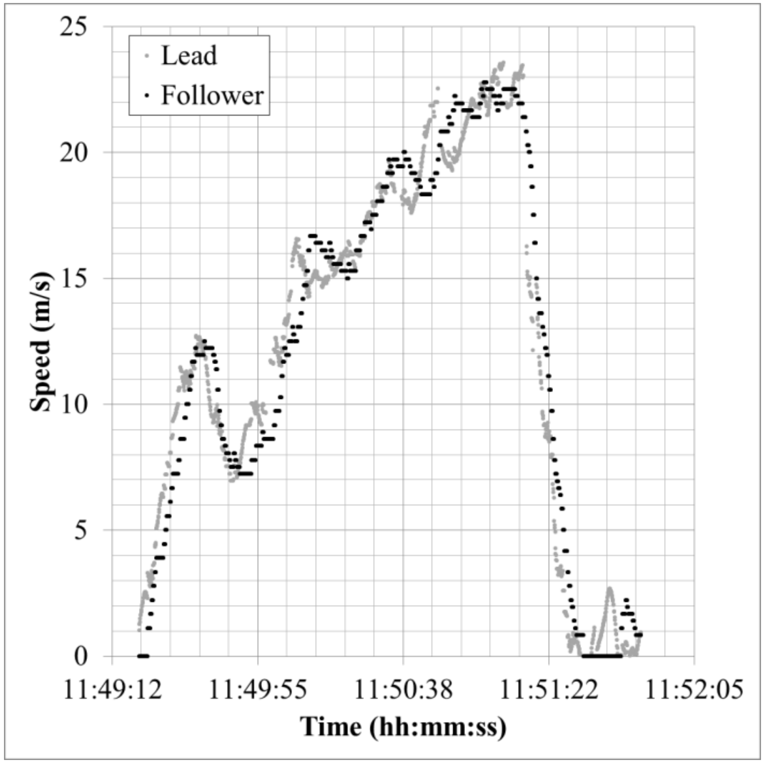
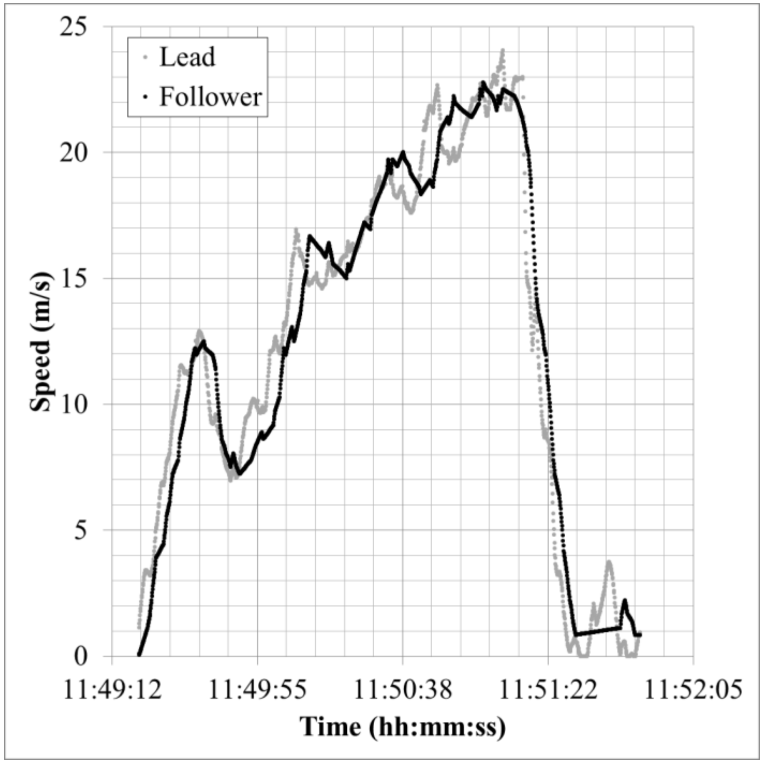
Data Reduction

- Interpolation of data feeds





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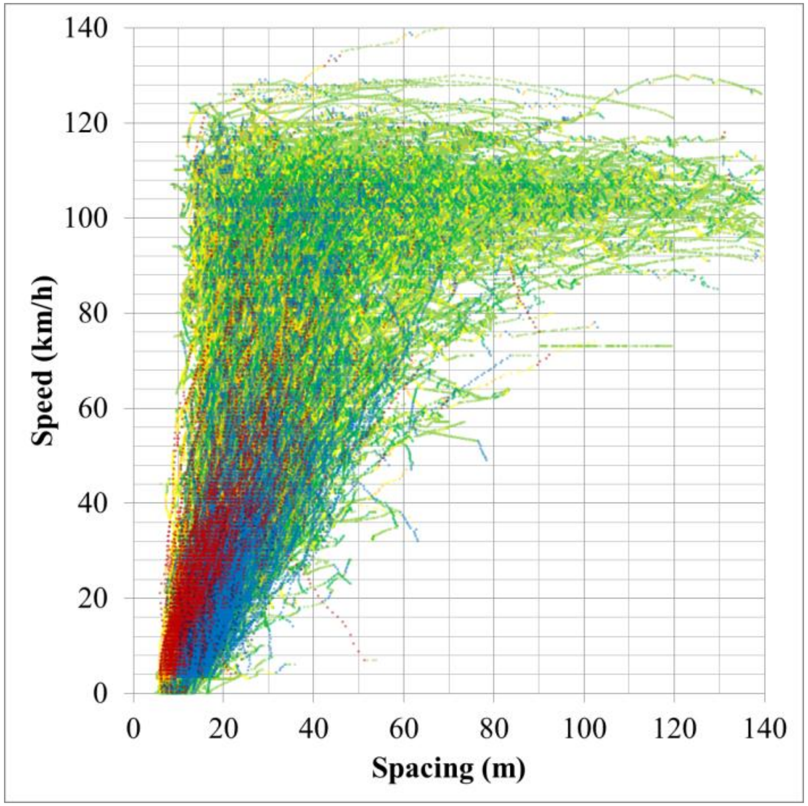
Dataset Extracted from Database

- Green indicates steady-state travel, red for deceleration, and blue for acceleration.



Dataset Extracted from Database

- Full database (Hundred Car Study) includes 108 drivers, 337,000 hours of data, 207,000 trips.
- GIS identified 15 drivers commuting on Dulles Airport Access Road.
- Validated data available for 7 drivers.
- Final dataset includes 7 drivers, 1,732 car-following events totaling 789 minutes.

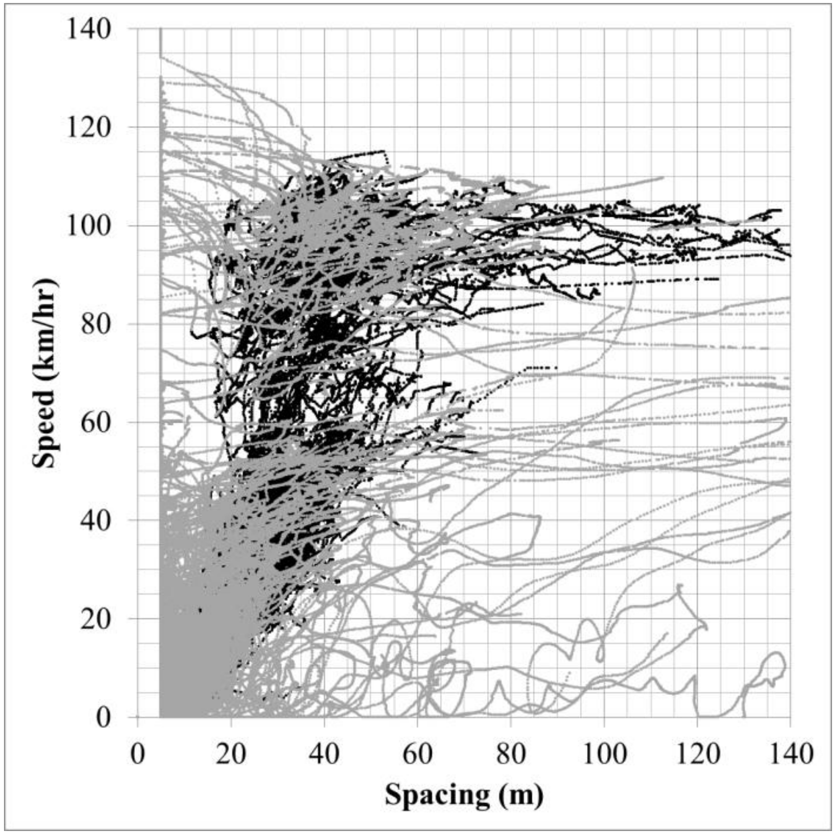
Car-following models analyzed

- Gaxis-Herman-Rothery (GHR) Model
  - GHR-1 model incorporated in ACC systems
- Gipps Model
  - Incorporated in the AIMSUN software
- Intelligent Driver Model (IDM)
  - Extension of the Gipps model
- Rakha-Pasumarthy-Adjerid (RPA) Model
  - Van Aerde steady-state model
  - Vehicle dynamics acceleration constraints and collision avoidance constraints

Car-following simulation results

- Gaxis-Herman-Rothery (GHR) Model

$$\ddot{x}_{n+1}(t) = \left\{ \frac{\alpha[\dot{x}_{n+1}(t)]^z}{[\Delta x_{n\to n+1}(t-\tau)]^l} \right\} \cdot [\Delta \dot{x}_{n\to n+1}(t-\tau)]$$



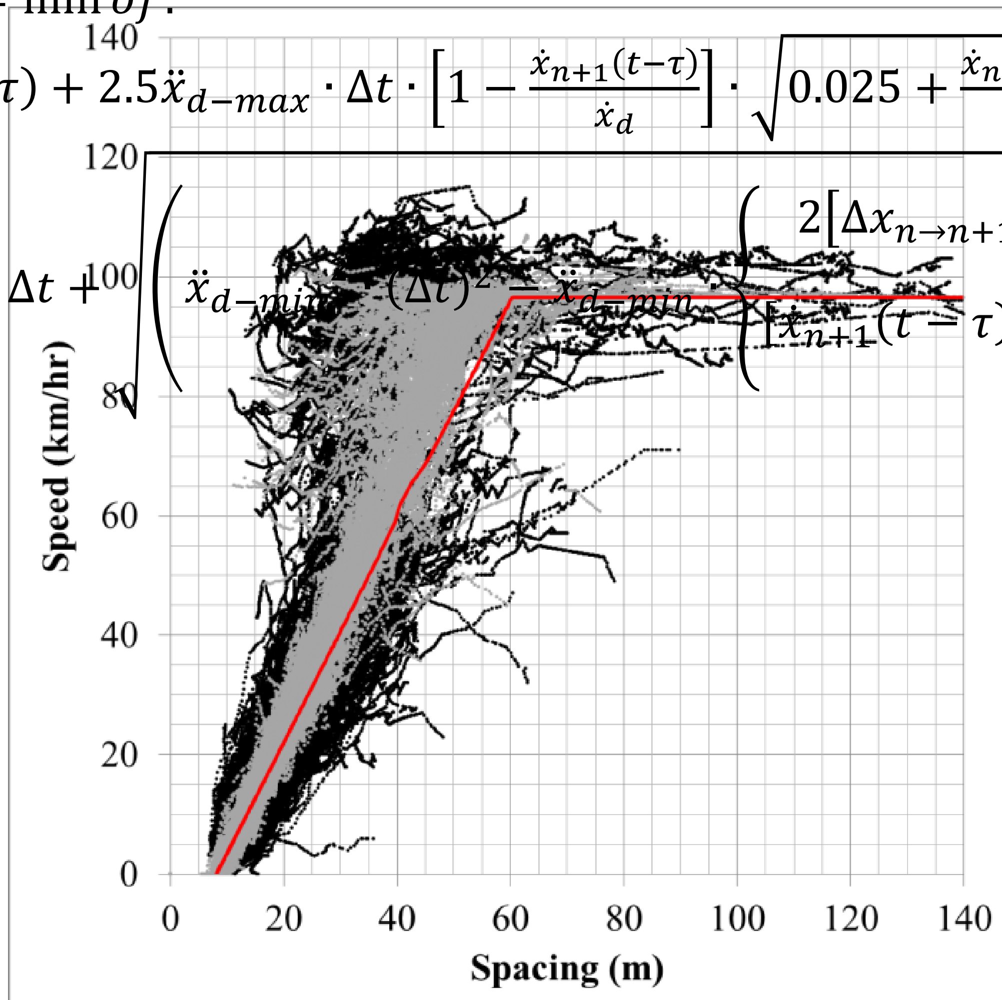
Car-following simulation results

- Gipps Model

$$\dot{x}_{n+1}(t) = \min of:$$

$$\dot{x}_{n+1}(t-\tau) + 2.5\ddot{x}_{d-max}\cdot\Delta t\cdot\left[1-\frac{\dot{x}_{n+1}(t-\tau)}{\dot{x}_d}\right]\cdot\sqrt{0.025+\frac{\dot{x}_{n+1}(t-\tau)}{\dot{x}_d}}\ ,$$

$$\ddot{x}_{d-min}\cdot\Delta t + \sqrt{\left(\ddot{x}_{d-min}\cdot(\Delta t)^2 - \ddot{x}_{d-min}\left\{\begin{matrix} 2[\Delta x_{n\to n+1}(t-\tau)-\Delta x_j] - \\ [\dot{x}_{n+1}(t-\tau)\cdot\Delta t] - \dfrac{\dot{x}_n(t-\tau)^2}{\ddot{x}_{(n)-min}}\end{matrix}\right\}\right)}$$



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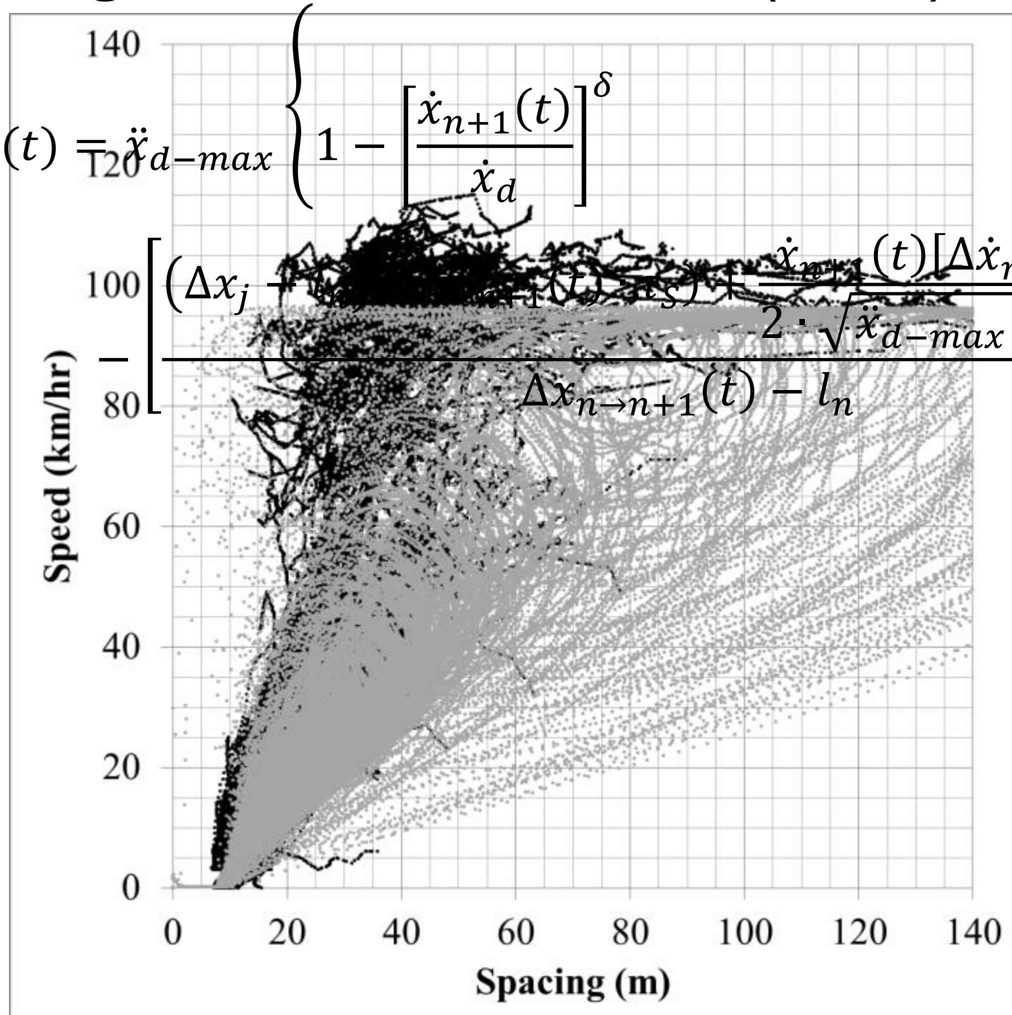
Car-following simulation results

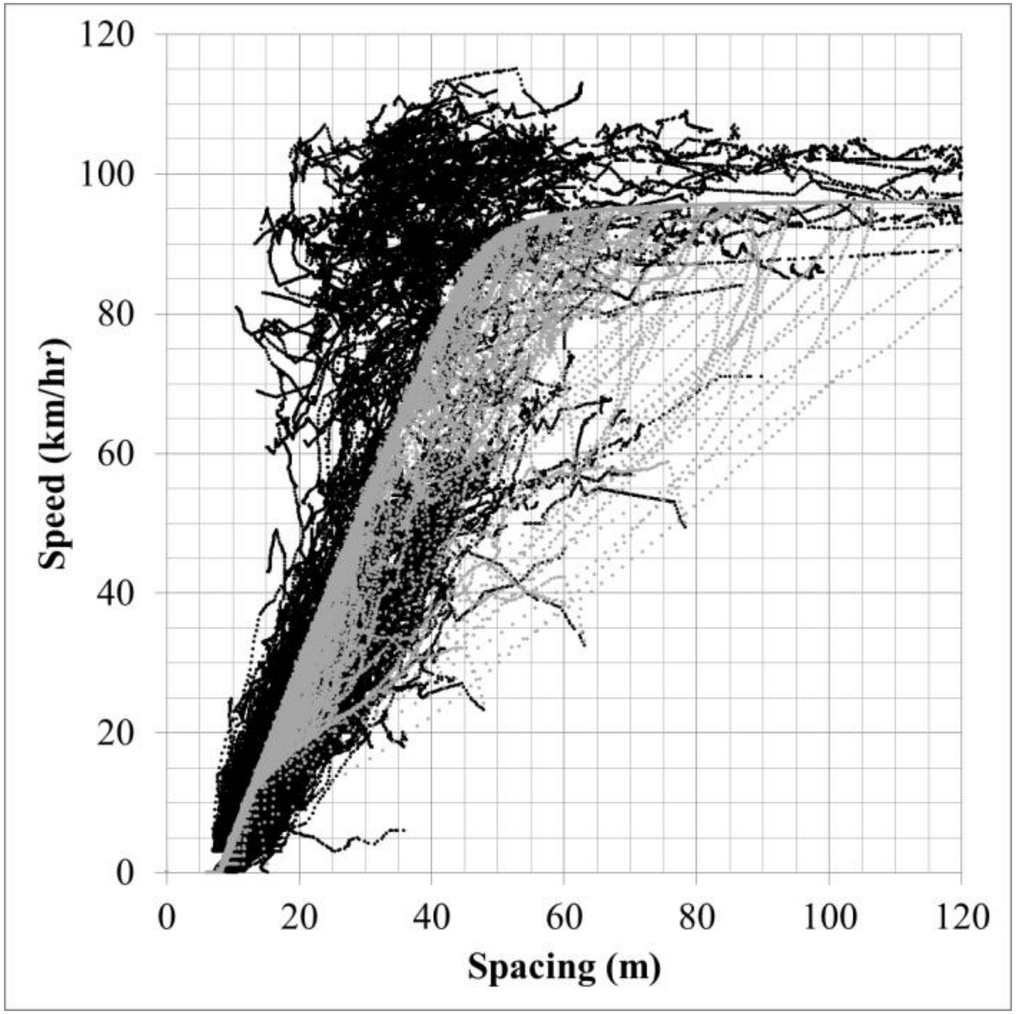
- Intelligent Driver Model (IDM)



$$\ddot{x}_{n+1}(t) = \ddot{x}_{d-max}\left\{1 - \left[\frac{\dot{x}_{n+1}(t)}{\dot{x}_d}\right]^{\delta} - \left[\frac{\left(\Delta x_j - l_n\right) + \dot{x}_{n+1}(t)\cdot\tau_S + \frac{\dot{x}_{n+1}(t)[\Delta\dot{x}_{n\to n+1}(t)]}{2\cdot\sqrt{\ddot{x}_{d-max}\cdot|\ddot{x}_{d-min}|}}}{\Delta x_{n\to n+1}(t) - l_n}\right]^2\right\}$$

Car-following simulation results

- Rakha-Pasumarthy-Adjerid (RPA) Model

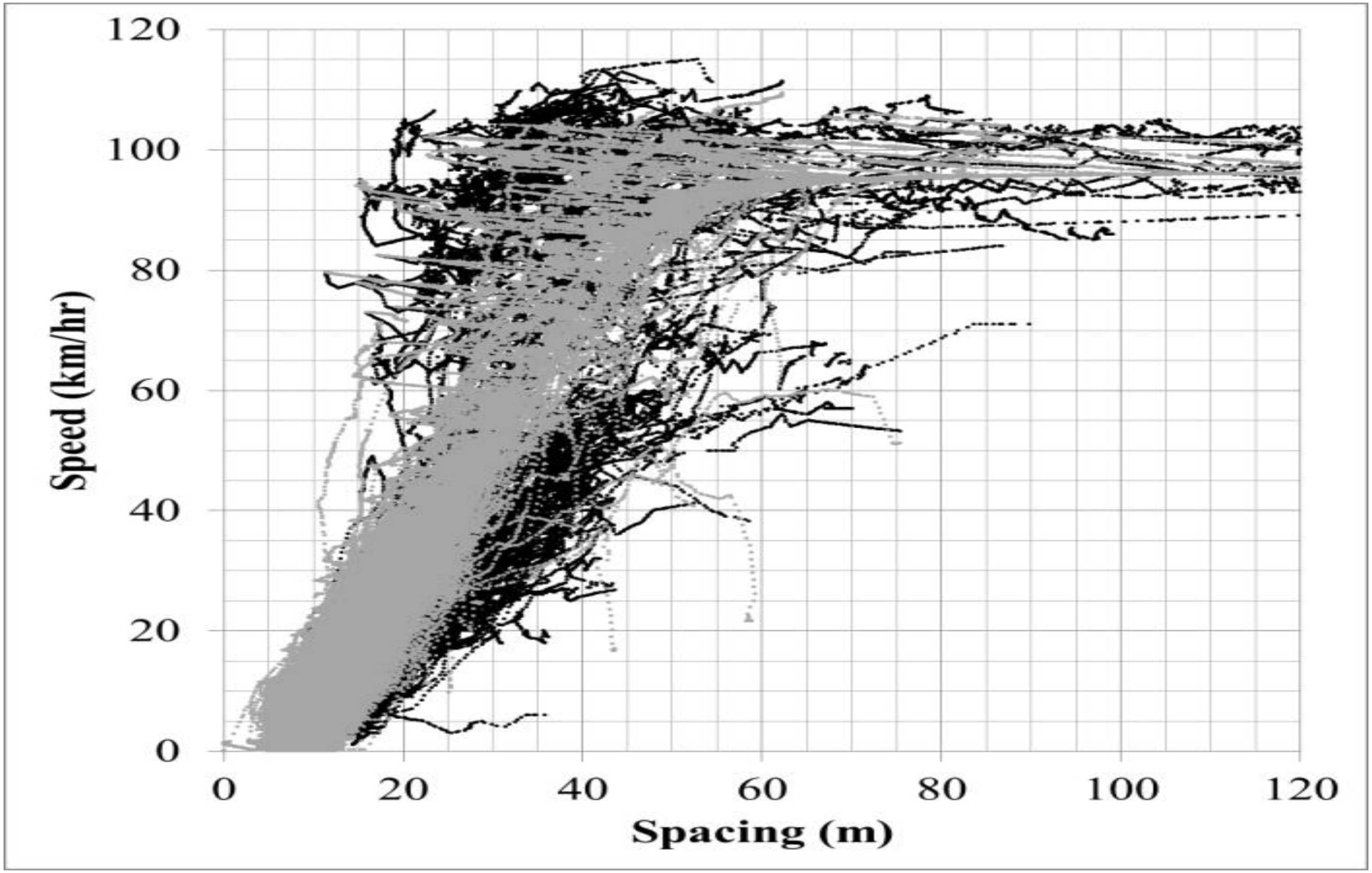


Car-following simulation results

- Comparison of Error Measures

Model	D124	D304	D316	D350	D358	D363	D462	Aggregate
GHR Model	0.00079	0.00082	0.00096	**0.00080**	0.00104	0.00046	0.00069	0.00033
Gipps Model	**0.00064**	**0.00033**	**0.00030**	0.00094	**0.00028**	**0.00019**	**0.00055**	**0.00014**
IDM	0.00142	0.00172	0.00101	0.00181	0.00069	0.00068	0.00328	0.00026
RPA Model	0.00086	0.00037	0.00044	0.00118	0.00034	**0.00019**	0.00087	0.00021

Results of Comparative Analysis



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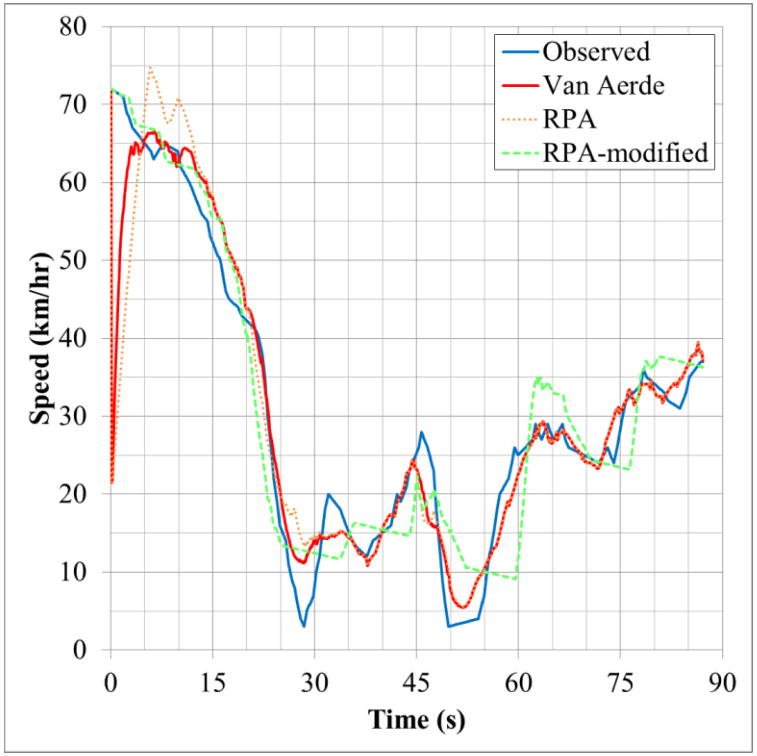
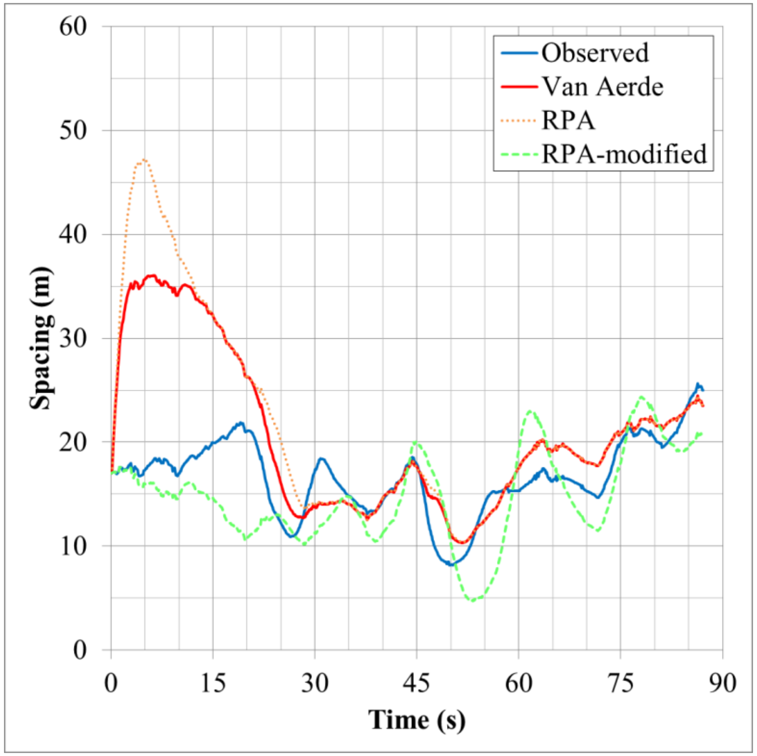
Car-following simulation results

- Sample Event





Car-following simulation results

- Comparison of Error Measures

Model	D124	D304	D316	D350	D358	D363	D462	Aggregate
Van Aerde Model	0.00073	0.00037	0.00036	0.00105	0.00030	0.00017	0.00052	0.00018
RPA Model	0.00086	0.00037	0.00044	0.00118	0.00034	0.00019	0.00087	0.00021
Revised RPA Model	**0.00065**	**0.00032**	**0.00029**	**0.00088**	**0.00029**	**0.00015**	**0.00036**	**0.00015**

Parameter	D124	D304	D316	D350	D358	D363	D367	D462	Aggregate
GHR	0.00079	0.00082	0.00096	**0.00080**	0.00104	0.00046	0.00104	0.00069	0.00033
Gipps	0.00064	0.00033	0.00030	0.00094	0.00028	0.00019	0.00040	0.00055	0.00014
IDM	0.00142	0.00172	0.00101	0.00181	0.00069	0.00068	0.00057	0.00328	0.00026
RPA	**0.00063**	**0.00031**	**0.00026**	0.00082	**0.00026**	**0.00015**	**0.00038**	**0.00035**	**0.00012**

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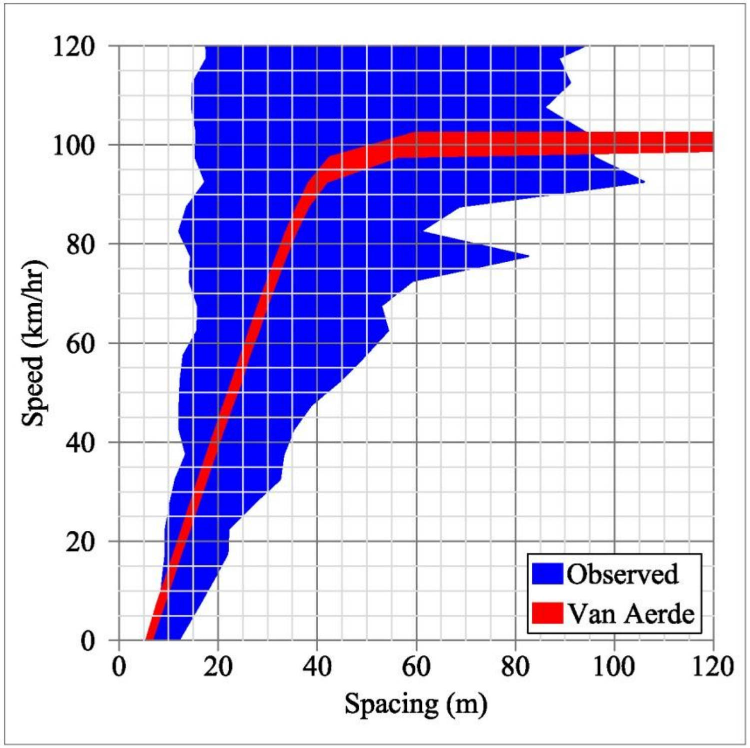
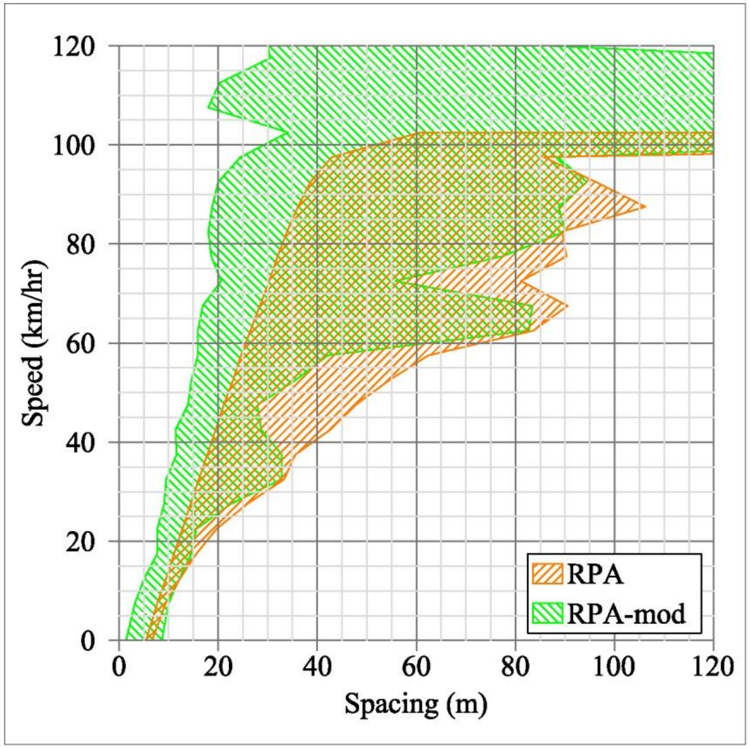
Model Coverage

- Coverage using 90th percentile range.





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Conclusions

- Naturalistic data provides a wealth of data for use in studying traveler behavior:
  - Departure time trends
  - Route set size
  - Route choice behavior
  - Car-following behavior
- Augmentation with other data sources to give larger picture can also be beneficial

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