Towards Realistic Models of Driver Behavior

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Personal Introduction

EDUCATION

Ph.D., 2009	Civil & Coastal Engineering, University of Florida, Gainesville, Florida.
M.S., 2005	Civil & Coastal Engineering, University of Florida, Gainesville, Florida.
Diploma, 2003	Rural and Surveying Engineering, (five year program) National Technical University of Athens, Athens, Greece.

EMPLOYMENT

8/2014 – present	**Assistant Professor,** University of Kansas, Lawrence, Kansas.
11/2012 – 8/2014	**Postdoctoral Associate,** University of Florida, Gainesville, Florida.
1/2011 – 1/2013	**Transportation Researcher**, National Technical University of Athens, Athens, Greece.
8/2009 – 11/2012	**Transportation Engineering Consultant,** ANKA Consulting, Athens, Greece.
8/2004 – 7/2009	**Graduate Research Assistant**, University of Florida, Gainesville, Florida.
1/2004 – 5/2004	**Graduate Research Assistant**, Penn State University, State College, Pennsylvania.

Research Work

At KU

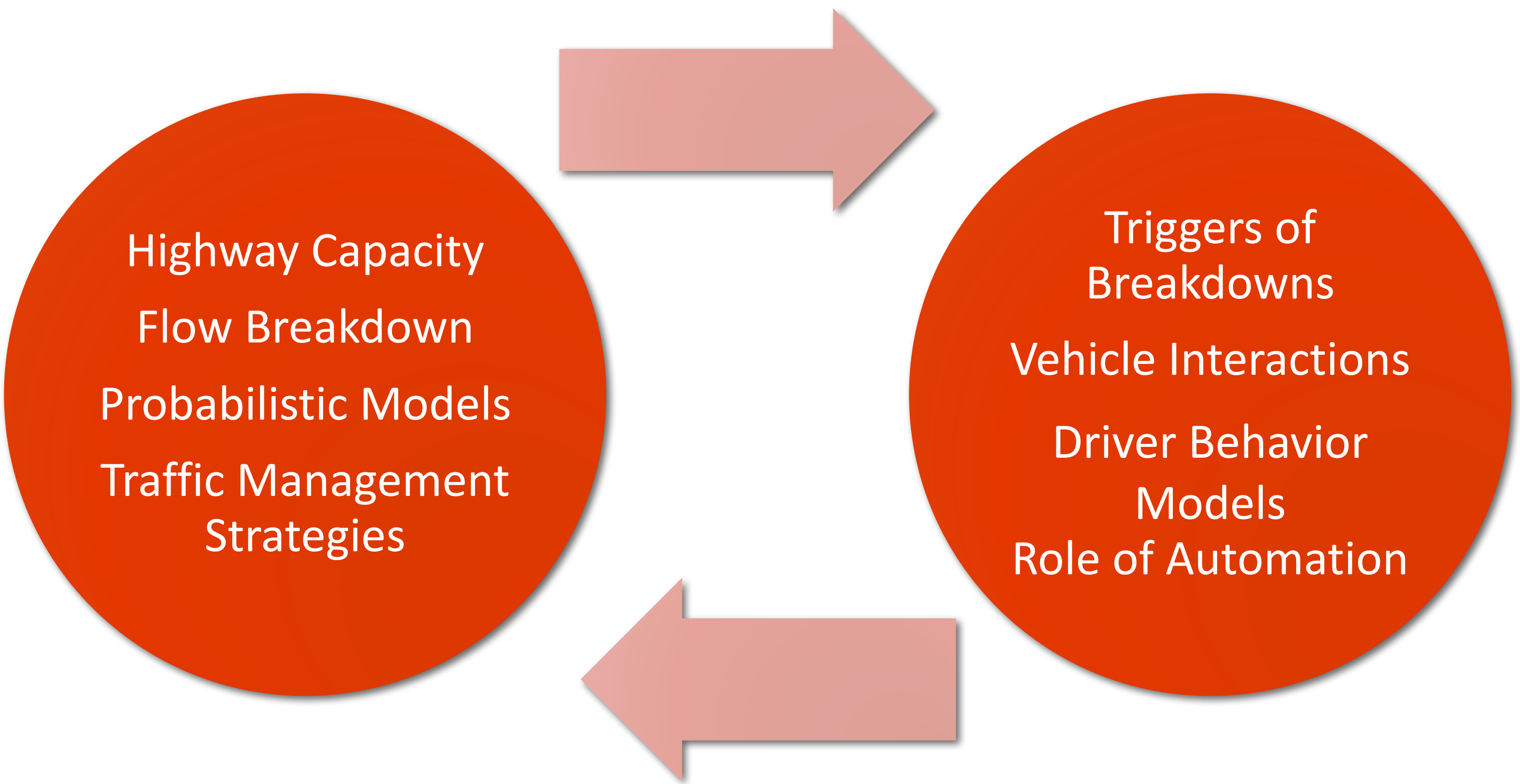
1. “Alternative Designs to Alleviate Freeway Bottlenecks at Merge/Diverge and Weaving Areas” FHWA
2. “Narrowing Freeway Lanes and Shoulders to Create Additional Travel Lanes” FHWA
3. “Promoting the Transportation Systems Management & Operations Program in Kansas” KDOT
4. “Modeling Driver Aggressiveness and its Impact on Safety Using Biobehavioral Methods” USDOT
5. “2016 Work Zone and Guardrail Safety Training Grant” FHWA
6. “Providing Crash Data Analysis Services for the Kansas Department of Transportation” KDOT
7. “Improving the Accuracy and Applicability of Kansas Traffic Data” KDOT
8. “Evaluation of Ramp Metering Effectiveness Along the I-35 Corridor in the Kansas City Metropolitan Area” KDOT

Research Work

At UF

1. “Investigating the Effect of Drivers’ Body Motion on Traffic Safety” USDOT
2. “Comparison of Methods for Measuring Travel Time at Florida Freeways and Arterials” FDOT
3. “Estimation of Capacities on Florida Freeways” FDOT
4. “Proactive Ramp Management Under the Threat of Freeway Flow Breakdown” NCHRP
5. “Investigation of ATDM Strategies to Reduce the Probability of Breakdown” USDOT
6. “Lifting High-Occupancy-Vehicle Lane Eligibility and Shoulder Use Restrictions for Traffic Incident Management” FDOT
7. “Impact of Trucks on Arterial LOS and Freeway Work Zone Capacity” FDOT
8. “Development of Guidelines for Driveway Location and Median Configuration in the Vicinity of Interchanges” FDOT
9. “Capacity and Quality of Service of Interchange Ramp Terminals” NCHRP

Introduction



Driver Behavior at Freeway Merges

Objectives:

- Investigate how driver behavior affects traffic operations and gap acceptance decisions at freeway merging segments;

- Explore the relationship between vehicle interactions and breakdown events.

Data Collection

PART A: Focus Groups

- Investigate drivers' thinking process and intended actions at freeway-ramp merges

- Identify factors that affect gap acceptance decisions and merging interactions

PART B: Instrumented Vehicle Experiment

- Collect data to develop models of driver behavior

Data Collection

FOCUS GROUP EXPERIMENT

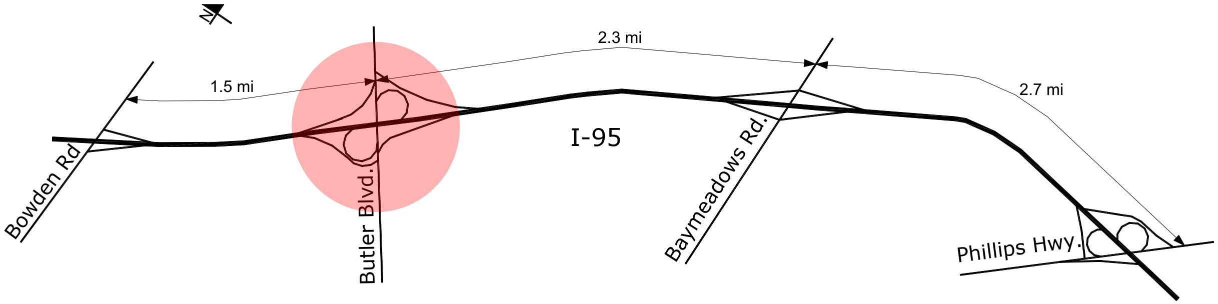
- Factors that affect drivers' gap acceptance decisions have been identified.
- Factors that affect drivers' decisions to initiate cooperative merge or forced merge have been identified.
- Freeway vehicles prefer to change lanes and avoid decelerating.
- Driver behavior: criterion of selfishness for defining behavioral categories.
  → Aggressiveness depends on the task and the traffic conditions.
- Congested conditions: Driver behavior displays less variability
  → more predictable.

Kondyli and Elefteriadou, 2009

Data Collection

INSTRUMENTED VEHICLE EXPERIMENT

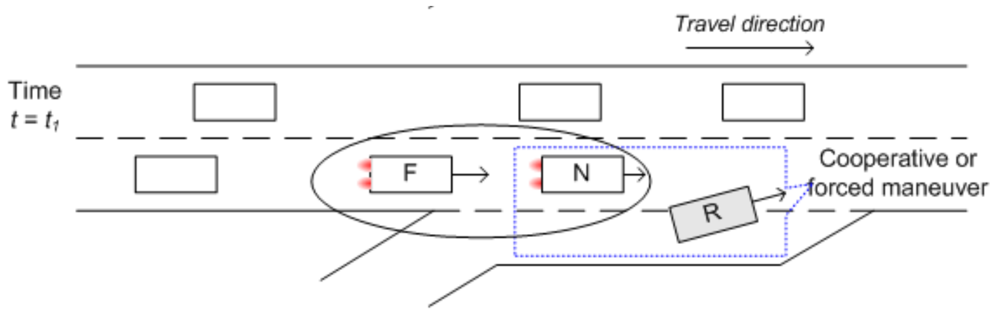
- GPS;
- mounted cameras;
- hard drive equipment;
- 31 participants;
- Drivers testimonials during experiment.



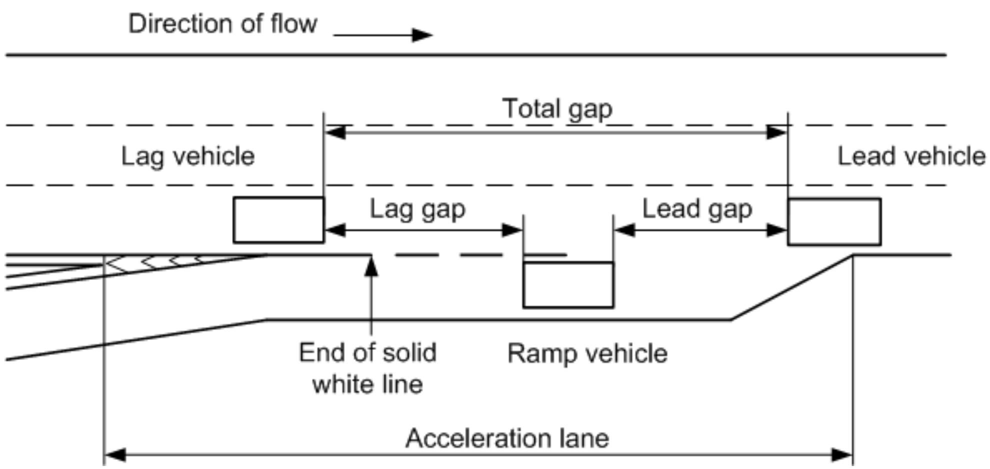
Kondyli and Elefteriadou, 2012

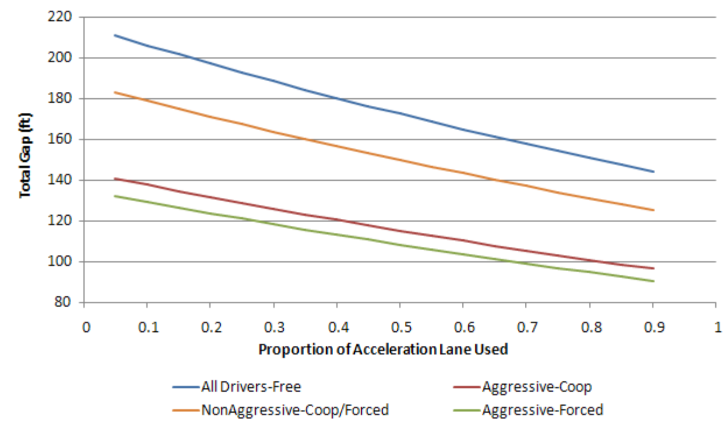
Merging Maneuver Types

1. ***Free merges:*** no obvious interaction between the merging vehicle and the mainline vehicle
2. ***Cooperative merges:*** the mainline vehicle yields to the ramp vehicle by either slowing down or changing lanes, to create an acceptable gap
3. ***Forced merges:*** clear conflict between the two vehicles. The merging vehicle initiates the maneuver and the mainline vehicle reacts by either slowing down or changing lanes



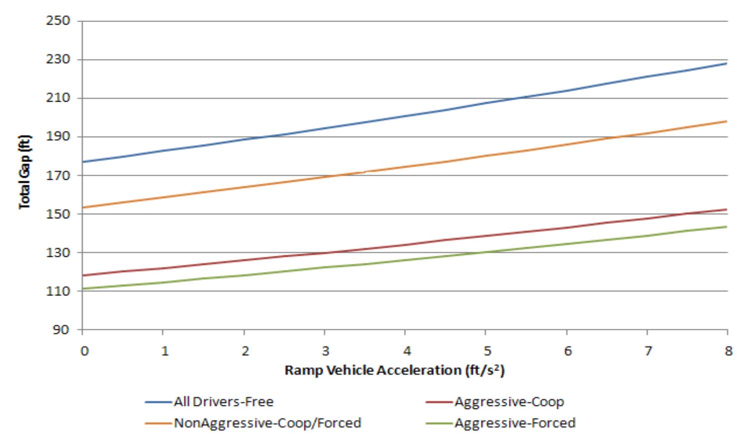
Gap Acceptance





$$\ln(G_R^{total}) = 5.343_{(33.46)} + 0.141_{(1.86)} * M^{free} - 0.324_{(-2.80)} * DT^{agr} * M^{forced}$$

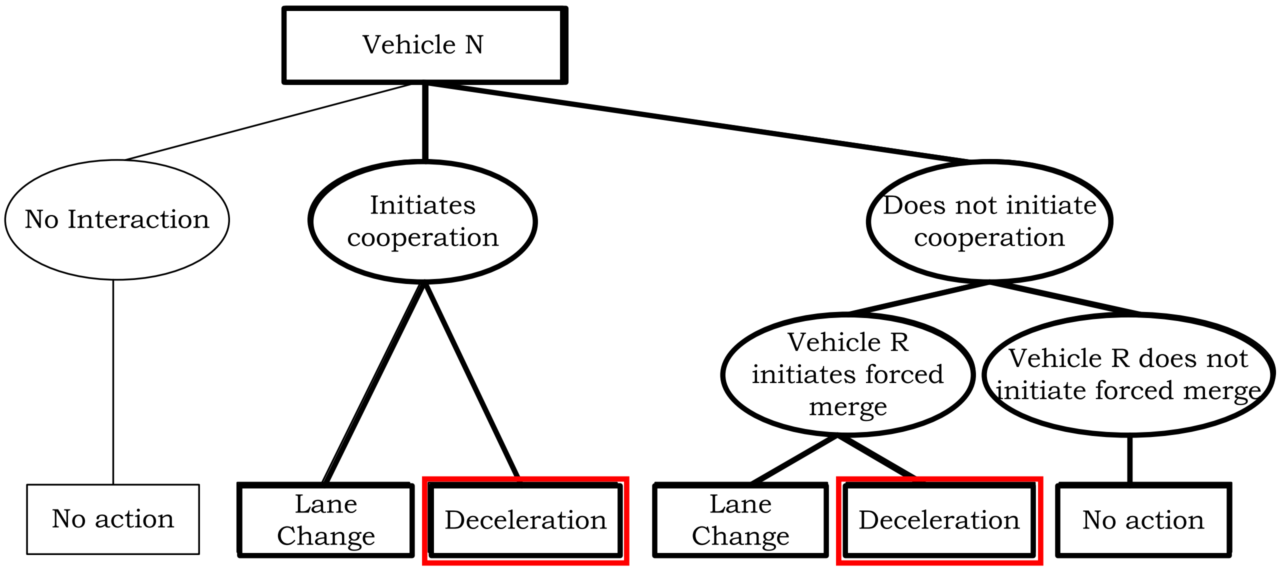
$$- 0.262_{(2.46)} * DT^{agr} * M^{coop} - 0.445_{(-2.43)} * \frac{l}{D} - 0.005_{(-1.66)} * k + 0.032_{(1.84)} * a_R$$



Function of:

- Merging maneuver
- Driver's aggressiveness

Freeway Vehicle Behavior



$$P(MergingTurbulence) = \frac{1}{RampFlowRate}\sum_{N=1}^{n} P_N(Dec)$$

$$P_N(DEC_t) = P_N\left(DEC, s_{t,N} = coop / s_{t-1,N} = normal\right)$$
$$+ P_N\left(DEC, s_{t,N} = forced / s_{t-1,N} = normal\right)$$

Kondyli and Elefteriadou, 2011

Freeway Vehicle Behavior

MNL Model: Deceleration Model due to Cooperation

$$V_{dec,N}^{coop} = 0$$

$$V_{CL,N}^{coop} = 4.179 + 0.002 * (D - l) - 0.018 * y - 0.071 * k$$

$$V_{no-action,N}^{coop} = 2.055 + 0.002 * (D - l) - 0.724 * N_r$$

$$- 0.144 * (\min(0, V_{avg} - V_N)) + 0.008 * y * DT^{non-agr}$$

$$Adjusted \;\; R^2 = 21.6\% \qquad LL = -39.499$$

Freeway Vehicle Choices:

- Do not initiate cooperation
- Change lanes
- Decelerate (least preferred)

$(D\text{-}l)$ = distance to the end of the acceleration lane (ft)
y = distance between ramp and freeway vehicle (ft)
k = average freeway density (veh/mi/ln)
N_r = cluster size
$(V_{avg}\text{-}V_N)$ = freeway average speed less the subject freeway vehicle speed (mph)
$Dt^{non\text{-}agr}$ = driver type dummy for non aggressive drivers

Freeway Vehicle Behavior

Binary Logit Model: Deceleration due to forced merge

$$V_{no-action,N}^{normal} = 0$$

$$V_{dec,N}^{forced} = -15.28 + 0.10 * k + 21.64 * l / D$$

$$+1.14 * N_r * DT^{agr} + 0.88 * a_r$$

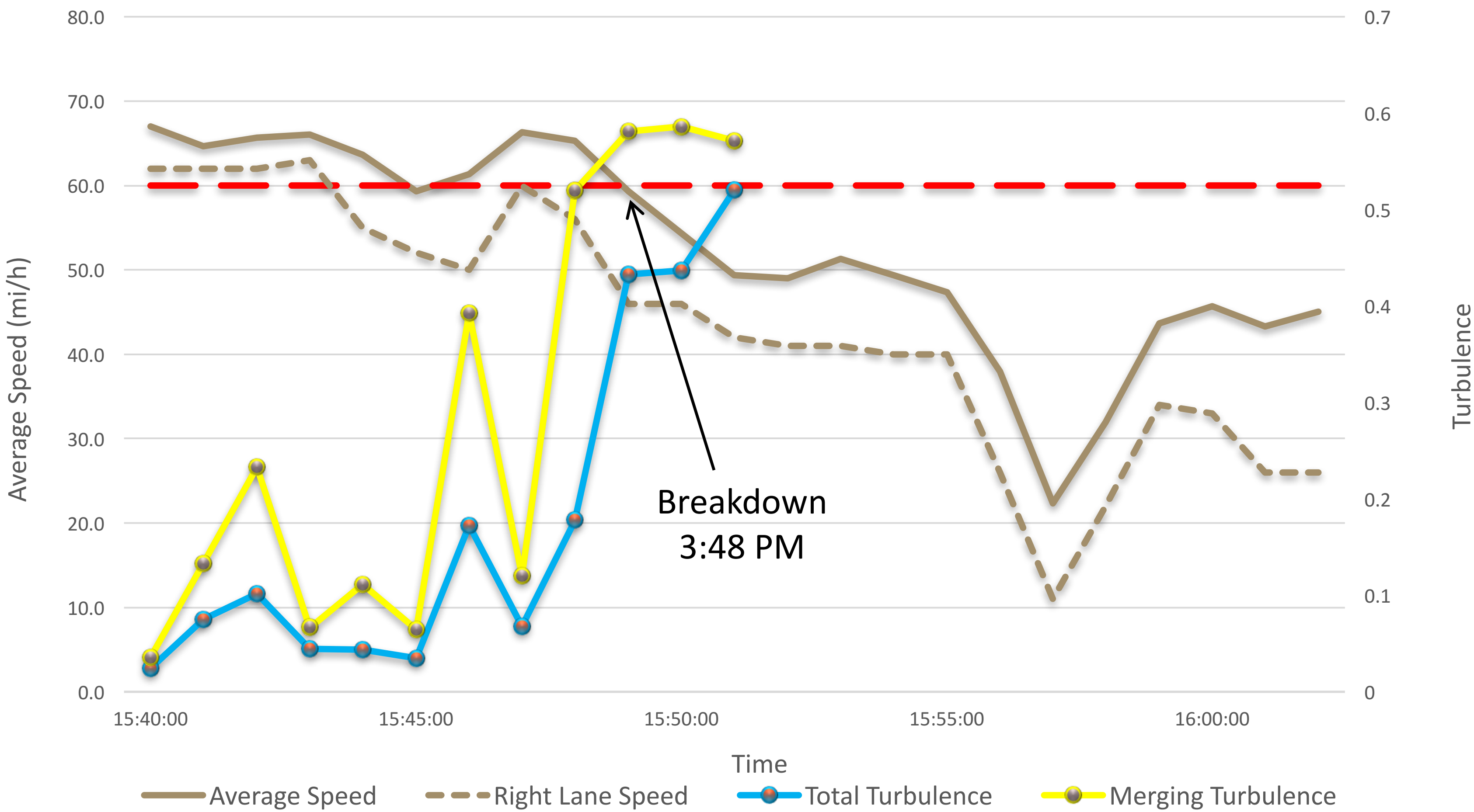
$$Adjusted \;\; R^2 = 61.9\% \quad LL = -11.060$$

Ramp Vehicle Choices:

- Do not initiate forced merge
- Initiate forced merge

(l/D) = proportion of acceleration lane used
k = average freeway density (veh/mi/ln)
a_r = ramp vehicle acceleration (ft/s^2)
N_r = cluster size
Dt^{agr} = driver type dummy for aggressive drivers

Merging Turbulence



Findings and Recommendations

- Development of a gap acceptance model that considers drivers' degree of aggressiveness and maneuver type
- Development of a merging turbulence model that captures vehicle interactions and the triggers for vehicle decelerations considering drivers' aggressiveness
- Evaluation of merging turbulence model based on macroscopic observations
- Inclusion of the effect of driver behavior on vehicle interactions for refining or developing microsimulation models
- Verification of the merging turbulence model with additional data

Car-Following by Driver Type, Traffic, and Weather Conditions

- Car-following models considered: Pitt, modified Pitt, Gipps, MITSIM
- Calibration by traffic conditions, weather conditions, and driver type for speed and spacing, using instrumented vehicle data

Model	Parameters	Calibration with all drivers and conditions	Calibration by condition				Calibration by driver type		
			Uncongested	Congested	Rain uncongested	Rain congested	Aggressive	Average	Conservative
Gipps	a_n (m/s^2)	3.30	3.30	2.94	3.30	3.30	3.30	3.11	3.30
	b_n (m/s^2)	−3.40	−4.56	−2.00	−2.33	−2.00	−5.00	−2.19	−4.44
	$\hat{b}$ (m/s^2)	−3.40	−4.56	−2.00	−2.33	−2.00	−5.00	−2.19	−4.44
Pitt	k(s)	0.45	0.46	0.13	0.75	0.38	0.36	0.70	0.47
	b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
MITSIM	α^+	0.50	0.96	0.50	4.00	0.67	0.50	0.50	0.50
	β^+	−1.00	−0.90	−1.00	1.00	−1.00	−0.81	−1.55	−0.85
	γ^+	−1.00	−0.88	−1.00	2.16	−1.00	−0.84	−1.00	−0.93
	α^-	1.25	0.55	1.25	0.58	1.31	1.20	2.00	1.19
	β^-	1.00	0.00	1.00	2.00	1.15	0.69	0.00	0.13
	γ^-	1.00	−0.26	1.00	2.31	1.00	1.13	0.65	0.30
Modified Pitt	K	0.12	0.16	0.45	0.07	0.18	0.12	0.21	0.16
	h (s)	0.86	0.72	1.91	1.10	0.93	0.78	0.89	0.67
	L_l (m)	6.71	6.71	6.71	6.71	6.71	7.81	9.76	7.34

Soria, Elefteriadou, and Kondyli, 2014

Car-Following by Driver Type, Traffic, and Weather Conditions

- All models were more accurate in predicting car-following under congested traffic conditions. This occurs because there is much less freedom and variability in driver behavior during congested conditions.
- The MITSIM and Gipps models were better in predicting average driver behavior.
- Both conservative and aggressive driver behaviors were better predicted when calibrated by driver type, particularly for non-congested conditions.
- Congested conditions were better predicted when the parameters are calibrated by condition.
- Uncongested conditions were better predicted when the parameters are calibrated by driver type.
- Variability of the various car-following parameter values when considering different driver types and also when considering varying traffic and weather conditions.

Freeway Lane Changing Behavior

- Instrumented vehicle lane changing analysis by driver type.
- Cluster analysis revealed four driver type groups.
- Lane change duration varies by driver type. Aggressive drivers have shorter lane change durations compared to conservative drivers.
- Accepted gaps follow the Gamma distribution. Lane change durations follow the Johnson Su (similar to lognormal) distribution.
- Degree of congestion affects lane changing operations. Lane changing duration is greater in congested conditions than in uncongested conditions. The accepted average size is also smaller.

Hill, Elefteriadou, and Kondyli, 2015

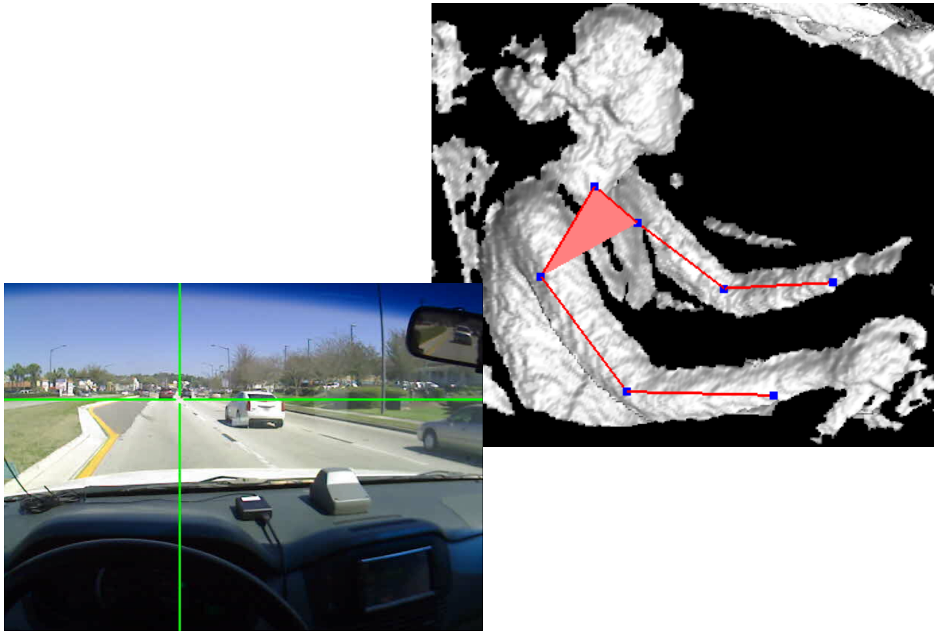
3D Body Posture

Goal:

- Develop a novel approach that tracks body movements and investigate the relationship between potentially unsafe driving maneuvers and the actual driver body posture.

Method:

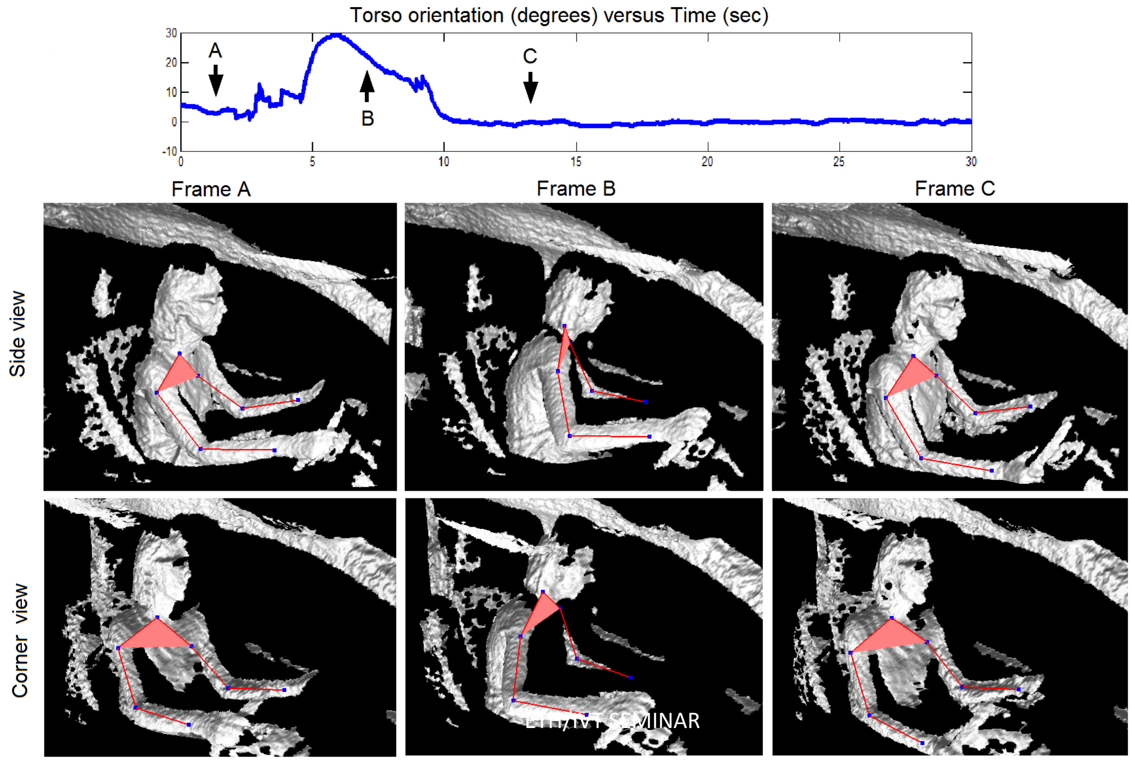
- Monitor drivers
- Traffic conditions
- Marker-less motion tracking algorithm
- Eye tracking



Kondyli,Sisiopiku and Barmpoutis, 2015

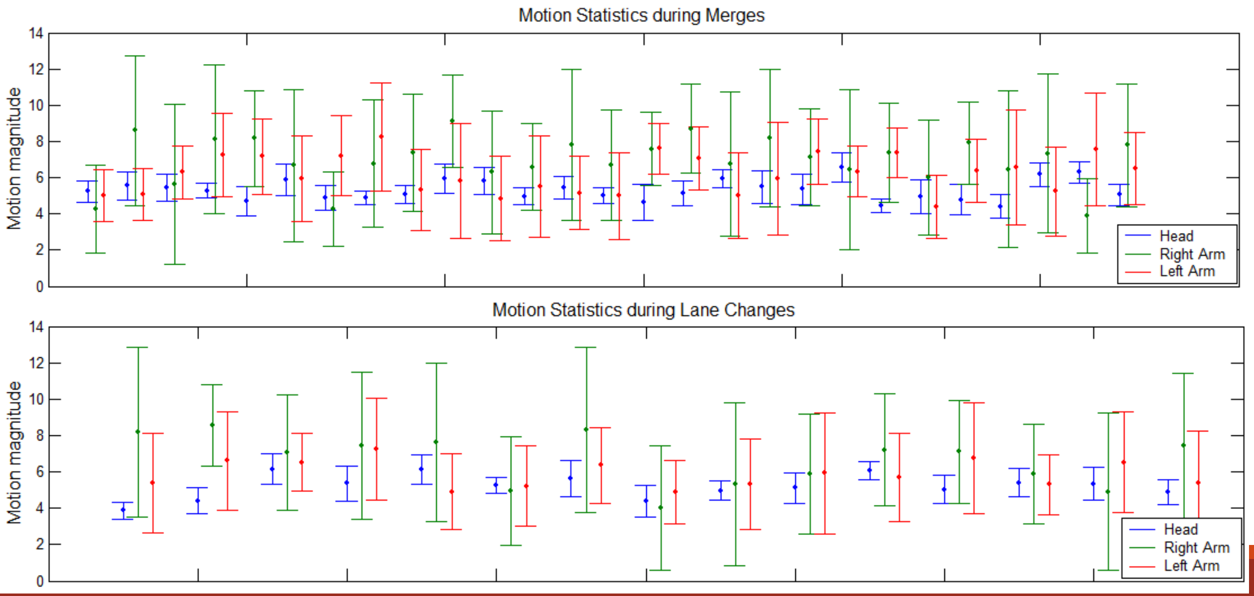
3D Body Posture

- Naturalistic data collection
- 35 participants
- Real time 7-point skeleton tracking: right wrist, right elbow, right shoulder, neck, left shoulder, left elbow, and left wrist.



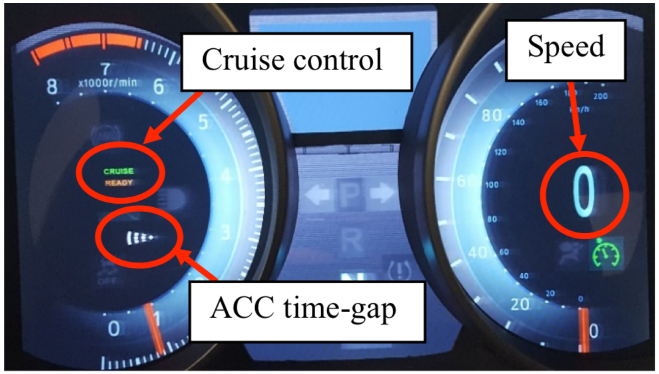
3D Body Posture

- Investigation of driver posture and interaction with other vehicles
- Observations of real-life driving conditions
- Development of a novel algorithm for tracking drivers' arms and head movement



Adaptive Cruise Control

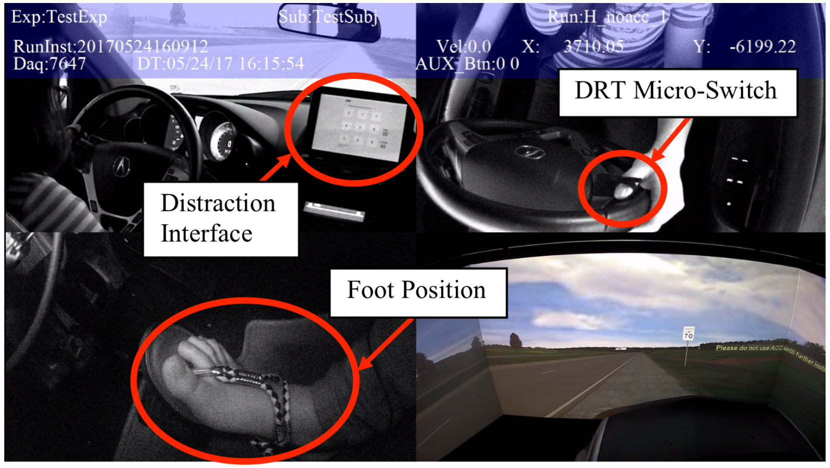
- Effects of ACC on car-following behavior and awareness using a Driving Simulator
- Control and treatment driving scenarios involving car-following under various levels of workload and distraction
- Cognitive workload was measured using a detection response task (DRT) device
- 18 participants (9 male, 9 female)



Kummetha, Kondyli and Schrock, 2017 (under review)

Adaptive Cruise Control

- Participants reach lower max speeds and longer spacing when driving with ACC
- Increased reaction times, brake force and deceleration rates when driving with ACC
- Workload is reduced with ACC - Secondary tasks performed better
- ACC vehicles should be equipped with emergency braking or active collision avoidance system to compensate for these effects



Modeling Driver Behavior and Driver Aggressiveness Using Biobehavioral Methods

- Current models do not accurately describe breakdown events and capacity drop

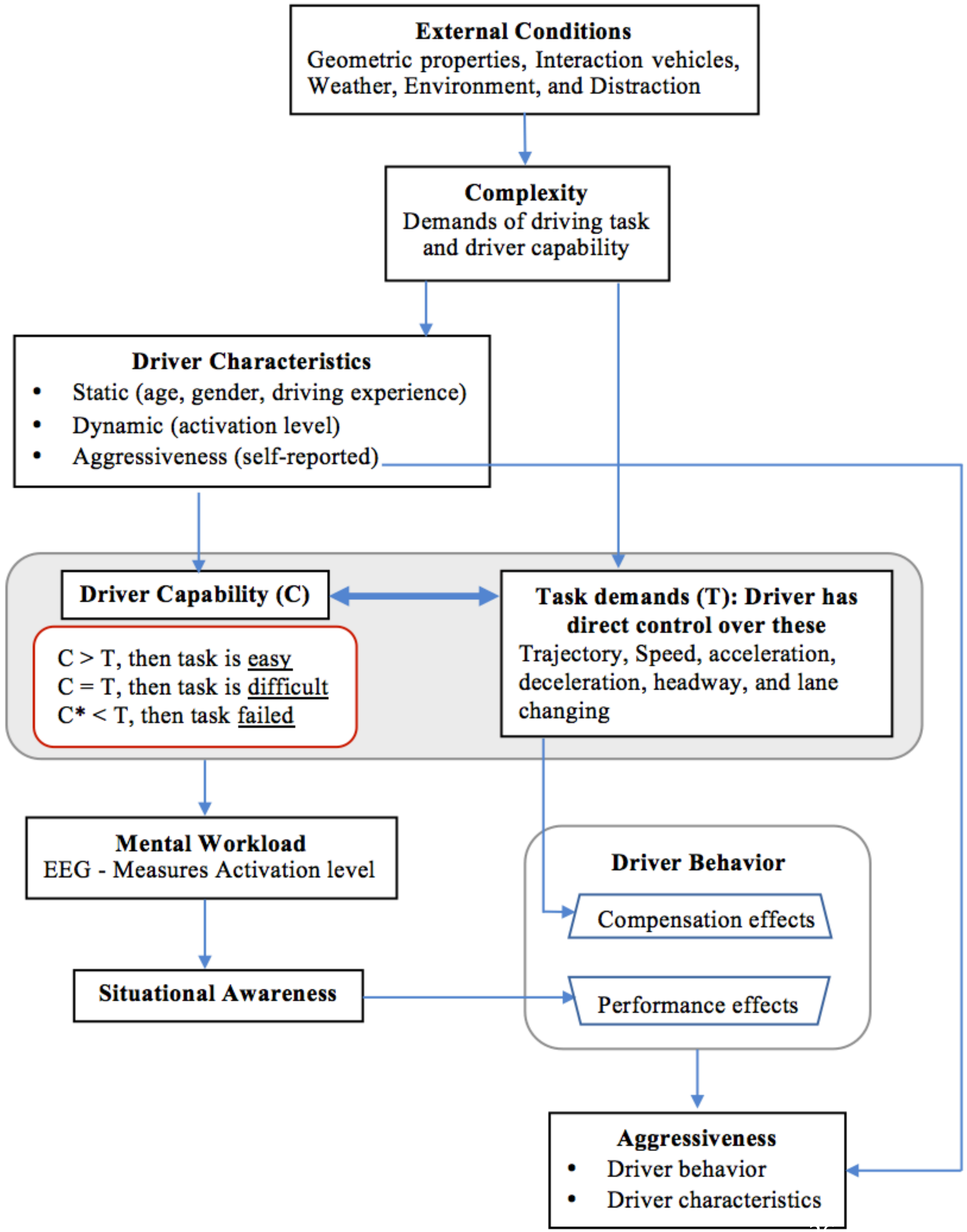
Goal: investigate relationship between driver aggressiveness and driving performance, borrowing concepts from the fields of cognitive science and psychology.

Method:

- Driving simulator study
- Obtain metrics of reaction times, driving performance (speed, acceleration) during lane changing and car-following
- Obtain psychophysical measures (EEG, HR, questionnaires)
- Consider various levels of workload and driver awareness

Behavioral Framework

- Establish behavioral thresholds for different driver types
- Incorporate driver aggressiveness in car-following models (Wiedemann, IDM)



Driver Behavior and CAVs

- Current models are mostly descriptive of driver behavior
- Model parameters (reaction times, degree of aggressiveness) are set exogenously and calibrated to current conditions
- Change in driving environment due to CAVs will cause changes in driving behavior
- There is need to provide new model parameters, considering psychological elements

Expand Behavioral Framework for CAVs

Goal: develop driver behavior algorithms of car-following, lane changing, and gap acceptance that realistically capture the impact of emerging vehicle technologies such as automated vehicles and connected vehicles on mobility and travel time reliability.

Objective 1: Expand behavioral theory framework for describing the effects of automated vehicle technologies on driver capability, workload, and situational awareness.

Objective 2: Integrate framework with a microsimulation framework that incorporates car-following and lane changing

Objective 3: Calibrate and validate simulation framework with naturalistic data. Analyze the effects of driver-vehicle interactions on traffic operations (capacity and reliability)

THANK YOU!

QUESTIONS?