Moving FHWA Work Zone Driver Model towards Practical Application

A work zone add-on for microsimulation tools

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U.S. Department of Transportation

Federal Highway Administration

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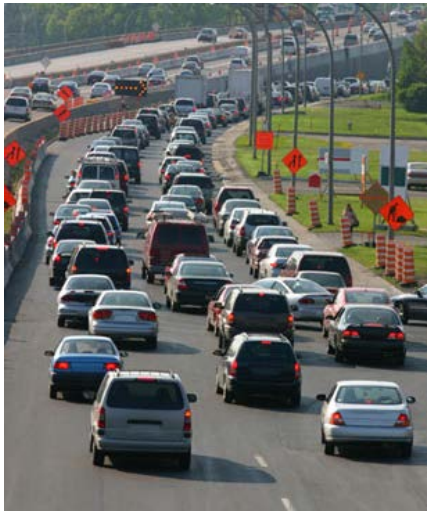
Saxton Transportation Operations Laboratory

Problem



- Work zones can have significant operational impacts.
- The number of freeway work zones in the US is projected to increase.
- DOTs need accurate tools that can accurately predict work zone impacts.
  - FHWA identified microscopic models as having the potential to better predict work zone operational impacts.[1]
- Most microsimulation tools are not designed to simulate driver behavior through work zones.
  - Therefore, they cannot be used to accurately predict work zone impacts (such as queue, delay, etc).

[1] FHWA Traffic Analysis Toolbox

Project Overview

Project Goal:

Create a work zone software to interface with existing microsimulation software tools, that enables them to accurately simulate car-following behavior through freeway work zones

Project Purpose:

To provide engineers and planners at State/local DOTs and consulting firms with a tool that can better predict the operational impacts of freeway work zones

Project Overview

Project Objectives:

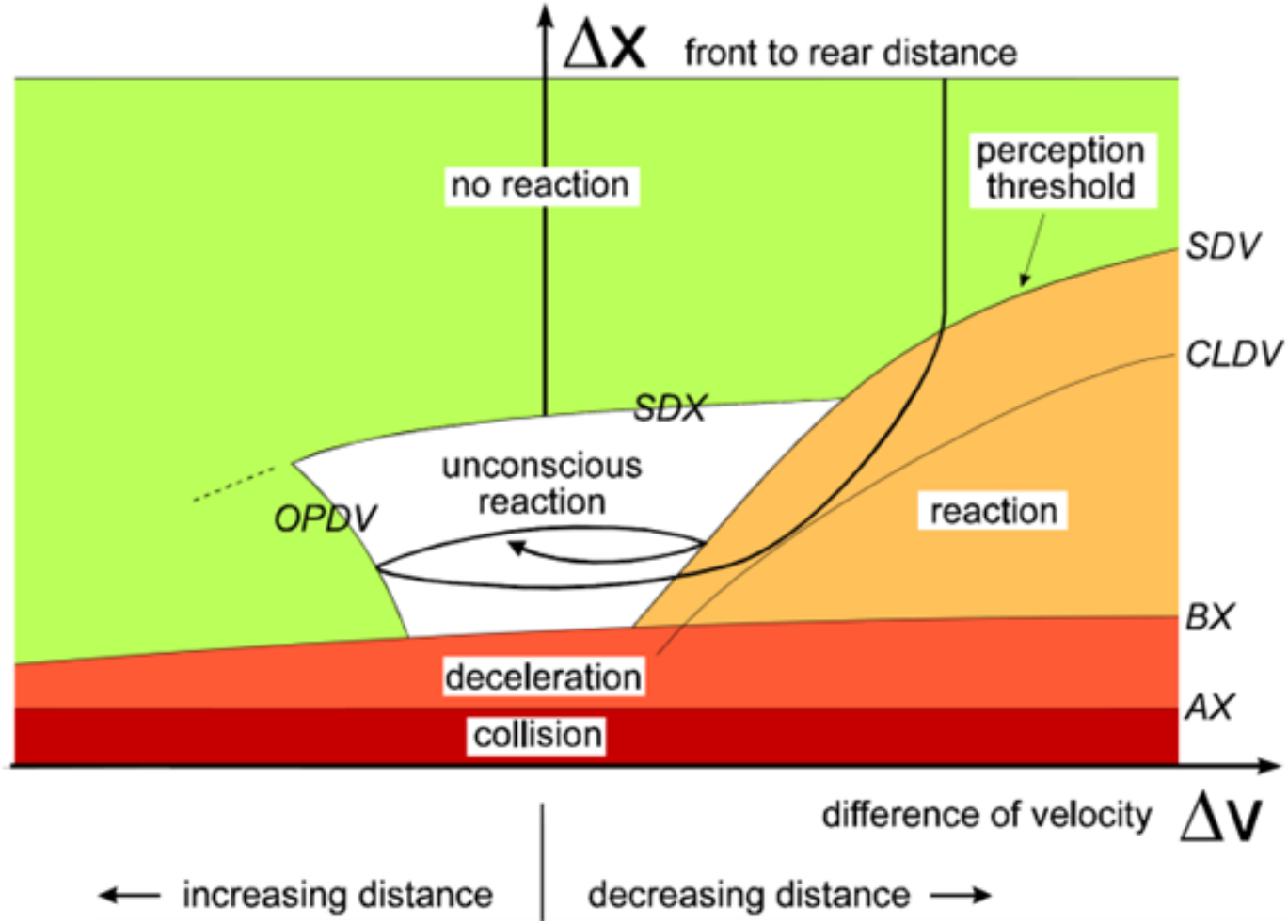
- Identify & review the most prevalently used microsimulation tools
- Process FHWA Living Laboratory Work Zone Driving Data
- Calibrate and validate the work zone driver behavior algorithms
- Using an instrumented vehicle & data from MassDOT, collect work zone driver behavior data in freeway work zones in MA
- Create a Work Zone Software to interface microsimulation tools
- Interface the Work Zone Software with one (1) of the microsimulation tools
- Demonstrate capabilities of the Work Zone Software by interfacing with a microsimulation software tool
- Create a User's Guide
- Conduct R&D in a manner that fosters T2

Project Overview

Timeline for Project:

- ✓ **1. Kick-Off Project:** August 27th & 28th, 2015
- ✓ **2. Review Microsimulation Software Tools:** January 2016
- ✓ **3a. Process TFHRC LL Data:** May 2016
- ❑ **3b. Data Collection in MA Work Zones:** October 2016
- ❑ **4a. Calibrate and Validate Algorithms:** November 2016
- ❑ **4b. Create Work Zone Software:** October 2016
- ❑ **5. Demonstrate the Work Zone Software using VISSIM:** May 2017
- ❑ **6. Create a User's Guide:** October 2017

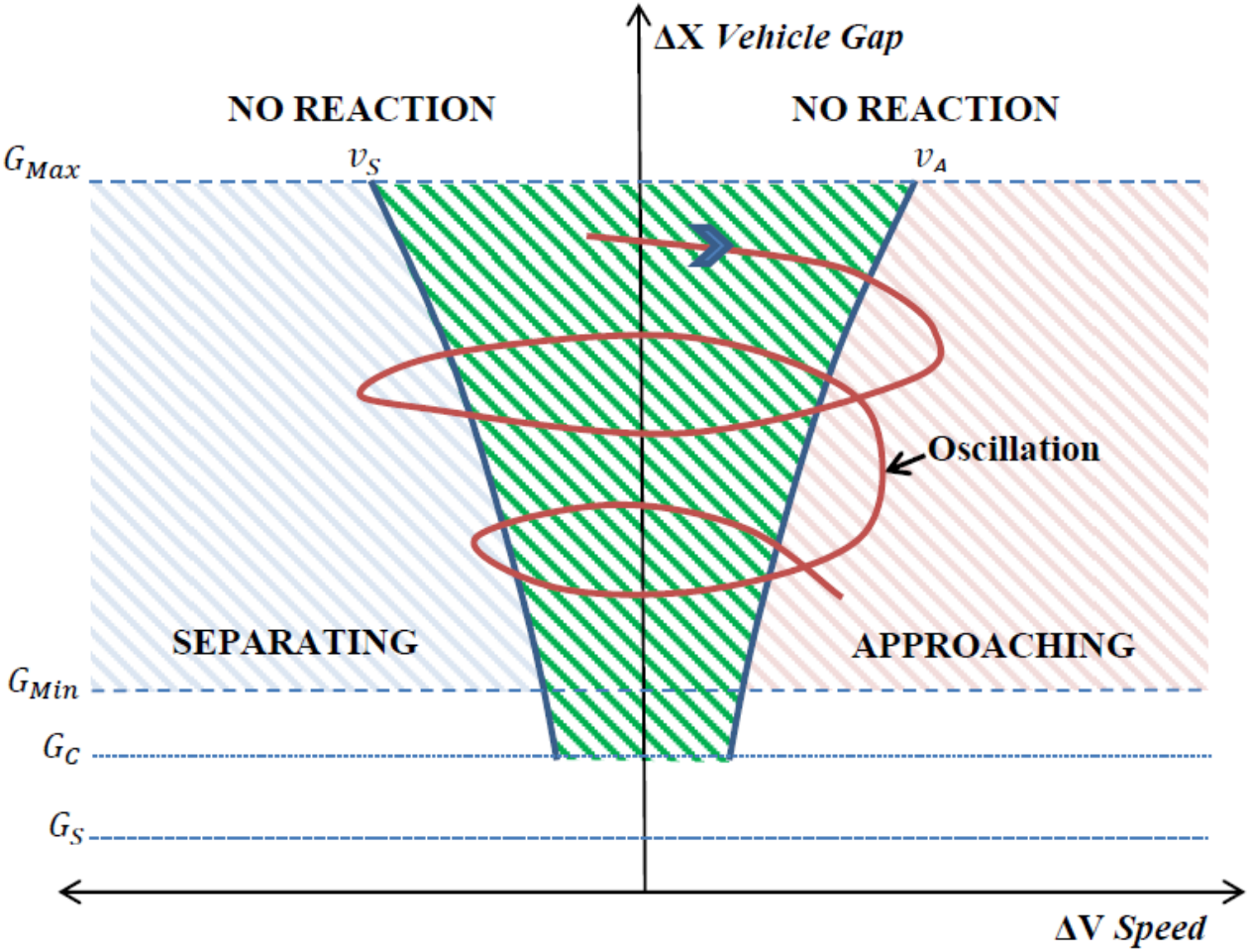
Background: Car-Following



Wiedemann 74 Car-Following Model (used in VISSIM)[1]

[1] PTV-AG, VISSIM 5.10 User Manual. 2008

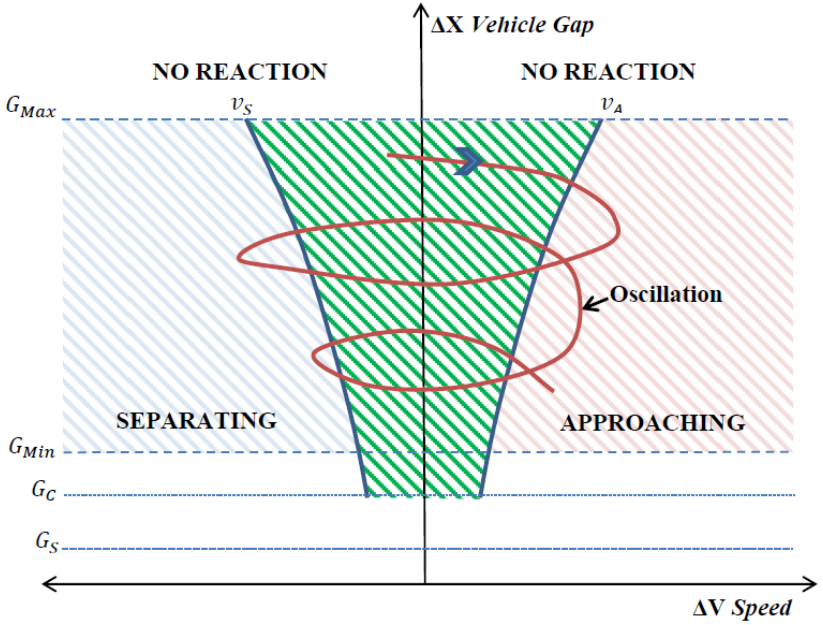
Background: FHWA Work Zone Model



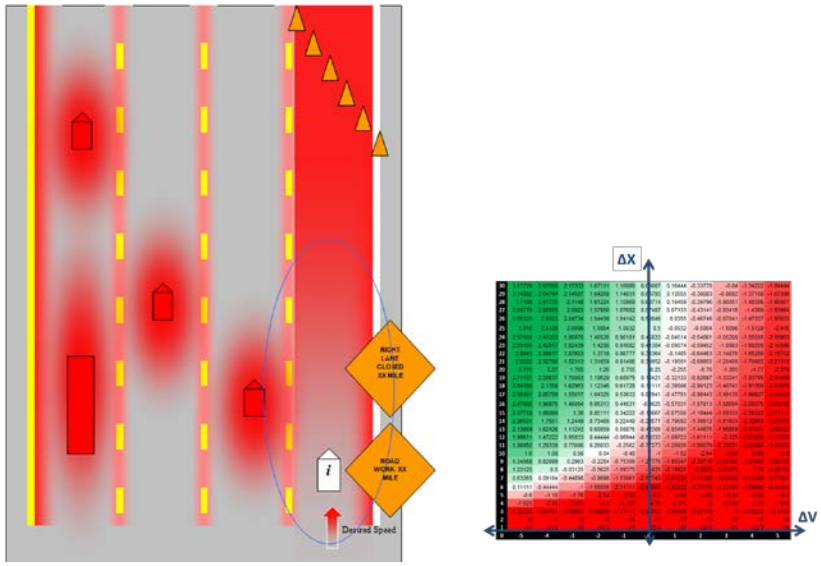
Multidimensional Car-Following Model[1]

[1] Lochrane (2015). "A New Multidimensional Psycho-Physical Framework for Modeling Car-Following in a Freeway Work Zone"

Background: FHWA Work Zone Model



Multidimensional Psycho-Physical Car-Following Framework[1]



Modified Field Theory[2]

[1] Lochrane (2015). "A New Multidimensional Psycho-Physical Framework for Modeling Car-Following in a Freeway Work Zone"

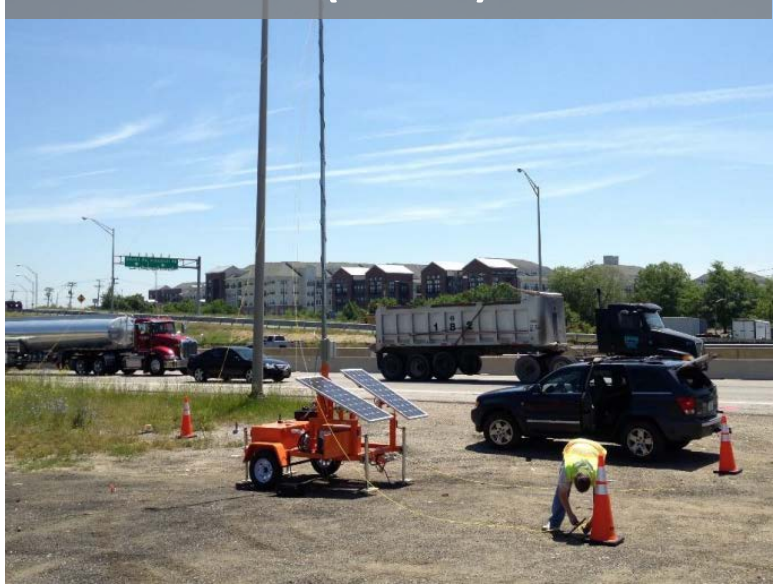
[2] Berthaume (2015). "Microscopic Modeling of Driver Behavior Based on Modifying Field Theory for Work Zone Application"

Background: TFHRC Living Laboratory Work Zone Data

Instrumented Road Vehicle (IRV)

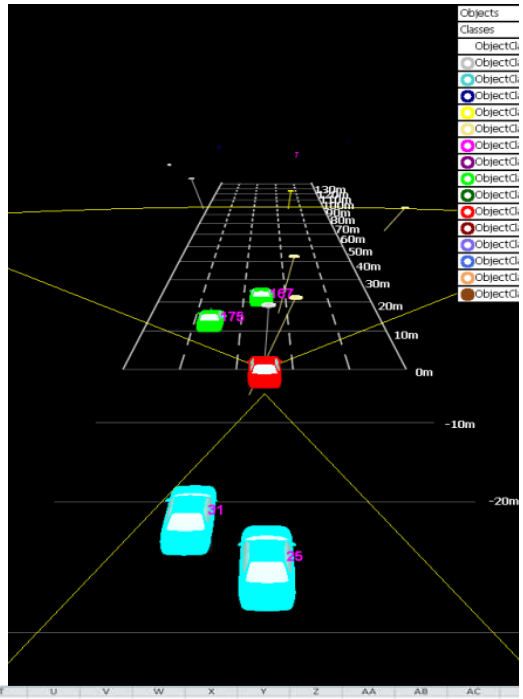
- **Car-following data**, collected at 40Hz for every vehicle & reported at 10 Hz for each run.
- Includes: relative distance, velocity, accel/decel, etc.

Remote Traffic Microwave Sensor (RTMS) Units



- **Macroscopic data**, collected & reported per lane, per 15 minute interval
- Includes: volume, occupancy, 85th percentile speeds, & average gap

3a. Process Work Zone Data



Latitude	Longitude	ID		Time	Work	AvgOfx_P	AvgOfy_P	AvgOfSpe	AvgOfSpe	Object ID	Accelerati	ACC	inver	A2	Part_ID	Vehicle_ID	_2SelectV	Hertz	Speed	Longitudi	Lateral Ac	Follow ID	Time Since	NW2 vs W	Order ID #	Order ID #	Order ID #	Object ID	Speed_X (	Speed_X (	Spa
38.81563	-77.1386	15	07:13:43:1	2	9.088	0.368	-1.1	0	174	-0.17	0.17			15	1.06E+09	10561024	10	2.839709	0	0	15174	64357.8	2	63376	63376	63376	63376	0.085444	1.30011	1.
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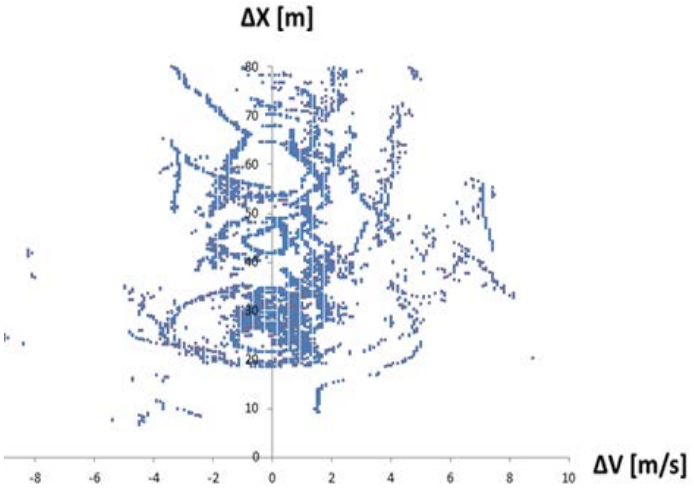
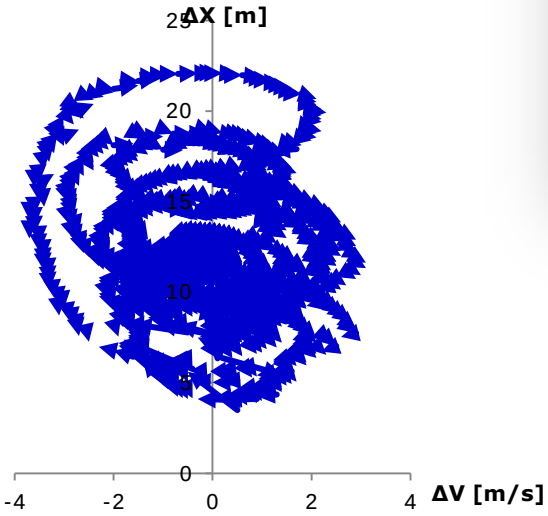
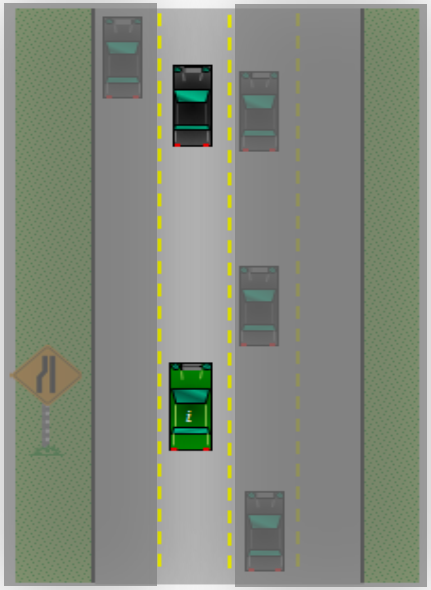
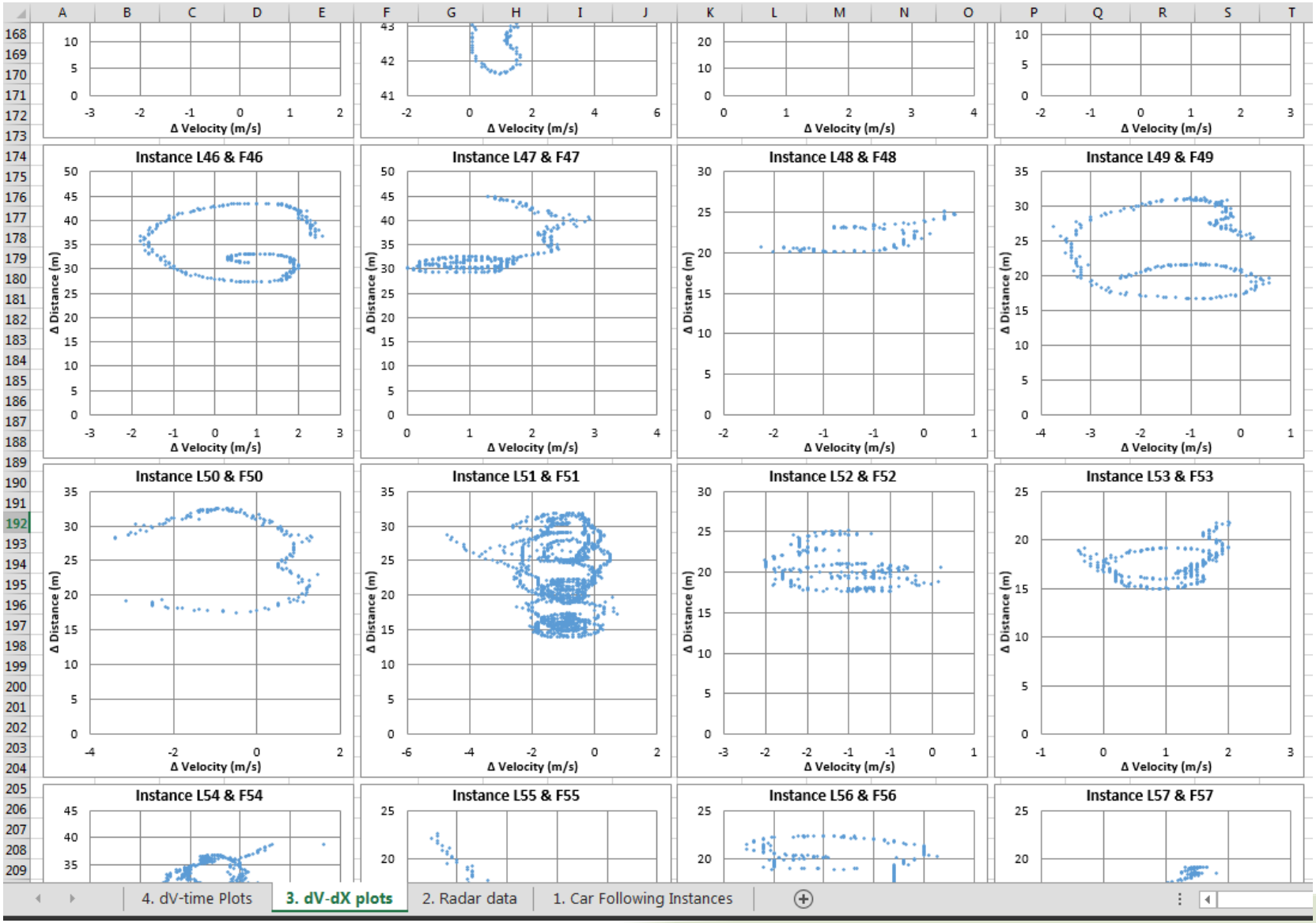
3a. Process Work Zone Data (*cont.*)





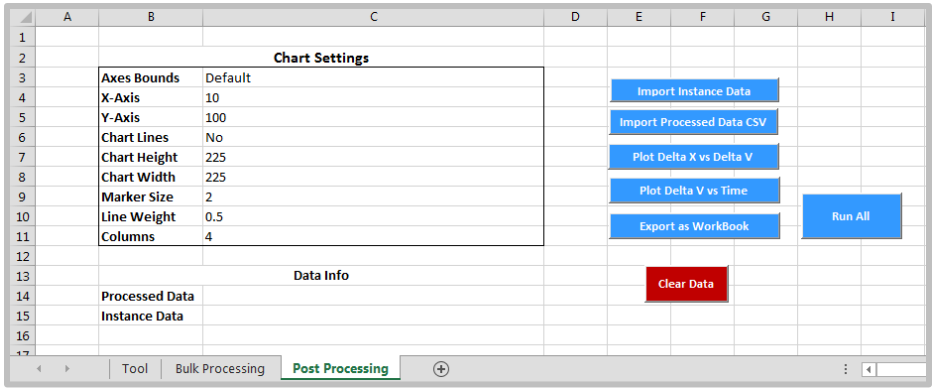


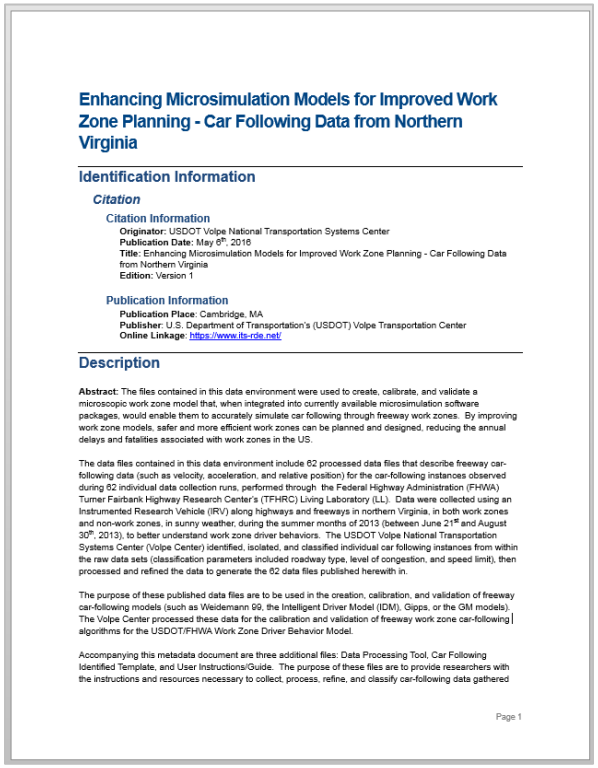
3a. Process Work Zone Data (*cont.*)



3a. Processed Driver Books

62 Processed Driver Books will be published to the **Research Data Exchange (RDE),** along with a **Metadata document**, a version of the **processing tool** we developed, and **a** short **report** describing how we processed the radar data.





Enhancing Microsimulation Models for Improved Work Zone Planning - Car Following Data from Northern Virginia

Identification Information

Citation

Citation Information

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Edition: Version 1

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Online Linkage: https://www.its-rde.net/

Description

Abstract: The files contained in this data environment were used to create, calibrate, and validate a microscopic work zone model that, when integrated into currently available microsimulation software packages, would enable them to accurately simulate car following through freeway work zones. By improving work zone models, safer and more efficient work zones can be planned and designed, reducing the annual delays and fatalities associated with work zones in the US.

The data files contained in this data environment include 62 processed data files that describe freeway car-following data (such as velocity, acceleration, and relative position) for the car-following instances observed during 62 individual data collection runs, performed through the Federal Highway Administration (FHWA) Turner Fairbank Highway Research Center's (TFHRC) Living Laboratory (LL). Data were collected using an Instrumented Research Vehicle (IRV) along highways and freeways in northern Virginia, in both work zones and non-work zones, in sunny weather, during the summer months of 2013 (between June 21st and August 30th, 2013), to better understand work zone driver behaviors. The USDOT Volpe National Transportation Systems Center (Volpe Center) identified, isolated, and classified individual car following instances from within the raw data sets (classification parameters included roadway type, level of congestion, and speed limit), then processed and refined the data to generate the 62 data files published herewith in.

The purpose of these published data files are to be used in the creation, calibration, and validation of freeway car-following models (such as Weidemann 99, the Intelligent Driver Model (IDM), Gipps, or the GM models). The Volpe Center processed these data for the calibration and validation of freeway work zone car-following algorithms for the USDOT/FHWA Work Zone Driver Behavior Model.

Accompanying this metadata document are three additional files: Data Processing Tool, Car Following Identified Template, and User Instructions/Guide. The purpose of these files are to provide researchers with the instructions and resources necessary to collect, process, refine, and classify car-following data gathered

Page 1

Each booklet contains four tabs:

3a. Processed Driver Books *(cont.)*

1. Car Following Instances.
Information about each car-following instance, taken from the Car-Following Identification Template.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Leading Vehicles				Following Vehicles				Time From	Time Until	Roadway Type	Congestion	Speed Limit
2	NewID	Radar	ID #'s	Vehicle Type	NewID	Radar	ID #'s	Vehicle Type					
3	[Assi	[#]	[Object Class	passenger car=PC,heavy vehicle=HV, bus=B, motorcycle=M	[Assi	[#]	[Object Class	passenger car=PC,heavy vehicle=HV, bus=B, motorcycle=M	[h:mm:ss.00]	[h:mm:ss.ss]	{HW, IS, AW, TZ, WZ1, or WZ2}	{C or U}	[mi/hr]
4	L01	0	127	PC	F01	10	Subject	--	0:04:23.10	0:04:47.30	HW	uncong	50
5	L02	10	Subject	--	F02	1	161/163	PC	0:05:48.10	0:06:11.30	HW	uncong	50
6	L03	10	Subject	--	F03	1	161/163	PC	0:06:11.40	0:06:21.20	HW	uncong	50
7	L04	0	138	PC	F04	10	Subject	--	0:06:23.00	0:06:34.10	HW	uncong	50
8	L05	0	141	PC	F05	10	Subject	--	0:06:38.60	0:07:24.40	HW	uncong	50
9	L06	0	145	PC	F06	0	146	M	0:07:13.70	0:07:24.40	HW	uncong	50
10	L07	0	160	PC	F07	10	Subject	--	0:08:00.90	0:08:29.30	HW	uncong	50
11	L08	10	Subject	--	F08	1	200	PC	0:08:51.20	0:09:07.10	HW	uncong	50
12	L09	0	175	PC	F09	10	Subject	--	0:09:44.60	0:10:38.60	HW	uncong	40
13	L10	10	Subject	--	F10	1	220/226/232	PC	0:10:52.70	0:12:04.20	HW	uncong	40
14	L11	0	186/193	PC	F11	10	Subject	--	0:10:57.40	0:11:10.20	HW	uncong	40
15	L12	0	186/193	PC	F12	1	228/231	PC	0:11:14.10	0:11:28.30	HW	uncong	40
16	L13	0	204/205/206/	PC	F13	10	Subject	--	0:12:44.50	0:12:57.50	HW	uncong	45
17	L14	0	204/205/206/	PC	F14	10	Subject	--	0:12:57.60	0:13:25.50	HW	uncong	45
18	L15	0	226/229/232	PC	F15	10	Subject	--	0:15:59.70	0:16:34.10	HW	uncong	45
19	L16	0	226/229/233	PC	F16	10	Subject	--	0:16:43.20	0:17:01.30	HW	uncong	45
20	L17	0	226/229/234	PC	F17	10	Subject	--	0:17:01.40	0:18:00.10	HW	uncong	45
21	L18	0	247/252/253	PC	F18	10	Subject	--	0:18:41.70	0:19:01.40	IS	uncong	55
22	L19	0	12/22/27/30	PC	F19	10	Subject	--	0:20:00.70	0:20:32.50	IS	uncong	55
23	L20	0	12/22/27/30	PC	F20	10	Subject	--	0:20:32.60	0:21:09.10	IS	uncong	55
24	L21	0	37	PC	F21	10	Subject	--	0:21:18.90	0:21:45.90	IS	uncong	55
25	L22	10	Subject	--	F22	1	154	PC	0:22:45.90	0:23:06.90	AW	uncong	55
26	L23	10	Subject	--	F23	1	154	PC	0:23:09.70	0:23:17.60	AW	cong	55
27	L24	0	68/70	PC	F24	10	Subject	--	0:23:21.10	0:23:37.30	AW	uncong	55
28	L25	0	74/78	PC	F25	10	Subject	--	0:23:58.20	0:24:13.10	AW	uncong	55
29	L26	10	Subject	--	F26	1	203/206	PC	0:24:01.10	0:24:24.90	AW	uncong	55
30	L27	0	74/78	PC	F27	10	Subject	--	0:24:13.20	0:24:38.70	WZ2	uncong	55
31	L28	0	90/91	PC	F28	10	Subject	--	0:24:38.80	0:25:09.20	WZ2	uncong	55
32	L29	0	98	PC	F29	10	Subject	--	0:25:11.80	0:25:29.70	WZ2	uncong	55
33	L30	10	Subject	--	F30	1	245/246	PC	0:25:35.30	0:25:45.70	WZ2	uncong	55
34	L31	0	103/118	PC	F31	10	Subject	--	0:25:35.80	0:25:58.10	WZ2	uncong	55
35	L32	10	Subject	--	F32	1	255	PC	0:25:48.10	0:25:58.80	WZ2	uncong	55

4. dV-time Plots | 3. dV-dX plots | 2. Radar data | 1. Car Following Instances

3a. Processed Driver Books *(cont.)*

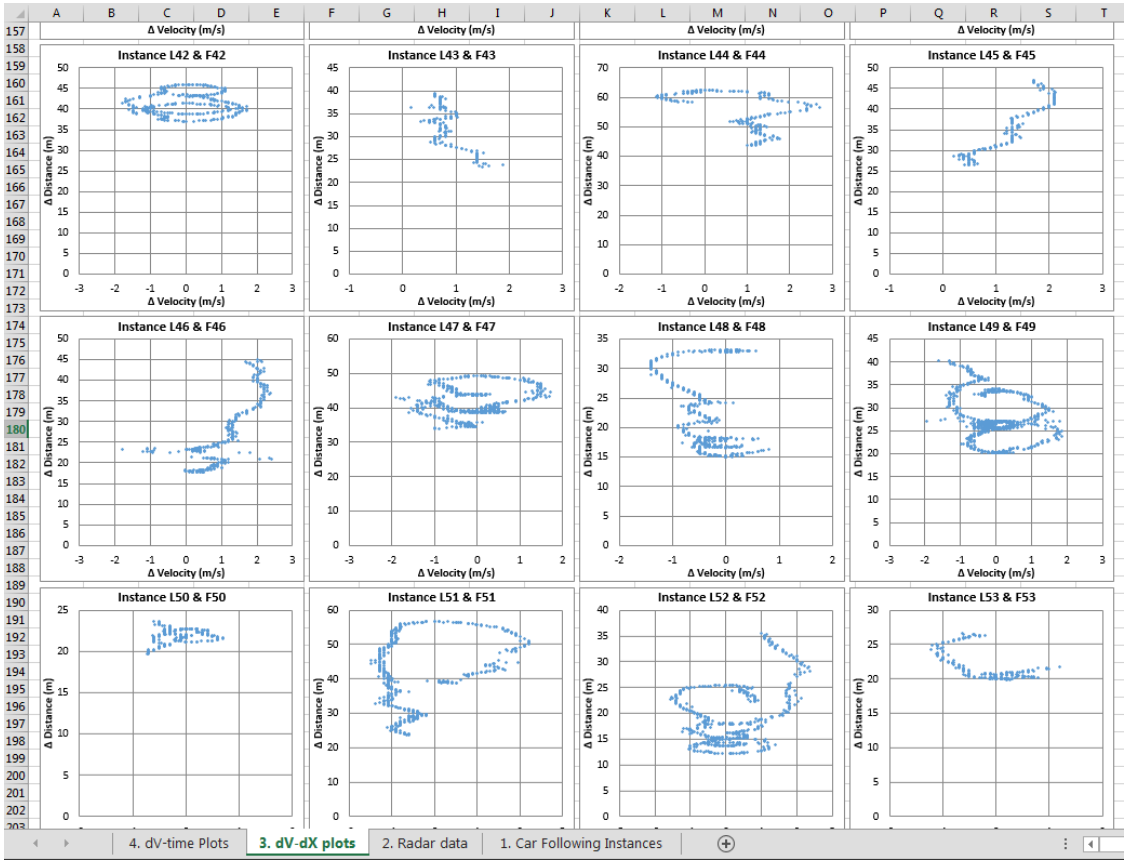
2. Radar Data. Processed 10 Hz car-following data

	A	B	C	D	E	F	G	H	I	J	K
1	Time	Lead Vehicle				Following Vehicle				Δ Distance	Δ Velocity
2		ID	Radar#	Velocity	Accel.	ID	Radar#	Velocity	Accel.		
3	[hh:mm:ss.s	[L#	[0=F, 1=R, 10	[m/s]	[m/s	[F#	[0=F, 1=R, 10	[m/s]	[m/s^2	[m]	[m/s]
4	0:04:23.193	L01	0	23.696	0.578	F01	10	14.870	0.090	17.479	-7.826
5	0:04:23.292	L01	0	23.691	0.548	F01	10	14.891	0.090	18.209	-7.800
6	0:04:23.392	L01	0	23.496	0.505	F01	10	14.696	0.020	18.970	-7.800
7	0:04:23.492	L01	0	23.714	0.330	F01	10	14.814	0.040	19.694	-7.900
8	0:04:23.594	L01	0	24.008	0.022	F01	10	15.308	0.110	20.267	-7.700
9	0:04:23.693	L01	0	23.666	0.453	F01	10	15.138	0.040	21.085	-7.528
10	0:04:23.794	L01	0	24.016	0.594	F01	10	15.416	0.100	21.833	-7.600
11	0:04:23.892	L01	0	24.016	0.305	F01	10	15.416	0.070	22.564	-7.600
12	0:04:23.993	L01	0	23.711	0.270	F01	10	15.411	0.060	23.278	-7.300
13	0:04:24.093	L01	0	23.761	0.134	F01	10	15.467	0.060	24.014	-7.294
14	0:04:24.192	L01	0	23.978	-0.084	F01	10	15.827	0.140	24.741	-7.151
15	0:04:24.292	L01	0	23.804	-0.049	F01	10	15.812	0.100	25.426	-6.992
16	0:04:24.393	L01	0	24.244	0.044	F01	10	16.244	0.160	26.135	-7.000
17	0:04:24.493	L01	0	24.118	0.060	F01	10	16.218	0.110	26.846	-6.900
18	0:04:24.593	L01	0	23.926	0.060	F01	10	16.326	0.110	27.461	-6.600
19	0:04:24.693	L01	0	24.026	0.296	F01	10	16.326	0.120	28.185	-6.700
20	0:04:24.793	L01	0	24.176	0.370	F01	10	16.476	0.210	28.871	-6.700
21	0:04:24.892	L01	0	24.559	0.546	F01	10	16.959	0.210	29.523	-6.600
22	0:04:24.993	L01	0	23.894	1.037	F01	10	16.388	0.010	30.209	-6.506
23	0:04:25.092	L01	0	24.317	0.834	F01	10	16.506	0.040	30.889	-6.811
24	0:04:25.192	L01	0	24.384	0.433	F01	10	16.784	0.080	31.545	-6.600
25	0:04:25.293	L01	0	24.164	0.310	F01	10	16.764	0.050	32.202	-6.400
26	0:04:25.393	L01	0	24.251	0.126	F01	10	16.851	0.060	32.829	-6.400
27	0:04:25.493	L01	0	24.116	-0.139	F01	10	16.851	0.150	33.410	-6.265
28	0:04:25.594	L01	0	24.478	-0.238	F01	10	17.278	0.020	34.082	-6.200
29	0:04:25.693	L01	0	23.933	0.049	F01	10	16.923	0.020	34.685	-6.010
30	0:04:25.793	L01	0	24.319	-0.020	F01	10	17.119	0.060	35.315	-6.200
31	0:04:25.892	L01	0	24.335	-0.116	F01	10	17.335	0.100	35.886	-6.000
32	0:04:25.994	L01	0	24.032	-0.080	F01	10	17.232	0.040	36.488	-5.800
33	0:04:26.095	L01	0	24.636	-0.180	F01	10	17.736	0.160	37.138	-5.900
34	0:04:26.194	L01	0	24.073	-0.231	F01	10	17.273	0.000	37.709	-5.800
35	0:04:26.294	L01	0	23.818	0.063	F01	10	17.273	0.050	38.267	-5.545
36	0:04:26.394	L01	0	24.302	0.073	F01	10	17.484	0.010	38.874	-5.818
37	0:04:26.493	L01	0	23.961	0.006	F01	10	17.371	0.010	39.412	-5.590

4. dV-time Plots | 3. dV-dX plots | **2. Radar data** | 1. Car Following Instances

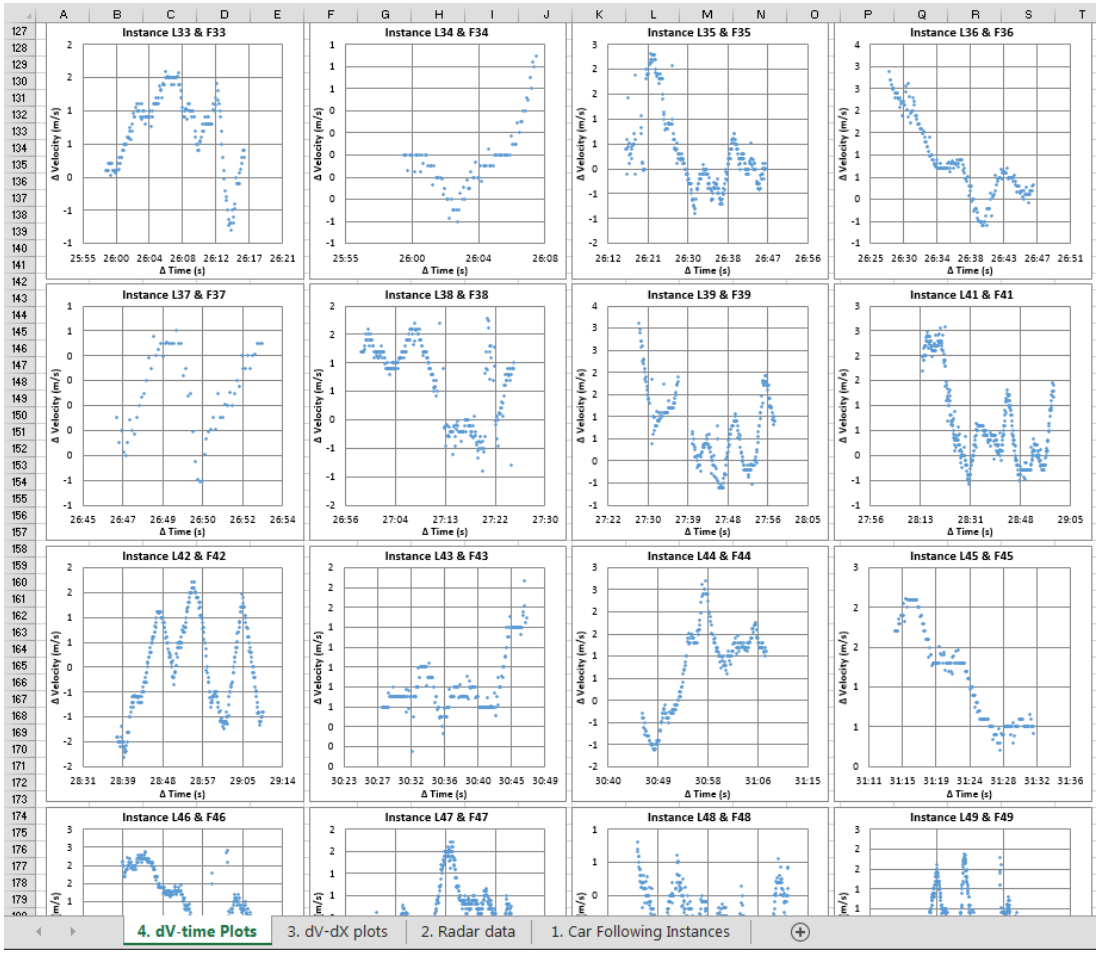
3a. Processed Driver Books *(cont.)*

3. ΔV/ΔX Plots. Relative distance (ΔX) [m] vs. relative velocity (ΔV) [m/s] for each car-following instance.



3a. Processed Driver Books *(cont.)*

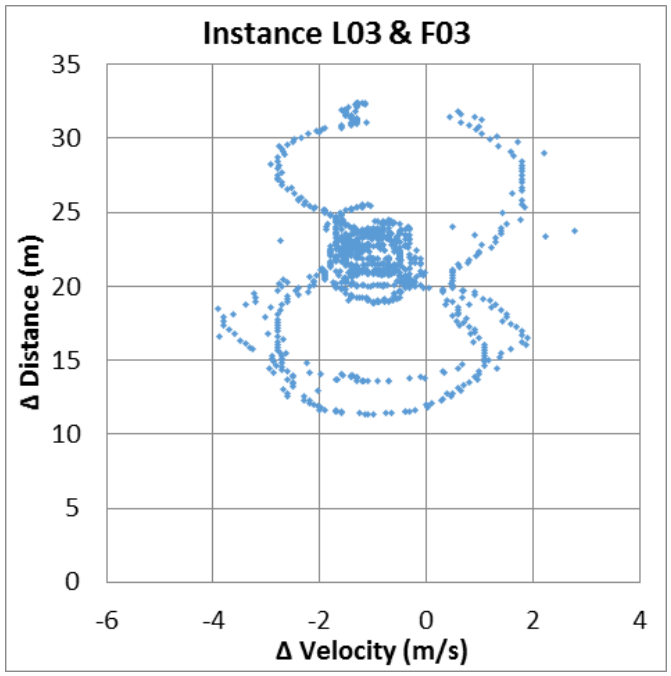
4. ΔV/ΔT Plots. Relative velocity (ΔV) [m/s] over time (ΔT) [hh:mm:ss.s] for each car-following instance.

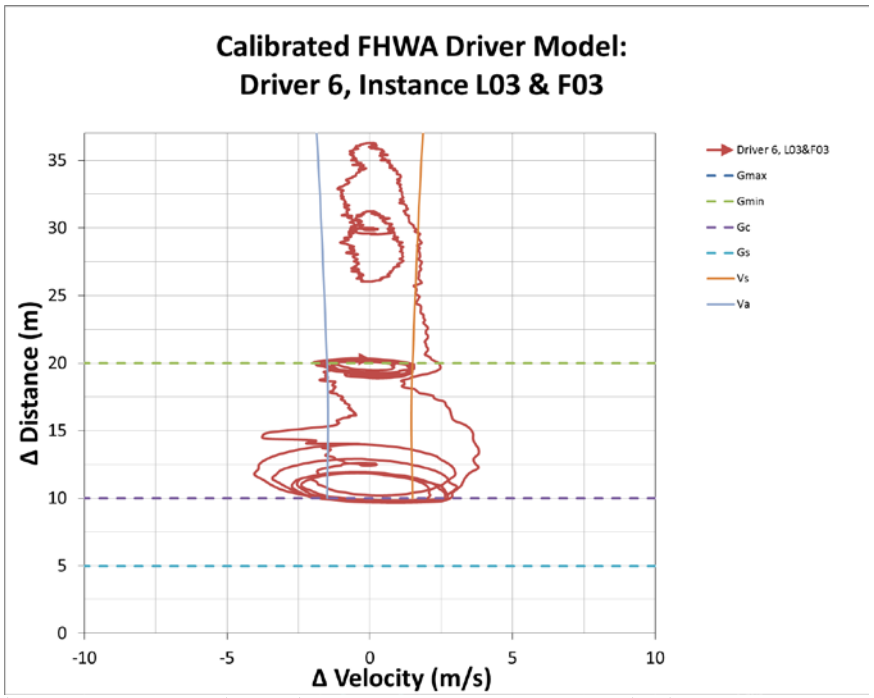


3b. Collect Data in MA

- Will collect car-following data in Massachusetts work zones using the IRV
- Will identify and classify car-following instances.
  - Will use the fields from the VA study + additional fields (such as road weather, peak vs. off-peak, rural vs. urban freeways, etc.)
- Working with MassDOT to supplement data with macroscopic data (such as traffic counts, where available) and geometric data for work zones (where available).

4a. Calibrate Model…





Framework Variables	
Gmax	70
Gmin	20
Gc	10
Gs	5
Vs@gmax	3.5
Vs@gmin	1.5
Va@gmax	-3.5
Va@gmin	-1.5

MFT Variables (accel & decel)			
Fdes	Cdes	2	
	Vdes	25	m/s
Fproximity	Npc	5	
	Cx,pc	10	
Fv,pc	Cv,pc	5	
Perception-Reaction Times	PRT_Δv	1	
	PRT_ΔX	0.5	
	PRT_vi	0.5	
	Threshold	0.5	

Vehicle Attributes			
Max Accel	5	m/s^2	max a
Max Decel	9.8	m/s^2	max d

Model Parameters		
time step (s):	0.1	s
Starting value for Δx =	30	m

4a. …Validate Model

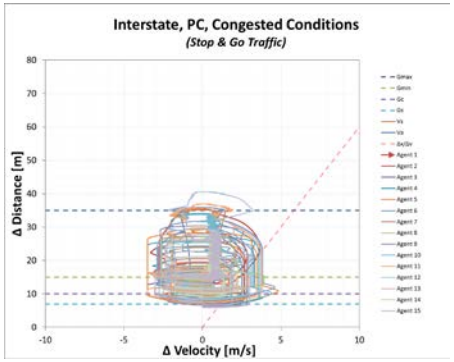
Aggregate field data for each driving condition & compare **calibrated model *(left)*** in Excel to **field data *(right)*.**

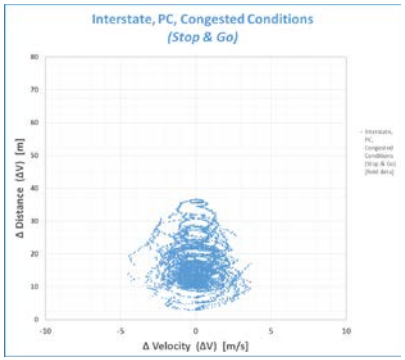
Use Microscopic Performance Measures

Framework Variables			MFT Variables (accel & decel)			
Gmax	35	m	Fdes	Cdes	1	
Gmin	15	m		Vdes	25 (+/- 2)	m/s
Gc	10	m	Fproximity	Npc	5	
Gs	7	m		Cx,pc	17.5	
Vs@gmax	1.5	m/s^2	Fv,pc	Cv,pc	20	
Vs@gmin	0.75	m/s^3	Perception-Reaction Times	PRT_Δv	0.3	
Va@gmax	-1.5	m/s^4		PRT_ΔX	0.2	
Va@gmin	-0.75	m/s^5		PRT_vi	0.2	
Δx/Δv threshold	6	sec to im		Threshold	0	
Δx/Δv decel value	-2	m/s^2	Fgap	Cgap	5	
				Tsafe	0.9	sec
			Fchmbl	Cchmbl	25	
				Cchmbl2	1	

Vehicle Attributes		
Max Accel	2.5	m/s^2
Max Desired Decel	2.5	m/s^2
Emergency Decel	5	m/s^2

Model Parameters		
time step (s):	0.1	s
Starting value for Δx =	30	m

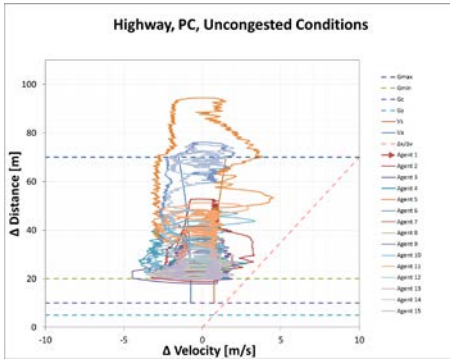


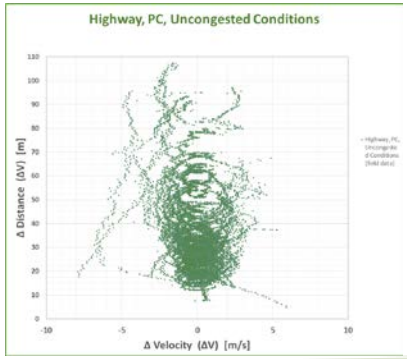


Framework Variables			MFT Variables (accel & decel)			
Gmax	70	m	Fdes	Cdes	0.75	
Gmin	20	m		Vdes	25 (+/- 2)	m/s
Gc	10	m	Fproximity	Npc	5	
Gs	5	m		Cx,pc	15	
Vs@gmax	1.5	m/s^2	Fv,pc	Cv,pc	10	
Vs@gmin	0.75	m/s^3	Perception-Reaction Times	PRT_Δv	0.5	
Va@gmax	-1.5	m/s^4		PRT_ΔX	0.25	
Va@gmin	-0.75	m/s^5		PRT_vi	0.35	
Δx/Δv threshold	7	sec to im		Threshold	0	
Δx/Δv decel value	-2	m/s^2	Fgap	Cgap	5	
				Tsafe	0.9	sec
			Fchmbl	Cchmbl	15	
				Cchmbl2	10	

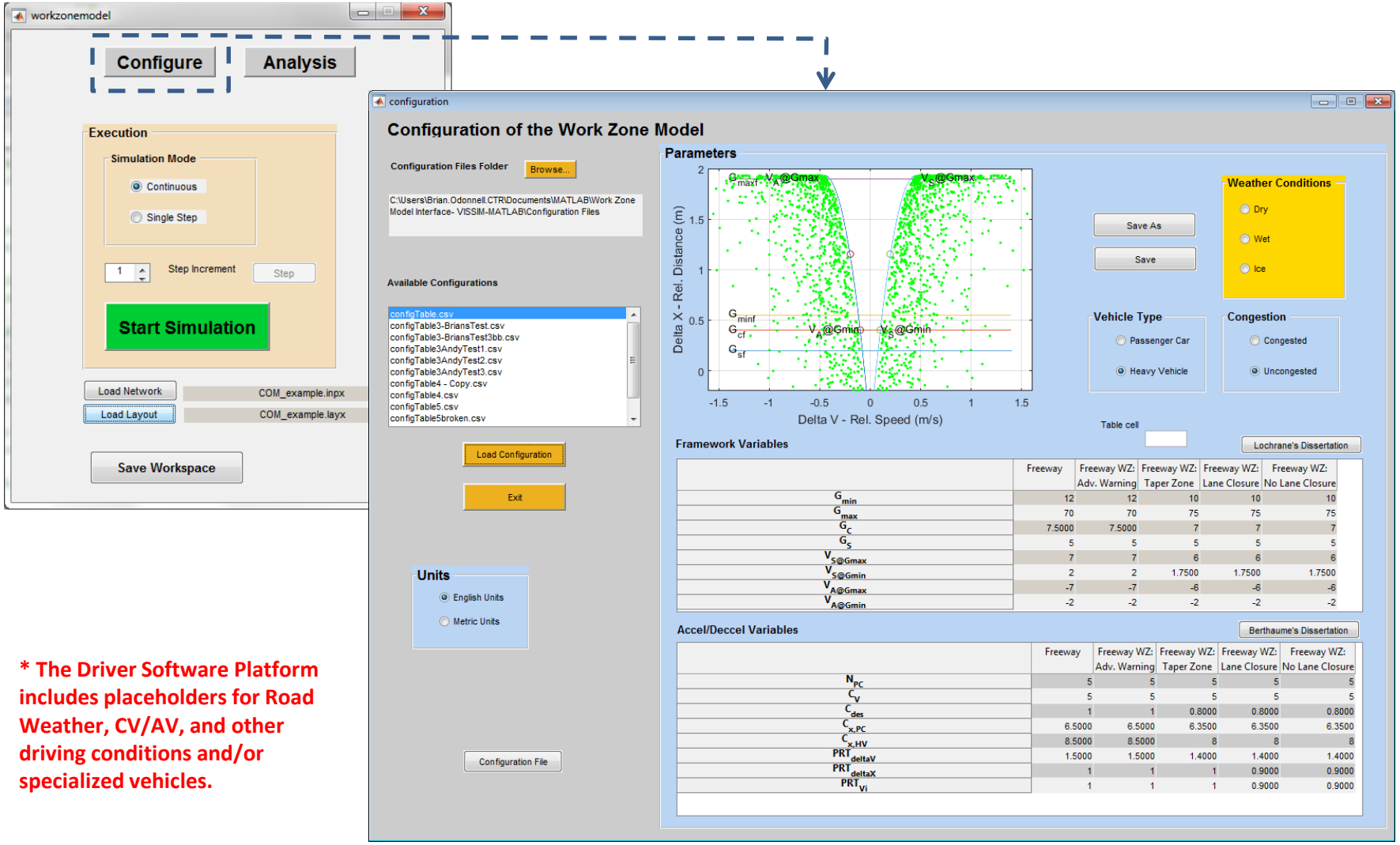
Vehicle Attributes		
Max Accel	2.5	m/s^2
Max Desired Decel	2.5	m/s^2
Emergency Decel	5	m/s^2

Model Parameters		
time step (s):	0.1	s
Starting value for Δx =	30	m





4b. Create Work Zone Software

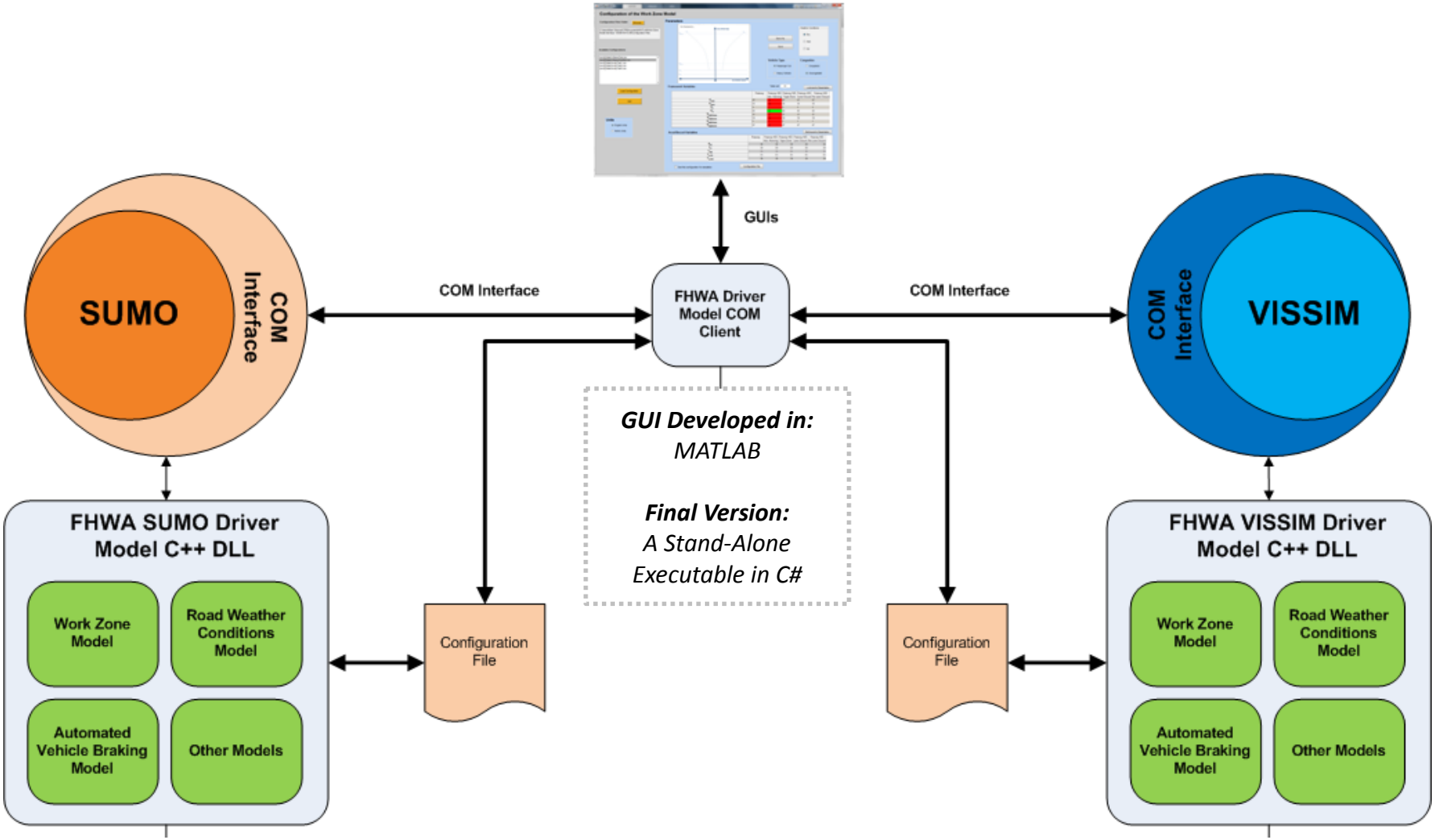


	Freeway	Freeway WZ: Adv. Warning	Freeway WZ: Taper Zone	Freeway WZ: Lane Closure	Freeway WZ: No Lane Closure
G_{min}	12	12	10	10	10
G_{max}	70	70	75	75	75
G_C	7.5000	7.5000	7	7	7
G_S	5	5	5	5	5
$V_{S@Gmax}$	7	7	6	6	6
$V_{S@Gmin}$	2	2	1.7500	1.7500	1.7500
$V_{A@Gmax}$	-7	-7	-6	-6	-6
$V_{A@Gmin}$	-2	-2	-2	-2	-2

	Freeway	Freeway WZ: Adv. Warning	Freeway WZ: Taper Zone	Freeway WZ: Lane Closure	Freeway WZ: No Lane Closure
N_{PC}	5	5	5	5	5
C_V	5	5	5	5	5
C_{des}	1	1	0.8000	0.8000	0.8000
$C_{x,PC}$	6.5000	6.5000	6.3500	6.3500	6.3500
$C_{x,HV}$	8.5000	8.5000	8	8	8
PRT_{deltaV}	1.5000	1.5000	1.4000	1.4000	1.4000
PRT_{deltaX}	1	1	1	0.9000	0.9000
PRT_{Vi}	1	1	1	0.9000	0.9000

*** The Driver Software Platform includes placeholders for Road Weather, CV/AV, and other driving conditions and/or specialized vehicles.**

4b. Create WZ Software (*cont.*)



* SUMO and VISSIM are used as examples.
* Alternative interfaces can be designed for each software, and/or the FHWA Driver Model Software could be directly incorporated

5. Demonstrate WZ Software in a Microsimulation Package

- Interface Work Zone Software with a microsimulation software package using a DLL interface
- Construct three networks using the software package:
  1. A straight work zone segment
  2. I-395 in VA (work zones from 2013)
  3. I-91 in Springfield, MA (work zones from 2016)
- For each network, compare:

Field vs. *Microsim Software* vs. *Microsim Software w/ WZ Add-On*

Use Macroscopic Performance Measures (such as capacity, queue length, total delay, and average travel speed)

6. Create a User's Guide

- Define the type of data you'll need to calibrate your models
- Explain how to process this data
  - How to use data processing tools
- Explain how to calibrate the Work Zone model
- Explain how to use Work Zone Software
  - How to install the software
  - How to use the GUI
  - Documents describing software architecture (for those who wish to modify it)
- Explain how to use Work Zone Software w/ VISSIM

Expert Panel

Volunteer Expert Panelists **provide feedback** on research approach and products.

Panelists include representation from **three groups**:

- **End Users** [engineers and planners at State/Local DOTs, MPOs, and private engineering consultancies]
- **Technical Experts** in Microscopic Modeling [professors, researchers, and FHWA staff]
- **Microsimulation Software Companies** [software engineers and market analysts]

Thank you

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