CUTR
CENTER for URBAN TRANSPORTATION RESEARCH

Understanding Interactions between Drivers and Pedestrian Features at Signalized Intersections

October 2015

PROJECT NO.
BDV25 TWO 977-16

PREPARED FOR
Florida Department of Transportation

Understanding Interactions between Drivers and Pedestrian Features at Signalized Intersections

BDV25 TWO 977-16

Final Report

Prepared for:

Prepared by:

USF Center for Urban Transportation Research
Pei-Sung Lin, Ph.D., P.E., PTOE, Program Director
Achilleas Kourtellis, Ph.D., Research Associate
Zhenyu Wang, Ph.D., Research Associate
Rui Guo, Ph.D., Postdoctoral Scholar

October 2015

Disclaimer

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the Department of Transportation University Transportation Centers Program and the Florida Department of Transportation, in the interest of information exchange. The U.S. Government and the Florida Department of Transportation assume no liability for the contents or use thereof.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

Technical Report Documentation

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle *Understanding Interactions between Drivers and Pedestrian Features at Signalized Intersections*	**5. Report Date** *October 2015*	
	6. Performing Organization Code	
7. Author(s) *Pei-Sung Lin, Achilleas Kourtellis, Zhenyu Wang, Rui Guo*	**8. Performing Organization Report No.**	
9. Performing Organization Name and Address *Center for Urban Transportation Research* *University of South Florida* *4202 East Fowler Avenue, CUT100* *Tampa, FL 33620-5375*	**10. Work Unit No. (TRAIS)**	
	11. Contract or Grant No. *BDV25 TWO 977-16*	
12. Sponsoring Agency Name and Address *Florida Department of Transportation* *605 Suwannee Street, MS 30* *Tallahassee, FL 32399-0450*	**13. Type of Report and Period Covered** *Final Report* *January 2015–October 2015*	
	14. Sponsoring Agency Code	

15. Supplementary Notes

16. Abstract

Florida experienced serious pedestrian safety problems and had the highest pedestrian fatality rate in the U.S. from 2008–2011. Pedestrian safety at signalized intersections is the most serious concern due to frequent and severe conflicts between vehicles and pedestrians. Pedestrian features directly related to pedestrian safety are used to increase driver compliance behaviors and reduce vehicle-pedestrian conflicts. This project aimed to explore driver behaviors at signalized intersections with four identified pedestrian features—"STOP HERE ON RED," "NO TURN ON RED," "TURNING VEHICLES YIELD TO PEDESTRIANS," and "RIGHT ON RED ARROW AFTER STOP" signs—by using an innovative safety data source, the Strategic Highway Research Program 2 (SHRP 2) Naturalistic Driving Study (NDS) data. To improve data processing efficiency, two software tools were developed to assist researchers in data reduction in an automatic and/or semi-automatic manner: (1) the NDS Automatic Video Processing Tool, which automatically detects and tracks pedestrians and traffic signal indications in NDS videos, and (2) the NDS Data Reduction and Analysis Tool, which assists researchers in reviewing and analyzing NDS videos and sensor data. A cross-sectional analysis was used to assess the safety effectiveness of the selected pedestrian features by comparing the observed compliant driver behaviors between two groups: a feature group (with the pedestrian feature) and a control group (without the pedestrian feature). Chi-square tests were used to determine whether the proportional difference of compliant driver behaviors between the two groups was significant.

The major findings were the following: (1) The "NO TURN ON RED" sign had the highest rate of compliance (70%), followed by "RIGHT ON RED ARROW AFTER STOP" (67%), "TURNING VEHICLES YIELD TO PEDESTRIANS" (67%), and "STOP HERE ON RED" (55%). (2) Three features—"STOP HERE ON RED," "NO TURN ON RED," and "RIGHT ON RED ARROW AFTER STOP" signs—increased the likelihood of compliant behaviors compared to control groups. (3) Drivers had a much higher compliance percentage at the feature sites than at the control sites (67% vs. 29%) when pedestrians were not present at intersections; the difference was statistically significant. (4) Drivers generally were sensitive to pedestrian presence at both the feature sites and the control sites; the compliance percentages for both groups were higher when pedestrians were present than those when pedestrians were absent. (5) Drivers were more likely to comply with the feature at feature sites when pedestrians were present than at control sites (77% vs. 50%); however, there was no evidence to show the difference was statistically significant due to a small sample size. (6) Based on self-evaluation, female drivers were significantly more likely to believe they are easily distracted when driving compared to male drivers; older drivers (age 60+) believe they take significantly fewer risks and are less distracted than other drivers. (7) Female drivers tended to comply more consistently with the feature than male drivers. (8) Mid-age drivers tended to comply more consistently with the feature than others.

17. Key Words *Pedestrian Safety, Pedestrian Feature, Naturalistic Driving Study*		**18. Distribution Statement**	
19. Security Classification (of this report) *Unclassified*	**20. Security Classification (of this page)** *Unclassified*	**21. No. of Pages** *76*	**22. Price**

Metric Conversion

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft³	cubic feet	0.028	cubic meters	m³
yd³	cubic yards	0.765	cubic meters	m³
NOTE: volumes greater than 1000 L shall be shown in m³				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
ºF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	ºC

Acknowledgments

Executive Summary

INTRODUCTION

Florida experienced serious pedestrian safety problems and had the highest pedestrian fatality rate in the U.S. from 2008–2011 based on National Highway Traffic Safety Administration (NHTSA) Traffic Safety Facts annual reports. Florida continues to be in the top five states with the highest pedestrian fatality rates. The 2014 edition of *Dangerous by Design* ranked four metropolitan areas in Florida as the top four most dangerous areas to walk in the U.S.—Metro Orlando, Tampa-St. Petersburg, Jacksonville, and Miami. This is due primarily to the rapid spread of low-density neighborhoods that rely on wider streets with higher speeds to connect homes, offices, shops, and schools—roads that tend to be more dangerous for people walking.

One of Florida's highest priorities is investigating major contributing causes for pedestrian fatalities and developing effective countermeasures to significantly improve pedestrian safety. The intention of this project was to research and understand the interactions between drivers and pedestrian features (e.g., pedestrian signs, pedestrian signals, traffic signals, crosswalks, and pavement markings) at signalized intersections. Understanding these interactions can help the Florida Department of Transportation (FDOT) develop effective countermeasures to improve pedestrian safety.

The Strategic Highway Research Program 2 (SHRP2) Naturalistic Driving Study (NDS) recorded the driving behavior of a large sample of drivers in their personal vehicles, offering project researchers comprehensive naturalistic driving behavioral data for researching the interactions between drivers and various pedestrian features at selected signalized intersections through which they drove. This provides a unique opportunity to research the proposed research question in this project, "Based on information from the SHRP2 NDS and Road Information Database (RID) datasets, how do drivers interact with pedestrian features at signalized intersections?"

The research project intended to investigate the effectiveness of four pedestrian features ("Stop Here on Red," "No Turn on Red," "Turning Vehicles Yield to Pedestrians," and "Right on Red Arrow after Stop") used at signalized intersections that are directly related to pedestrian safety. With high compliance with these pedestrian features, pedestrian safety can be increased at intersections by reducing conflicts between vehicles and crossing pedestrians. Based on an understanding of interactions between drivers and pedestrian features at signalized intersections, effective countermeasures can be developed to increase driver compliance with pedestrian features to improve pedestrian safety.

GOALS

The first major goal of this project was to understand the interactions between drivers and pedestrian features at signalized intersections using the SHRP2 NDS datasets and to obtain initial results and findings. The second major goal was to demonstrate that the research team effectively used the NDS and RID databases to conduct research and analysis, leading

to development of effective countermeasures in future studies to improve pedestrian safety at signalized intersections.

OBJECTIVES

The specific objectives of this project were to:

1. Acquire knowledge and request data from the SHRP2 NDS and RID datasets to conduct initial analysis of driver interactions with pedestrian features at signalized intersections.
2. Develop effective data extraction and analysis tools and identify specific parameters and factors that will aid researchers pertaining to the research question, "Based on information from the SHRP2 NDS and RID datasets, how do drivers interact with pedestrian features at signalized intersections?"
3. Conduct initial analysis using a more manageable dataset of acquired NDS data, provide initial findings on the research question, and offer recommendations on future studies that can be implemented by FDOT.
4. Demonstrate the effective and successful use of the SHRP2 NDS datasets via this project to provide recommendations and guidance for future studies.

DATA USED

SHRP2-RID Dataset

The RID dataset includes the road characteristics and environment used by participants in the SHRP2 NDS study. The following characteristics were used for this project:

- Lanes – number, width, and type (thru, turn, passing, acceleration, car pool, etc.)
- Traffic signs - all traffic signs defined by the *Manual on Uniform Traffic Control Devices* (*MUTCD*)
- Intersections – location, number of approaches, control (signalized only)
- Median presence – type (depressed, raised, flush, barrier)
- AADT (Annual Average Daily Traffic)

The CUTR team obtained the RID dataset and used it to identify the locations and types of pedestrian features for analysis. Based on the location of the features (signs, markings), AADT, and lane configuration, 15 intersections were selected for filtering from the SHRP2 NDS trip data acquired from the Virginia Tech Transportation Institute (VTTI).

SHRP2-NDS Dataset

The SHRP2-NDS dataset includes data from participants, vehicles, and trips. The CUTR team specified the number of trips and participant data per intersection to be obtained. In total, 2,700 trip segments were obtained from the NDS dataset, which were divided into short segments passing through the intersections and longer (full) trips that were identified as passing through the predefined intersections.

The short trips (n=2,430) were stratified into required movements based on intersection geometry and lanes for each feature to maximize the number of useful trips. The number of

trips/participants for each featrue was required at three intersections: two intersections with similar characteristics (AADT, lanes, and speed limit) and the feature sign and one with similar characteristics without the feature sign to serve as the control intersection for comparison.

Using the trips/participants selected from the previous session, full trips were provided for 54 participants for a total of 270 trips using the following criteria: trip type, trip duration, minimum requirement for trip, and preferred trips.

Different age groups and genders of participants were requested to get a full representation of demographics. An equal breakdown between age groups and gender was requested for 54 drivers. In addition to the forward videos, time series data including acceleration, speed, braking, gas pedal position, steering, and GPS coordinates were requested. Also, information on age, gender, driving behavior, risk perception and risk taking, and medical condition and medications of each individual participant was obtained.

TOOL DEVELOPMENT

NDS data comprise a large-scale dataset containing video data and sensor data, so processing can be time-consuming. To improve the data processing efficiency, two software tools were developed to assist researchers in data reduction in an automatic and/or semi-automatic manner.

NDS Automatic Video Processing Tool

The NDS Automatic Video Processing Tool (AVPT) was designed primarily to (1) automatically detect and track pedestrians and (2) automatically detect traffic signal indications in NDS videos. Pedestrian detection was based on the Neural Network classifier. A sliding window-based algorithm was used to resolve the major challenge in the NDS video processing—movement of both the camera and pedestrians.

Traffic signal detection was achieved by recognizing any circle-shaped co-linear objects in red or green (based on color intensities) at a certain height in the video frame. This function can be used to collect the status of traffic signal indications (red, yellow, green) for a given movement (left turn, thru, or right turn) at an intersection. The AVPT can help researchers to:

- Detect pedestrian presence, pedestrian counts, and pedestrian location relative to drivers
- Identify screen time from video (for linking to other events)
- Automatically filter videos with pedestrian presence
- Automatically classify videos with different traffic signal indications

NDS Data Reduction and Analysis Tool

The NDS Data Reduction and Analysis Tool (DRAT) was developed to assist researchers in reviewing and analyzing NDS videos and sensor data. The major functions of the tool are to:

- Identify pre-defined events when researchers review NDS videos

- Detect driver behaviors (stopping, sudden braking, etc.) by scanning NDS sensor data
- Link collected data from different sources (videos, sensors, questionnaires, RID)
- Convert raw data to final data format for analysis

This tool was used to provide samples of pedestrian and signal scenarios for training and testing the NDS AVPT and to collect information on other than pedestrian and traffic signals, such as driver behaviors, roadway/weather conditions, and travel lanes.

DATA REDUCTION AND ANALYSIS

Researchers used the two tools to collect useful information from the original NDS videos, sensor data, and supplemental data. The collected data (events) included intersection features, driver behaviors and causes, status of traffic signal indications, and pedestrian and driver characteristics. The collected data were imported into a project database and converted to the final format based on analysis requirements.

The cross-sectional analysis was used in this study to assess the safety effectiveness of the selected pedestrian feature. In this analysis, the observed compliant driver behaviors were categorized into two groups: a feature group (with the pedestrian feature) and a control group (without the pedestrian feature). A series of comparisons of the compliant behaviors was conducted between each feature group and its control group. The higher the proportion of compliant behaviors observed, the better the safety performance is. Chi-square tests were used to determine whether the proportion of compliant driver behaviors at feature sites (P_{FE}) was significantly different from that at control sites (P_{CE}).

$$H0: P_{FE} = P_{CE}$$
(proportion of compliant driver behaviors at feature sites is same
as that at control sites)

$$Ha: P_{FE} \neq P_{CE}$$
(proportion of compliant driver behaviors at feature sites is different
from that at control sites)

The proportion comparisons also were conducted between different driver characteristics (gender, age, and risk groups) for each pedestrian feature. In addition, the difference in compliant behaviors by different driver characteristics and pedestrian presence were compared based on the overall data. All hypothesis tests were conducted at a minimum confidence level of 90%.

RESEARCH RESULTS

The data analysis helped to answer the major research question, "Based on information from the SHRP2 NDS and RID datasets, how do drivers interact with pedestrian features at signalized intersections?"

The major findings include the following:

- The proportion of compliant driver behaviors, defined based on a specific feature intention, is an effective measure of the interactions between drivers and pedestrian features. The "No Turn on Red" sign had the highest rate of compliance (70%), followed by "Right on Red Arrow after Stop" (67%), "Turning Vehicles Yield to Pedestrians" (67%), and "Stop Here on Red" (55%).
- Three features—"Stop Here on Red," "No Turn on Red," and "Right on Red Arrow after Stop"—increased the likelihood of compliant behaviors compared to control groups.
- Drivers had a much higher compliance percentage at the feature sites than at the control sites (67% vs. 29%) when pedestrians were not present at intersections. The difference was statistically significant.
- Drivers were generally sensitive to pedestrian presence at both the feature sites and the control sites. The compliance percentages for both groups were higher when pedestrians were present than when pedestrians were absent.
- Drivers were more likely to comply with the feature at feature sites when pedestrians were present than at control sites (77% vs. 50%). However, there was no evidence to show the difference was statistically significant due to a small sample size.
- Based on self-evaluation, female drivers were significantly more likely to believe they are easily distracted when driving compared to male drivers. Older drivers (age 60+) believe they take significantly fewer risks and are less distracted than other drivers.
- Female drivers tended to comply more consistently with the feature than male drivers.
- Mid-age drivers tended to comply more consistently with the feature than others.

RECOMMENDATIONS

The initial research results and preliminary findings in this project offer valuable insight into the effectiveness of specific pedestrian features and the effect of driver characteristics on their compliance with individual pedestrian features. A small sample size was used in this project to examine selected pedestrian features at signalized intersections, calibrate proposed methodologies for data analyses, and test the Automatic Video Processing Tool and the Data Reduction and Analysis Tool. A larger sample size is expected in feature studies for researchers to conduct detailed qualitative and quantitative analyses to obtain a full understanding of the effectiveness of selected pedestrian features at signalized intersections and the effect of driver characteristics on their compliance with individual pedestrian features.

A future study will build on the foundation of this project to produce tangible outcomes and detailed findings, which will lead to the development of implementable countermeasures. The future study will continue to align with the focus areas of (1) driver speed, (2) roadway features and driver performance, (3) preceding contributory events, (4) vulnerable road users, and (5) intersections.

Table of Contents

List of Figures

List of Tables

Chapter 1 – Introduction

1.1 Background

Florida experienced serious pedestrian safety problems and had the highest pedestrian fatality rate in the U.S. from 2008–2011 based on National Highway Traffic Safety Administration (NHTSA) Traffic Safety Facts annual reports. The 2014 edition of *Dangerous by Design* ranked four metropolitan areas in Florida as the top four most dangerous areas to walk in the U.S.—Metro Orlando, Tampa–St. Petersburg, Jacksonville, and Miami. The potential reason was primarily the rapid spread of low-density neighborhoods that rely on wider streets with higher speeds to connect homes, shops, and schools—roads that tend to be more dangerous for people walking. One of Florida's highest priorities is investigating major contributing causes for pedestrian fatalities and developing effective countermeasures to significantly improve pedestrian safety in the state. This project intended to research and understand the interactions between drivers and pedestrian features (e.g., pedestrian signs, pedestrian signals, traffic signals, crosswalks, and pavement markings) at signalized intersections. Understanding these interactions can help the Florida Department of Transportation (FDOT) develop effective countermeasures to improve pedestrian safety. The Strategic Highway Research Program 2 (SHRP2) Naturalistic Driving Study (NDS) recorded the driving behavior of a large sample of drivers in their personal vehicles, offering project researchers comprehensive naturalistic driving behavioral data for researching the interactions between drivers and various pedestrian features at selected signalized intersections through which they drove. This database provides great and unique opportunities to research the proposed research question in this project.

1.2 Research Questions and Supporting Information

The major proposed research question for this study was, "Based on information from the SHRP2 NDS and Roadway Information Database (RID) datasets, how do drivers interact with pedestrian features at signalized intersections?" These pedestrian features include pedestrian signs, pedestrian signals, traffic signals, crosswalks, and pavement markings. Driver interactions with pedestrian features may be observed from driver responses to different pedestrian features, yielding behaviors to pedestrians, driver speeds, braking patterns, and attention and/or distraction. The proposed research question covered four broad areas: Vulnerable Road Users, Roadway Features and Driver Performance, Intersections, and Driver Speed. Gender and age group were included in the research.

The findings of the research can help FDOT to better understand (1) driver interactions with various pedestrian features at signalized intersections, (2) the effectiveness of pedestrian features, (3) the impact of gender and age group on driver interactions, (4) specific interactions between drivers and pedestrians, and (5) the impact of driver attention and/or distraction on driver interactions. These understandings can assist FDOT in developing effective engineering, education, and enforcement strategies and countermeasures to reduce pedestrian fatalities and enhance pedestrian safety in Florida.

1.3 Supporting Data Sets for Research

SHRP2 NDS data consist of two large datasets. The main dataset includes naturalistic driving data from instrumented vehicles and supplemental driver information managed by the Virginia Tech Transportation Institute (VTTI); the second dataset includes the RID managed by the Center for Transportation Research and Education (CTRE) at the University of Iowa. Since the major research question targets pedestrian safety, the research team acquired the NDS data stream of vehicles passing selected signalized intersections in Tampa Bay with specific pedestrian features, high pedestrian activity, and/or crash frequency. This provided an excellent opportunity for researching the impact of pedestrian features and having a higher possibility for observing interactions between drivers and pedestrians. The intersection locations were identified in coordination with FDOT. To minimize the data required, a driver sample size that is sufficient for performing the analysis was used (This can be expanded to the whole database in the future research). Coordination with VTTI and CTRE was required for proper data acquisition. For the NDS data, specific data streams were requested and filtered to include only a few seconds of video before and after drivers negotiate through the specified signalized intersections. The data requested included but were not limited to forward movement video; vehicle forward and lateral acceleration; braking; turn indications; headlights; GPS path for the sections; and driver characteristics.

1.4 Previous Related Studies

Understanding the interactions between drivers and pedestrian features is important for developing effective countermeasures to improve pedestrian safety at signalized intersections. Driver interactions with pedestrian features include driver speeds, braking patterns, and yielding and stopping behaviors. Most commonly, drivers who fail to comply with pedestrian-related features near the crosswalks of signalized intersections can increase accident risk for pedestrians.

By using traditional data collection methods, several studies were conducted to evaluate the effectiveness of pedestrian signs. Herman (2000) designed a treatment-and-control study to evaluate the effects of "NO TURN ON RED/YIELD TO PEDESTRIANS" variable message signs. A video camera was set up on a sidewalk along a main road to record pedestrian and motorist behavior at selected intersections. The sites with the signs were found to have a lower ratio of motorists who illegally turned right on right, but there were no significant differences in terms of the number of right-turn-on-green motorists who yielded to pedestrians. Karkee et al. (2006) conducted a "before-and-after" study to test differences in several measures for "Turning Traffic Must Yield to Pedestrians" signs. Data were collected during AM and PM peak hours during each study period, and results showed increases in yielding behavior and both pedestrian and vehicle delay after the signs were installed.

A study performed by Pulugurtha et al. (2010) evaluated the effects of traffic signs based on field observations of pedestrian and driver behaviors. Results showed a general improvement in driver yielding behavior due to installation of "YIELD TO PEDESTRIANS" signs. Similarly, using field observation or fixed video recording methods, Pecheux et al.

(2009) and Fitzpatrick et al. (2014) included some general findings for pedestrian features such as "YIELD TO PEDESTRIANS" signs in their pedestrian safety studies.

Although these previous studies attempted to evaluate the effectiveness of traffic signs, the traditional methods failed to collect important safety-related factors such as driver speed profiles, braking patterns, driver characteristics (e.g., gender, age, frequency of risk-taking), vehicle factors, and various roadway/environmental conditions. The SHRP2 NDS datasets and RID databases provide rich and unique information for understanding the interactions between drivers and pedestrian features at signalized intersections to increase pedestrian safety.

1.5 Research Objectives

The first major goal of this project was to understand the interactions between drivers and pedestrian features at signalized intersections using the SHRP2 NDS and RID datasets and to obtain initial results and findings. The second major goal was to demonstrate that the research team effectively used the NDS and RID databases to conduct research and analysis, leading to development of effective countermeasures in future studies to improve pedestrian safety at signalized intersections.

The specific objectives of this project were to:

1. Acquire knowledge and request data from the SHRP2 NDS and RID datasets to conduct initial analysis of driver interactions with pedestrian features at signalized intersections.
2. Develop effective data extraction and analysis tools and identify specific parameters and factors that will aid in initial analysis in this project and full analysis in future studies pertaining to the research question: "Based on information from the SHRP2 NDS and RID datasets, how do drivers interact with pedestrian features at signalized intersections?"
3. Conduct initial analysis using a more manageable dataset of acquired NDS data, provide initial findings on the research question, and offer recommendations that can be implemented by FDOT in future studies.
4. Demonstrate the effective and successful use of the SHRP2 NDS and RID datasets via this project to provide recommendations and guidance for future studies.

Chapter 2 – Data Collection

This project involved the SHRP2 NDS database, one of the largest databases of naturalistic driving data from instrumented vehicles and supplemental driver information. A secondary database, the RID, provides information on the roads on which NDS participants traveled most frequently. The RID includes features such as signs, markings, lanes, Annual Average Daily Traffic (AADT), alignment, crashes, geometry, and other characteristics of the roadway on which the NDS participants drove. The research team focused on the Tampa Bay Area for this first pilot phase.

2.1 Selection of Pedestrian Features

Pedestrian safety at signalized intersections is essential. Implementation of effective countermeasures can significantly improve pedestrian safety at signalized intersections. Based on discussion with FDOT project panel members, the CUTR project team selected four pedestrian features, which are highly related to pedestrian safety at signalized intersections. These pedestrian features focused on specific traffic signs aiming to improve drivers' compliant behaviors and reduce vehicle-pedestrian conflicts at intersections. Understanding of the interactions between drivers and these pedestrian features is necessary to assess the performance of the features and successfully develop implementable countermeasures for improving pedestrian safety at signalized intersections.

"STOP HERE ON RED" Sign

According to the *Manual on Uniform Traffic Devices* (*MUTCD*), Section 8B.12, this sign (R10-6, R10-6a), as shown in Figure 1, defines and facilitates observance of stop lines at traffic control signals. As an option, this sign may be used at locations at which highway vehicles frequently violate the stop line or where it is not obvious to road users where to stop.
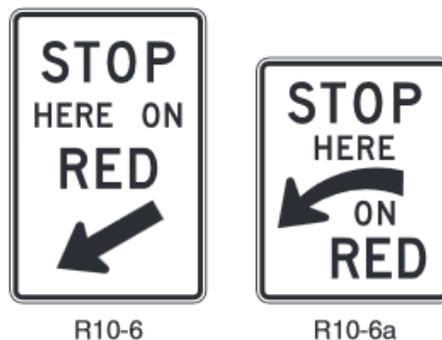
Figure 1. "STOP HERE ON RED" signs

This feature is used primarily when the stop line/bar is not visible or drivers do not stop behind the stop line/bar at a signalized intersection. The research team identified locations in the study area where this sign has been used to aid in the compliance of drivers stopping behind the stop bar and not stopping on the crosswalk, therefore impeding crossing

pedestrians. A total of 54 (46+8) of these signs existed in the RID database for the Florida region.

"NO TURN ON RED" Sign

According to *MUTCD*, Section 2B.54, this sign (R10-11, R10-11a, or R10-11b), as shown in Figure 2, is used where a right turn on red (or a left turn on red from a one-way street to a one-way street) is to be prohibited. If used, it should be installed near the appropriate signal head and should be considered when an engineering study finds that one or more of the following conditions exists:

A. Inadequate sight distance to vehicles approaching from the left (or right, if applicable).
B. Geometrics or operational characteristics of the intersection that might result in unexpected conflicts.
C. An exclusive pedestrian phase.
D. An unacceptable number of pedestrian conflicts with right-turn-on-red maneuvers, especially involving children, older pedestrians, or persons with disabilities.
E. More than three right-turn-on-red accidents reported in a 12-month period for the particular approach.
F. The skew angle of the intersecting roadways creates difficulty for drivers to see traffic approaching from their left.

Figure 2. "NO TURN ON RED" signs

For the purposes of this study, the "NO TURN ON RED" sign was used when either an exclusive left-turn phase exists or drivers should not make a right turn conflicting with crossing pedestrians. A total of 52 (6+31+15) of these signs existed in the RID database for the Florida region.

"TURNING VEHICLES YIELD TO PEDESTRIANS" Sign

According to *MUTCD*, Section 2B.53, this sign (R10-15), as shown in Figure 3, is used to remind drivers making turns to yield to pedestrians at a signalized intersection.

Figure 3. "TURNING VEHICLES YIELD TO PEDESTRIANS" sign

In this study, this sign was used to identify compliance from drivers making right turns (but also was applied to left turns) since it has been used extensively in the Tampa Bay Area as a reminder to drivers. A total of 46 of these signs existed in the RID database for the Florida region.

"RIGHT ON RED ARROW AFTER STOP" Sign

According to *MUTCD*, section 2B.54, this sign (R10-17a), as shown in Figure 4, is used in the same manner as the "NO TURN ON RED" signs.

Figure 4. "RIGHT ON RED ARROW AFTER STOP" sign

For this study, this sign was observed in conjunction with a "PHOTO ENFORCED" plaque used when red light cameras exist at intersections. Although red light cameras aid in enforcing red light running, they also help with pedestrian crossings because they enforce stop before right turns on red. A total of 7 of these signs existed in the RID database for the Florida region.

The intention and compliant behaviors for the selected features are summarized in Table 1.

Table 1. Intention and Compliant Behaviors for Selected Pedestrian Features

Feature Name	Feature Intention	Compliant Behaviors
STOP HERE ON RED	Used to tell drivers to stop at stop bar where sign is installed to ensure everyone's safety; if vehicles stop at stop bar and not on crosswalk, they can avoid hitting pedestrians crossing at crosswalk.	Stop before stop line on red
NO TURN ON RED	Used primarily at intersections with higher number of conflicts between vehicles making right turn on red light and vehicles or pedestrians crossing; especially in Florida, turning right on red is a major cause of pedestrian crashes at intersections.	Stop on red and wait for green signal

TURNING VEHICLES YIELD TO PEDESTRIANS	Informs turning vehicles making right or left turn at intersections to yield to crossing pedestrians; applies when traffic signal is red or green.	Yield to pedestrians on green or red
RIGHT ON RED ARROW AFTER STOP + PHOTO ENFORCED	Installed together in Tampa Bay to direct drivers to stop on red before making right turn; usually coupled with red light cameras for enforcement; installed where there is a higher number of violations of drivers not making a stop on red before proceeding to make a right.	Stop, observe, and turn on red

2.2 Identification of Intersections

Based on the identified features discussed in Section 2.1 and on the trip density maps provided by VTTI, the study team selected the intersections shown in Table 2 for NDS data to be obtained. Each feature included two intersections with the target feature and a control site with similar AADT, trip density, and geometry (lanes, crosswalks, etc.) used for baseline analysis. A total of 12 signalized intersections provided enough traversals for a statistical analysis of the 4 features.

Table 2. Selected Intersections for Analysis

ID	Intersection	Feature *MUTCD* Code	Feature Name	Site Type
1	E Fletcher Ave & N 42nd St	R10-6, R10-6a	STOP HERE ON RED	site1
2	E Fowler Ave & Raintree Blvd	R10-6, R10-6a	STOP HERE ON RED	site2
3	E Fletcher Ave & USF Palm Dr	None	None	control
4	Gunn Hwy & W Linebaugh Ave	R10-11, R10-11a, R10-11b	NO TURN ON RED	site1
5	W Linebaugh Ave & Sheldon Rd	R10-11, R10-11a, R10-11b	NO TURN ON RED	site2
6	E Fowler Ave & N Florida Ave	None	None	control
7	E Hillsborough Ave & 30th St	R10-15	TURNING VEHICLES YIELD TO PEDESTRIANS	site1
8	E Hillsborough Ave & N 34th St	R10-15	TURNING VEHICLES YIELD TO PEDESTRIANS	site2
9	E Busch Blvd & N 46th St	None	None	control
10	E Busch Blvd & N 56th St	R10-17a	RIGHT ON RED AFTER STOP	site1
11	E Fowler Ave & N 56th St	R10-17a	RIGHT ON RED AFTER STOP	site2
12	E Fletcher Ave & N Nebraska Ave	None	None	control

2.3 Institutional Review Board Approval

The necessary Protocol for data analysis were submitted to the Institutional Review Board (IRB) at the University of South Florida (USF) for review and approval, which was very important for ensuring that appropriate steps were taken to protect the rights and welfare of humans participating as subjects in the study. When performing research using human subjects, the IRB reviews the protocol of contact, procedures, methods, and interaction of

the research activities. In addition, the SHRP2 data are protected by IRB protocols, and approval from the IRB was required to request and access the sensitive data. Upon review, it was determined by the USF IRB that because this project was accessing the collected data anonymously without any use of identifiable information, it was exempt from IRB approval. The IRB determination and protocol can be found in the Appendices A and B.

2.4 Coordination with CTRE for SHRP2–RID Datasets

The SHRP2 NDS produced two datasets. The first, the RID, is maintained by CTRE at Iowa State University and includes the road characteristics and environment for the roads used by participants in the SHRP2 NDS study. The RID includes but is not limited to the following data:

- Horizontal curvature
    - Radius
    - Length
    - Point of curvature (PC)
    - Point of tangency (PT)
    - Direction of curve (left or right based on driving direction)
- Grade
- Cross-slope/superelevation
- Lanes – number, width, and type (thru, turn, passing, acceleration, car pool, etc.)
- Shoulder type/curb (and paved width, if it exists)
- All *MUTCD* signs
- Guardrails/barriers
- Intersections – location, number of approaches, and control (uncontrolled, all-way stop, two-way stop, yield, signalized, roundabout); ramp termini were considered intersections
- Median presence – type (depressed, raised, flush, barrier)
- Rumble strip presence – location (centerline, edgeline, shoulder)
- Lighting presence

In addition to the data from the mobile data collection project, roadway data from existing public resources (e.g., Highway Performance Monitoring System [HPMS] data and comprehensive data items available from state transportation agencies) and a list of supplemental data items were acquired and included in the RID. The term "supplemental" refers to any data item that characterizes a roadway segment that was not included as part of the mobile data collection undertaken by SHRP2 or existing roadway data acquired from transportation agencies within the six NDS sites. These supplemental items included crash histories, traffic, weather, work zones, changes to infrastructure, aerial imagery, Federal Railroad Administration (FRA) grade crossings, safety enforcement laws, and active safety campaigns. The existing and supplemental data that were acquired are estimated to cover about 200,000 centerline miles within the six NDS sites.

The RID was obtained for this study and used to identify the locations and types of pedestrian features used for analysis. Based on the location of the features (signs,

markings), AADT, and lane configuration, 12 intersections were selected to be used for the filtering of the SHRP2 NDS trip data required from VTTI.

2.5 Coordination with VTTI for SHRP2-NDS Dataset

The NDS dataset is maintained by VTTI and includes data from participants, vehicles, and trips. A website (https://insight.shrp2nds.us/) currently provides a summary of trips, vehicles, and participant information for use by researchers before officially requesting records. A thorough investigation of available data was conducted for this pilot phase of the project, and certain variables were identified to be used. In addition to the selected variables, a Data Sharing Agreement (DSA) between CUTR and VTTI to obtain the data. The DSA and the cost proposal for VTTI can be found in the Appendix C.

The number of trips and participant data per intersection were specified, and information on a total of 2,430 trips were obtained from the NDS dataset. These trips were divided into short and long (full) segments passing though the predefined intersections. To conduct the analysis, the short trips, totaling 2,160, were further stratified into required movements for each feature, as shown in Table 3, and number of trips/participants, as shown in Table 4. The purpose of stratifying the data in this manner was to maximize the number of useful trips because specific features apply only to specific movements, i.e., "NO TURN ON RED" applies only to right turns.

Table 3. Specified Movements Required for Each Pedestrian Feature

Pedestrian Feature	Right-Turn Movement	Left-Turn Movement	Through Movement
STOP HERE ON RED sign	Yes	No	Yes
NO TURN ON RED sign	Yes	No	No
TURNING VEHICLES YIELD TO PEDESTRIANS sign	Yes	No	No
RIGHT ON RED ARROW AFTER STOP sign & PHOTO ENFORCED sign	Yes	No	No

Table 4. Range of Trip Numbers for Each Pedestrian Feature

Pedestrian Feature	Range for Number of Trips		
	Intersections with Specified Pedestrian Feature (2 intersections)	Controlled Intersection (1 intersection)	Total Trips (3 intersections)
STOP HERE ON RED sign	243–297 (Ideal: 270)	243–297 (Ideal: 270)	486–594 (Ideal: 540)
NO TURN ON RED sign	243–297 (Ideal: 270)	243–297 (Ideal: 270)	486–594 (Ideal: 540)
TURNING VEHICLES YIELD TO PEDESTRIANS sign	243–297 (Ideal: 270)	243–297 (Ideal: 270)	486–594 (Ideal: 540)
RIGHT ON RED ARROW AFTER STOP sign & PHOTO ENFORCED sign	243–297 (Ideal: 270)	243–297 (Ideal: 270)	486–594 (Ideal: 540)

Notes:
- The acceptable range for number of trips for each participant passing through the intersections with the same pedestrian feature is from 0–20 trips.
- The acceptable range for number of trips for each participant passing through the control intersection with a specific pedestrian feature is also from 0–20 trips.

Using the trips/participants selected from the previous session, full trips were provided for 54 participants, for a total of 270 trips, using the following criteria:

- *Trip Type* – selected trips on surface roads only (no portion of trips on freeways or expressways)
- *Trip Duration* – selected trip duration between 15–30 minutes, excluding the deleted time for origin and destination identification.
- *Minimum Requirement for Trip* – each trip should pass through at least one intersection with the specified pedestrian feature and associated movement.
    - For each participant, there was a total of 5 trips. These combined 5 trips should cover at least 3 specified pedestrian features and associated movements, as shown in Table 3.
- *Preferred Trips* – a trip passes through at least two different intersections with two different specified pedestrian features and associated movements.
    - For each participant, there was a total of 5 trips. These combined 5 trips should cover all 5 specified pedestrian features and associated movements as well as 4 different control intersections.

The age breakdown of the data is shown in Table 5.

Table 5. Age Requirement for Full Trips

Age Group	Male	Female
16–20	7	7
21–35	7	7
36–65	7	7
66+	6	6

Chapter 3 – Development of Data Extraction and Data Analysis Tools

Two data extraction and analysis tools were developed in this project to produce subsets from the NDS datasets obtained from VTTI and CTRE and provide support for data analysis. The following sections provide the methodology used to develop the tools and the description of these tools.

3.1 Identification of Events for Pedestrian Features

Based on the brief literature review, the research team identified events and data needed for extraction from the NDS and RID datasets for different pedestrian features and organized for these datasets for specific data analysis. The identified events include intersection characteristics, environmental conditions, driver behaviors and causes, traffic signal status, and pedestrian presence. Table 6 shows the identified events.

Table 6. Identified Events for Data Extraction

Category	Event	Data Source
Intersection Characteristics	Lane configuration	RID, Google Map
	Pedestrian feature type	Google Map NDS Front Video
	Pedestrian feature location	
Environmental Conditions	Roadway condition (dry, wet, …)	NDS Front Video
	Weather condition (clear, rain, …)	
	Lighting condition (daylight, dark, …)	
Driver Behaviors	Behaviors approaching pedestrian features (slow down, stop, …) and causes	NDS Front Video NDS Time Series Data
	Time/speed passing pedestrian features	
	Behaviors approaching stop line (slow down, stop,…) and causes	
	Time/speed passing stop line	
	Behaviors approaching crosswalk on leaving leg (slow down, stop, …) and causes	
	Time/speed passing crosswalk on leaving leg	
Pedestrian	Presence	NDS Front Video
	Location (sidewalk, crosswalk, …)	
	Number	
Traffic Signal	Signal indicator status	NDS Front Video
	Time of signal changing	
Driver Information	Age group	NDS Supplementary Data
	Gender	
	Risk and distraction (based on questionnaires)	

3.2 Development of Data Processing Procedure

The research team developed a data extraction and analysis procedure, shown in Figure 5.
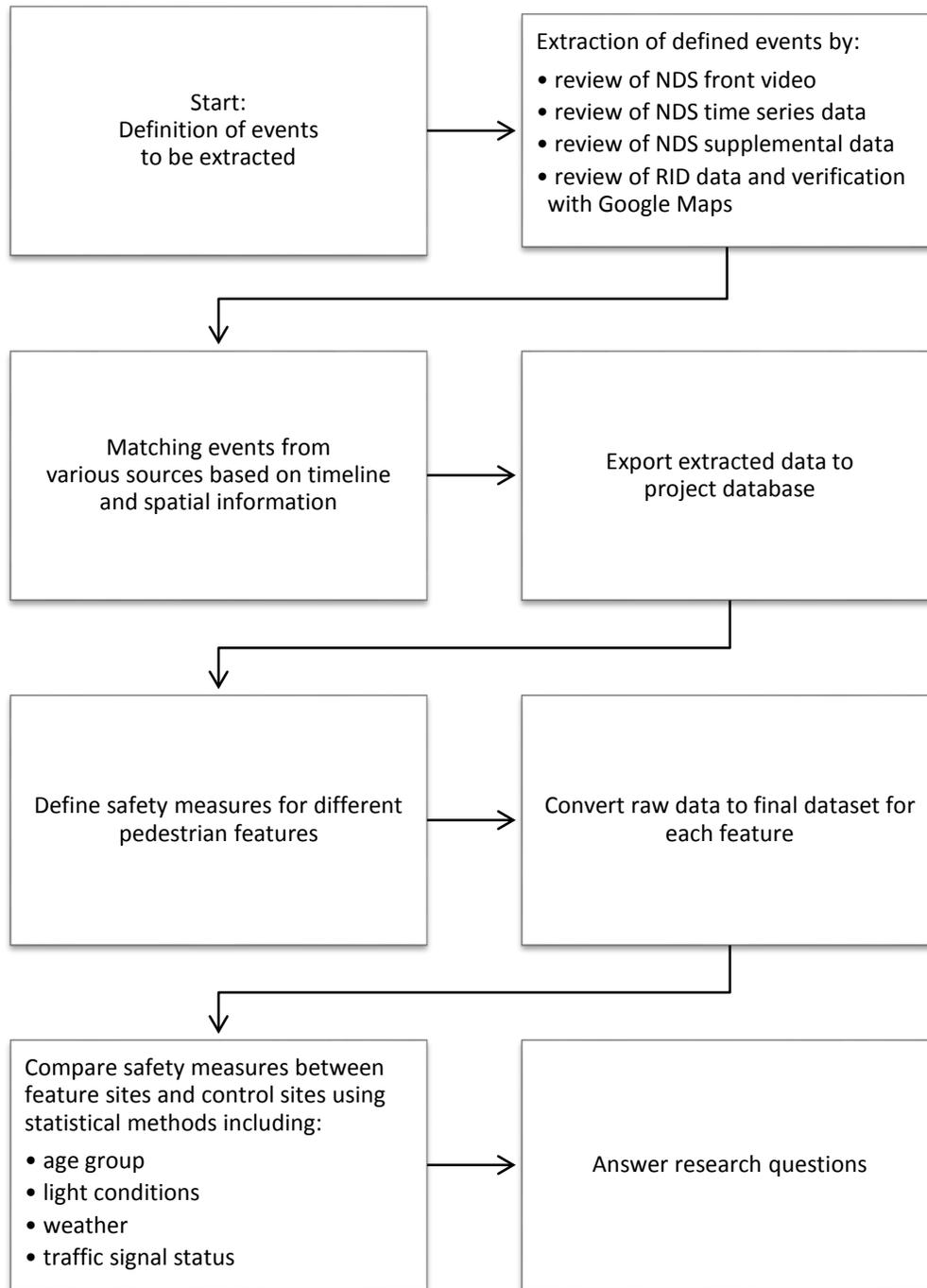
Figure 5. Data processing procedure

3.3 Development of NDS Data Reduction and Analysis Tool (DRAT)

As illustrated in Figures 6 through 9, the NDS Data Reduction and Analysis Tool (DRAT) is a computer software application based on the Microsoft .NET framework 4.0. Researchers can use this tool to review NDS front videos and associated speed data. By clicking pre-defined event buttons, the data items defined in Table 6 can be recorded and exported to the project database automatically. The data conversion function (from raw data to final data) is also integrated into this tool.

The major functions of the NDS DRAT include:

- Displaying NDS front videos and associated speed profile synchronously
- Recording pre-defined events and associated timeline automatically when reviewers click event buttons
- Exporting extracted data (raw data) to a project database (hosted in a MS SQL Server)
- Converting raw data to final data according to the needs of analysis
- Allowing users edit extracted data
- Generating data reports for second reviewing
- Providing user and data management
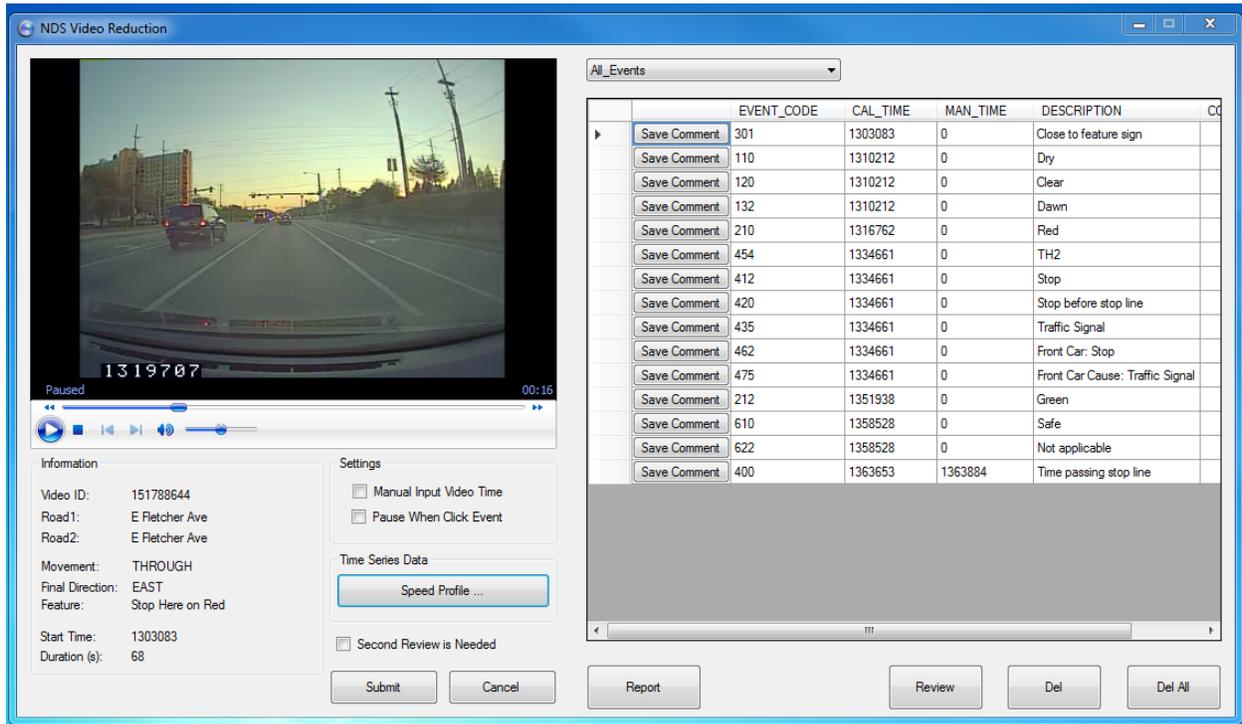
Figure 6. Video display interface of NDS Data Reduction and Analysis Tool

13
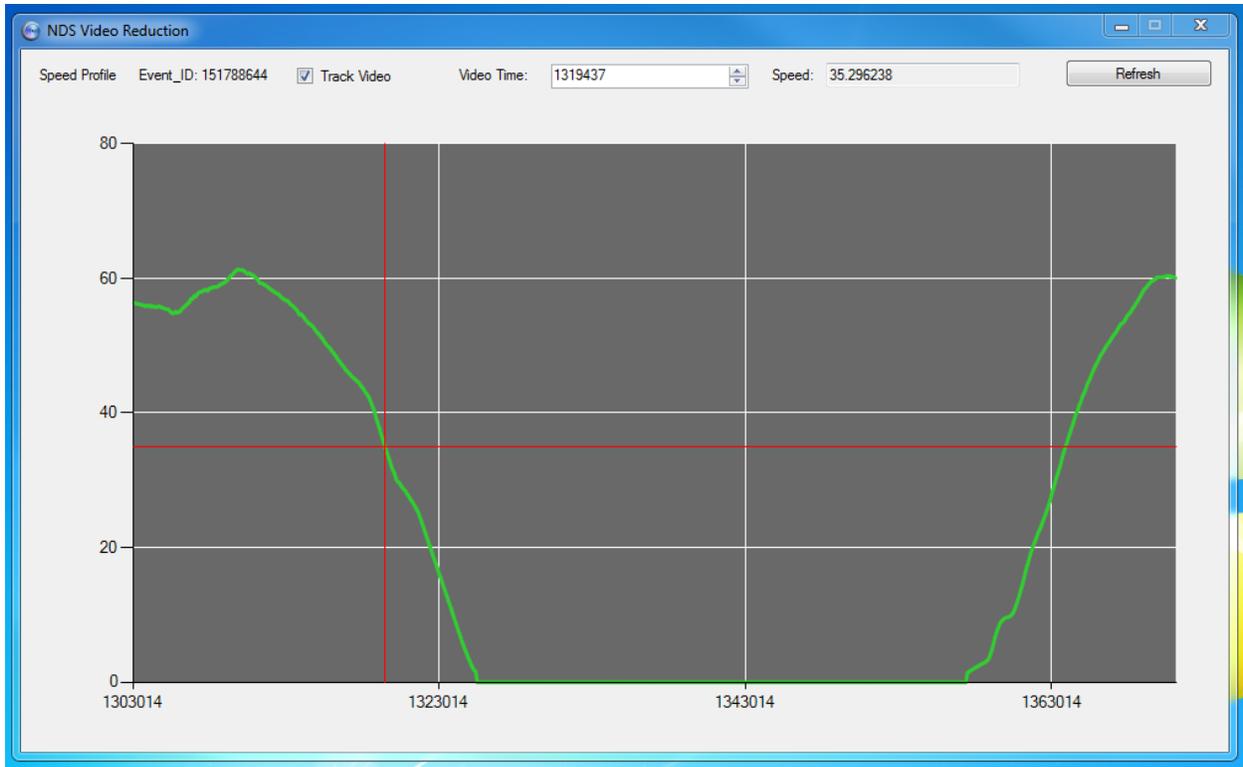
Figure 7. Speed profile interface of NDS Data Reduction and Analysis Tool
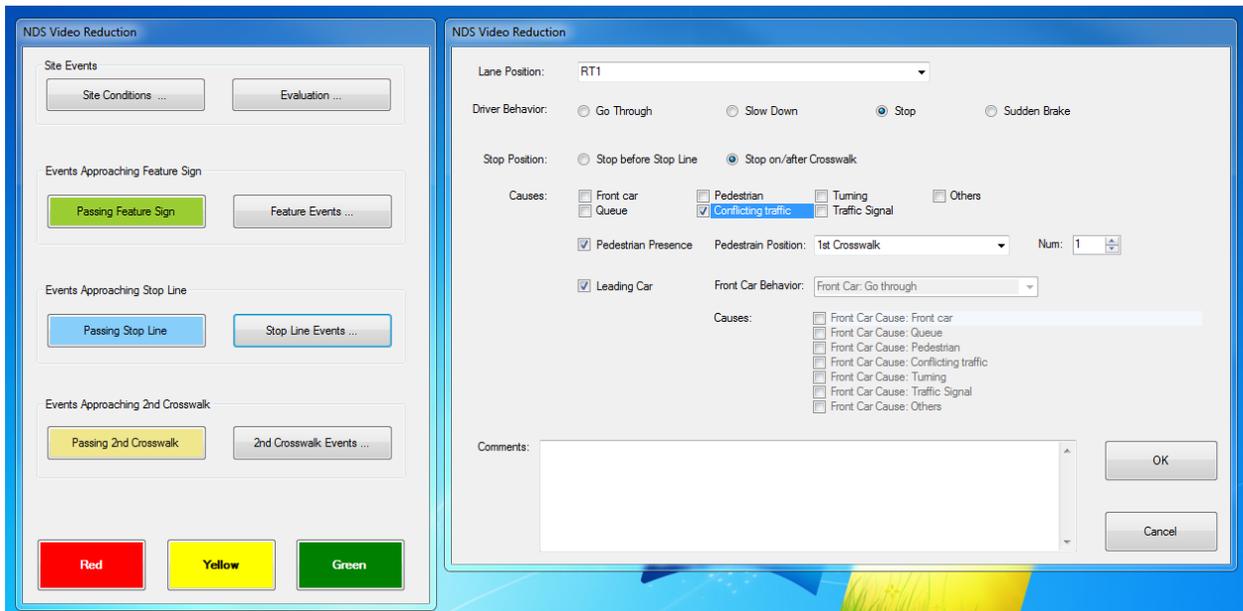
Figure 8. Pre-defined event panel of NDS Data Reduction and Analysis Tool
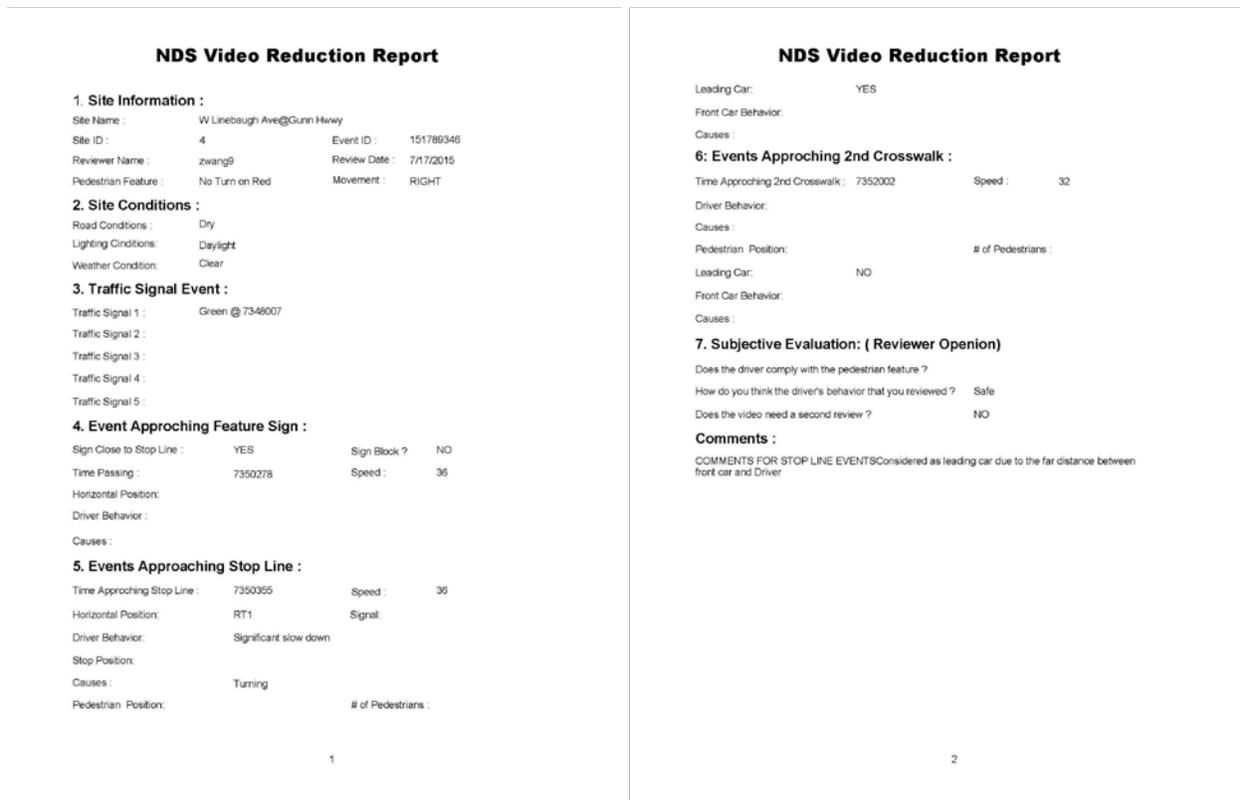
Figure 9. Example of NDS Data Reduction and Analysis report

3.4 Development of NDS Automatic Video Processing Tool (AVPT)

Reviewing and analyzing NDS video data is time-consuming work. A large number of NDS videos were difficult to review and analyze manually. To improve the effectiveness of video data extraction to support analysis, the research team developed the NDS Automatic Video Processing Tool (AVPT) to extract the information (pedestrian and traffic signal) from NDS videos using computer image processing technologies. The image processing algorithms were coded in the MATLAB platform. The major functions of the NDS AVPT are:

- Detecting and tracking pedestrians at signalized intersections (Figure 10)
- Detecting traffic signal status by color (Figure 11)
- Counting pedestrians in the four detection zones (to decide pedestrian horizontal location relative to the driver) (Table 7)
- Exporting to CSV files

The output provided by the data extraction and analysis tools, along with given driver characteristics from the NDS database and roadway characteristics from the RID, were used for qualitative, quantitative, and statistical analysis.

Figure 10. Example of pedestrian detection and tracking
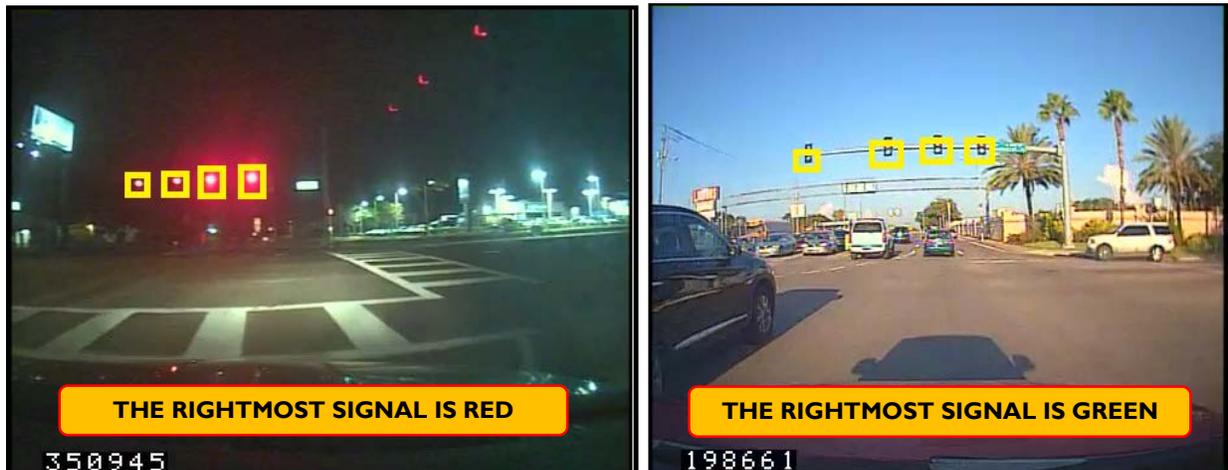
Figure 11. Example of traffic signal detection

Table 7. Example of NDS Automatic Video Processing Tool Output

Time in Seconds	No. of Pedestrians in Screen Zone A*	No. of Pedestrians in Screen Zone B*	No. of Pedestrians in Screen Zone C*	No. of Pedestrians in Screen Zone D*	Signal Color
1	3	2	0	0	red
2	2	2	0	0	red
3	2	0	1	0	red
4	2	0	1	0	red
5	2	0	1	0	red
6	2	0	1	0	red
7	2	0	1	0	red
8	1	0	0	1	green
9	1	0	0	0	green
10	1	0	0	0	green
…	…	…	…	…	…
…	…	…	…	…	…

* The pedestrian recognition algorithm splits the screen of a front video into four zones (Screen Zones A–D) from left side to right side to indicate pedestrian's relative location in the front video.

Chapter 4 – Data Compilation and Data Analysis

This chapter includes information on data compilation and data analysis for investigating interactions between drivers and pedestrian features at signalized intersections. First, the data extracted and processed from the NDS database, and found suitable for the data analysis, was validated and compiled. Then, the quantitative methods including statistical analysis were applied to compare driving behaviors with and without the selected pedestrian features. The effectiveness of specific pedestrian features on driving behaviors with pedestrian presence was also examined. Finally, the impact of driver characteristics on driver interaction with pedestrian features was examined.

The data analysis in this project helped answer the major research question, "Based on information from the SHRP2 NDS and RID datasets, how do drivers interact with pedestrian features at signalized intersections?" Specifically, the initial data analysis intended to provide answers to the following specific research questions:

1) What are driver interactions with different pedestrian features at signalized intersections?
2) What is the effectiveness of a specific pedestrian feature?
3) What are specific interactions between drivers and pedestrians?
4) Will drivers interact with pedestrian features differently when pedestrians are present?
5) What are the impacts of driver characteristics such as gender and age group on driver interactions?
6) What are the impacts of driver attention and/or distraction on driver interactions?

4.1 Data Compilation

The extracted and processed data include video data and digital data of signalized intersections with specific pedestrian features. These data first were validated by conducting data type checks, image checks, consistency checks, range checks, and format checks. After validation, the data were compiled further into different groups for analysis, such as signalized intersections with specified pedestrian features without the presence of pedestrians and signalized intersections with specified pedestrian features with the presence of pedestrians. Each group was further divided into subgroups for detailed analysis.

4.2 Data Analysis Method

Quantitative data analysis was conducted to provide quantifiable and easy-to-understand results. For this purpose, a cross-sectional analysis was used to compare the results from a feature group with that of its control group to assess the safety effectiveness of the selected pedestrian feature.

First, the compliant driver interactions (driver behaviors) with a specific pedestrian feature, as the safety measure in a cross-sectional comparison, were identified based on the intention of the pedestrian feature—the higher the proportion of compliant behaviors

observed, the better the safety performance of the pedestrian feature. The intention and compliant driver behaviors for each feature are shown in Table 8.

Table 8. Driver Behaviors for Each Feature

Feature	Feature Intention	Compliant Behaviors
"STOP HERE ON RED"	Tell drivers they need to stop at stop bar	Stop before stop line on red
"NO TURN ON RED"	Prohibit turning during red signal	Stop on red and wait for green signal
"TURNING VEHICLES YIELD TO PEDESTRIANS"	Inform turning vehicles to yield to pedestrians	Yield to pedestrians on green or red
"RIGHT ON RED ARROW AFTER STOP"	Direct drivers to stop on red before turning	Stop, observe, and turn on red

Second, observed behaviors were categorized into two groups: feature group (with the pedestrian feature) and control group (without the pedestrian feature), and their proportions (*P*) were calculated respectively, as shown in Table 9.

Table 9. Observed Driver Behaviors

Group	Compliant Behavior	Non-Compliant Behaviors
Feature	P_{FE}	$P_{FU} = 1 - P_{FE}$
Control	P_{CE}	$P_{CU} = 1 - P_{CE}$

- P_{FE} (proportion of compliant behaviors with feature in feature group) = N_{FE} (number of compliant behaviors in feature group) / N (total observations in feature group)
- P_{CE} (proportion of compliant behaviors with feature in control group) = N_{FE} (number of compliant behaviors in control group) / N (total observations in control group).

Comparisons of the compliant behaviors were conducted between each feature group and its control group—the higher the proportion of compliant behaviors observed, the better the safety performance. Chi-square tests were used to determine whether the proportion of compliant driver behaviors at feature sites *(P_{FE})* was significantly different from that at control sites *(P_{CE})*.

> H_0: P_{FE} = P_{CE} *(proportion of compliant driver behaviors at feature sites is the same as that at control sites)*

> H_a: P_{FE} ≠ P_{CE} *(proportion of compliant driver behaviors at feature sites is different from that at control sites)*

The proportion comparisons also were conducted between different driver characteristics (gender, age, and risk groups) for each pedestrian feature. In addition, the differences in compliant behaviors by different driver characteristics and pedestrian presence were compared based on the overall data. All hypothesis tests were conducted at a minimum confidence level of 90%.

4.3 Data Analysis Results

The data analysis helped to answer the major research question, "Based on information from the SHRP2 NDS and RID datasets, how do drivers interact with pedestrian features at signalized intersections?"

Statistical analysis results are presented for each of the four pedestrian features separately. For each feature, the following information is presented:

- Interactions between drivers and pedestrian features
- Comparison of compliant behaviors with features between feature and control sites
- Comparison of average speed before and after implementation of feature (for "TURNING VEHICLES YIELD TO PEDESTRIANS" sign only)
- Comparison of compliant behaviors at feature sites by driver gender and age group

In addition, overall comparisons (including all features) were conducted to explore:

- Impact of pedestrian presence on driver-feature interactions
- Effects of driver demographics (gender, age) on driver-feature interactions
- Impact of driver characteristics (risk, distraction) on compliant behaviors

4.3.1 Individual Analysis: Interactions between Drivers and Pedestrian Features

Figure 12 shows the distribution of interactions between drivers and feature signs for each pedestrian feature. A description of each follows.

"STOP HERE ON RED"

- 100% of drivers stopped on red.
- 55% of drivers stopped before the stop line.
- 45% of drivers stopped at an incorrect location (after stop line).

"NO TURN ON RED"

- 70% of drivers stopped until green signal was ON (compliant behavior).
- 30% of drivers turned on red (non-compliant behavior)—15% stopped for conflicting traffic and turned and 15% slowed down and turned.
- Only one observation was made with a pedestrian presence at the intersection with "NO TURN ON RED" sign. The driver (female, age 30–34) fully complied (stopped before stop line and waited for green signal).

"TURNING VEHICLES YIELD TO PEDESTRIANS"

- 67% of drivers yielded to pedestrians, and 33% of drivers did not yield.
- Limited pedestrian presence was observed for this feature. Most observations with pedestrian presence were excluded in the analysis shown in Figure 12 since there was no interactions between drivers and pedestrians (e.g., pedestrians on left sidewalk, pedestrian crossing was walking away from study vehicle, etc.).

"RIGHT ON RED ARROW AFTER STOP"

- 67% of drivers complied.
- 33% of drivers did not comply, including 10% who performed a rolling "stop" and turned and 23% who slowed down and turned.
- Observations of stopping behaviors caused by external factors such as conflicting traffic were removed from the analysis shown in Figure 12.

Pedestrian Feature Signs	Non-Compliant Counts	Compliant Counts	Total Counts	% Non-Compliant Behaviors	% Compliant Behaviors
STOP HERE ON RED	5	6	11	45%	55%
NO TURN ON RED	10	23	33	30%	70%
TURNING VEHICLES YIELD TO PEDESTRIANS	3	6	9	33%	67%
RIGHT ON RED ARROW AFTER STOP	27	54	81	33%	67%
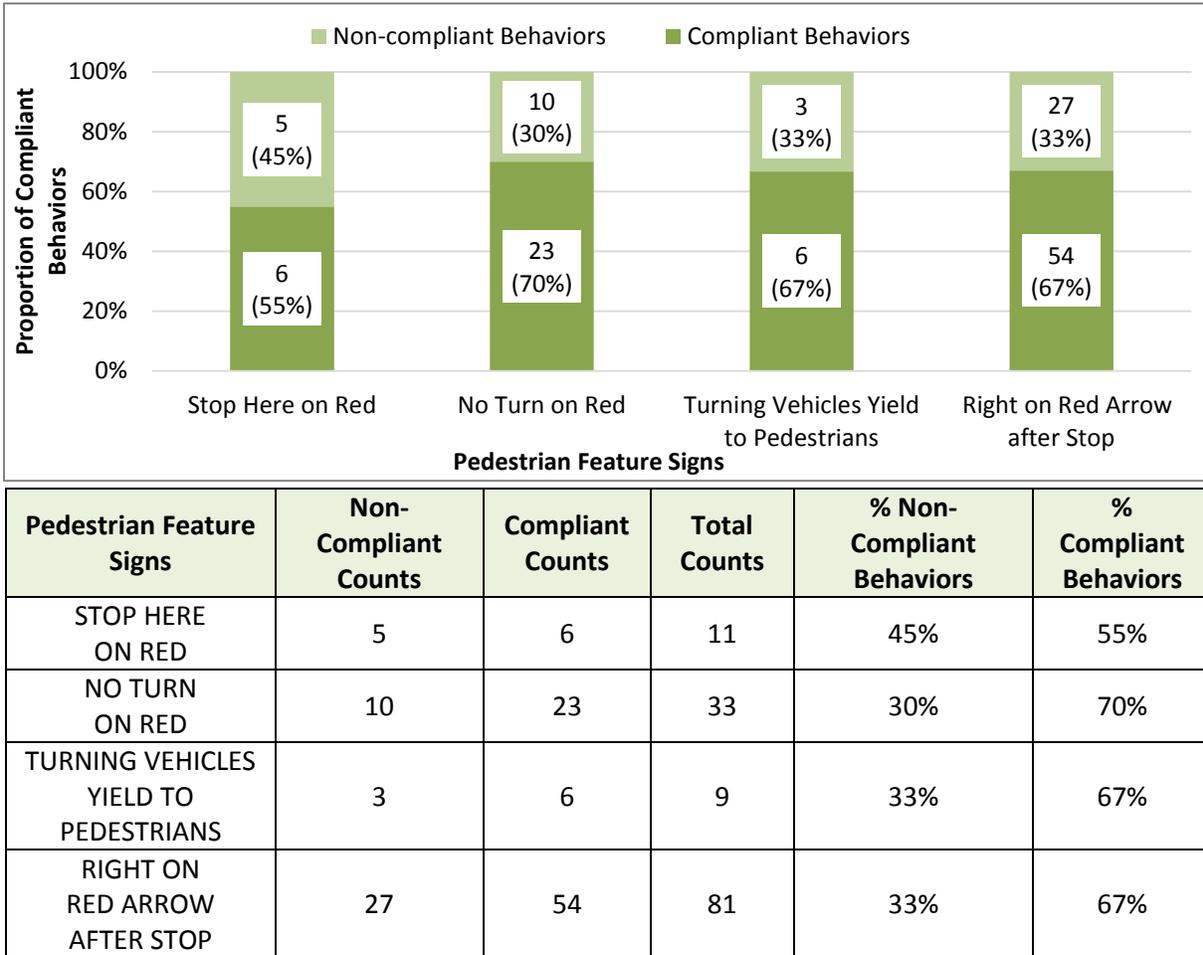
Figure 12. Interactions between drivers and different pedestrian features

4.3.2 Individual Analysis: Comparison between Feature Group and Control Group

Figure 13 shows the results of comparison of driver compliant behaviors with features between each feature and its associated control group.

- Three pedestrian features ("STOP HERE ON RED," "NO TURN ON RED," and "RIGHT ON RED ARROW AFTER STOP" signs) increased the compliant behaviors to the feature intention when compared to control groups. The difference for "RIGHT ON RED ARROW AFTER STOP" sign was significant at a confidence level of 95%.

- The "NO TURN ON RED" sign showed the highest increase in compliant behavior (64% = 70% - 6%), followed by "RIGHT ON RED ARROW AFTER STOP" (36% = 67% - 31%) and "STOP HERE ON RED" (33% = 55% - 22%).
- The "TURNING VEHICLES YIELD TO PEDESTRIANS" sign showed the same percentage of yielding behavior as that of the control group, but the observations of pedestrian presence at feature or control sites were very limited.
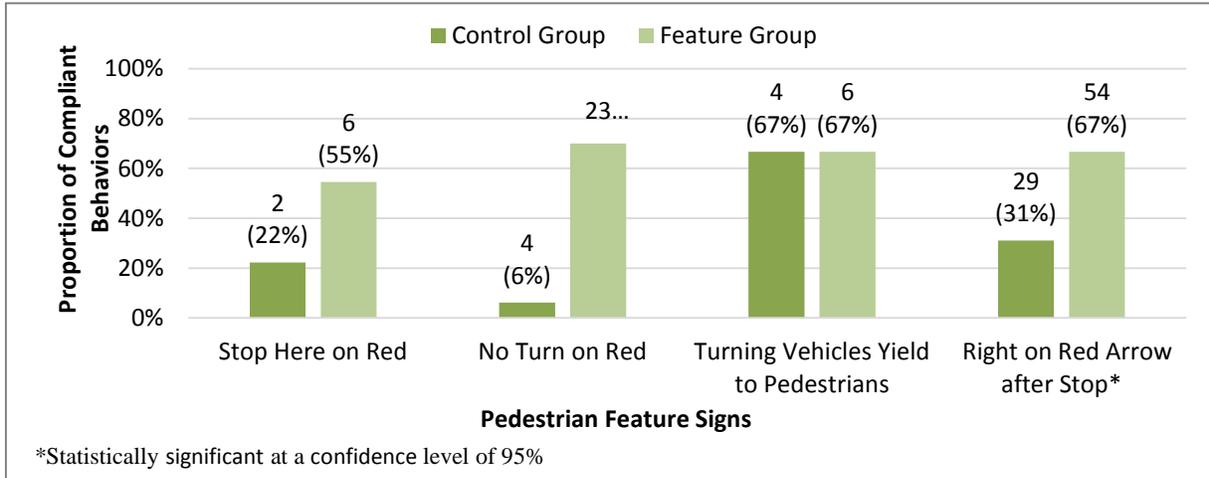
*Statistically significant at a confidence level of 95%

Pedestrian Feature Signs	Comparison Group	Non-Compliant Counts	Compliant Counts	Total Counts	% Compliant Behaviors
STOP HERE ON RED	Control Group	7	2	9	22%
	Feature Group	5	6	11	55%
NO TURN ON RED	Control Group	61	4	65	6%
	Feature Group	10	23	33	70%
TURNING VEHICLES YIELD TO PEDESTRIANS	Control Group	2	4	6	67%
	Feature Group	3	6	9	67%
RIGHT ON RED ARROW AFTER STOP	Control Group	64	29	93	31%
	Feature Group	27	54	81	67%

Figure 13. Comparison of compliant behaviors with features between feature group and control group

4.3.3 Individual Analysis: Comparison of Speed before and after Implementation

Figure 14 shows the results of the comparison of average speed before and after installing a "TURNING VEHICLES YIELD TO PEDESTRIANS" sign at the same site.

- The average speeds of right-turning vehicles at both the stop line and the second crosswalk were used to evaluate the impact of the feature on driver behaviors before and after the implementation of the feature sign. A lower speed indicates a safer environment for pedestrians.

- Compared to the "before implementation" group, the "TURNING VEHICLES YIELD TO PEDESTRIANS" sign reduced the average speed at both the stop line and the second crosswalk slightly on both green and red signal indications.
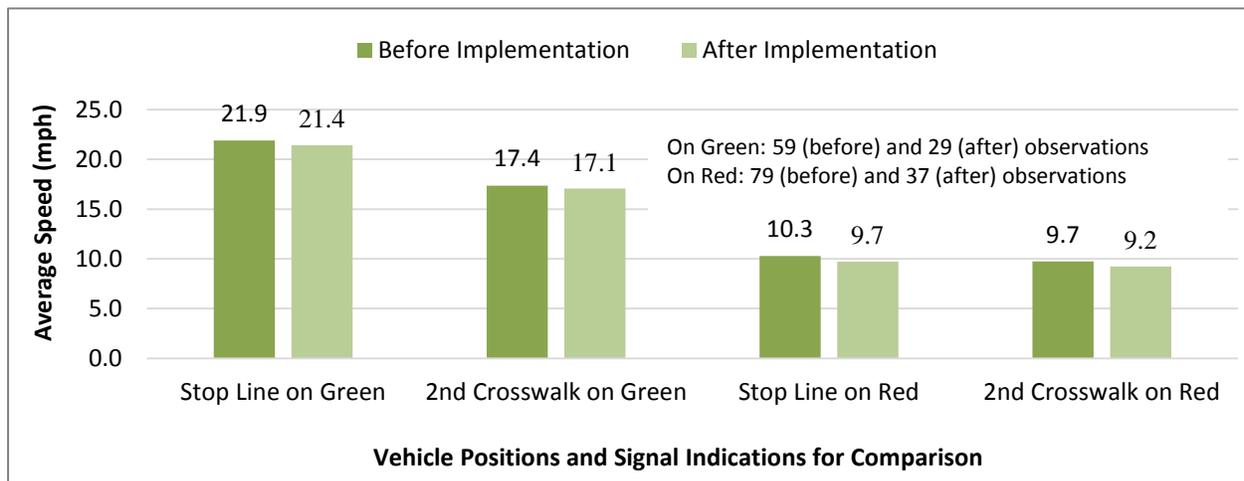
Figure 14. Comparison of average speed before and after implementation of "TURNING VEHICLES YIELD TO PEDESTRIANS" sign

4.3.4 Individual Analysis: Comparison of Compliant Behaviors by Gender at Feature Sites

Figure 15 compares the driver compliant behaviors at feature sites by gender.

- For "NO TURN ON RED" and "TURNING VEHICLES YIELD TO PEDESTRIANS" signs, female drivers were more likely to comply with the feature than male drivers.
- For the "STOP HERE ON RED" sign, female drivers were less likely to comply (stopping before stop line) than male drivers.
- For the "RIGHT ON RED ARROW AFTER STOP" sign, the difference between female and male drivers was very small.
- Overall, the sample size was small for this comparison. There was no statistically significant difference due to small sample sizes.
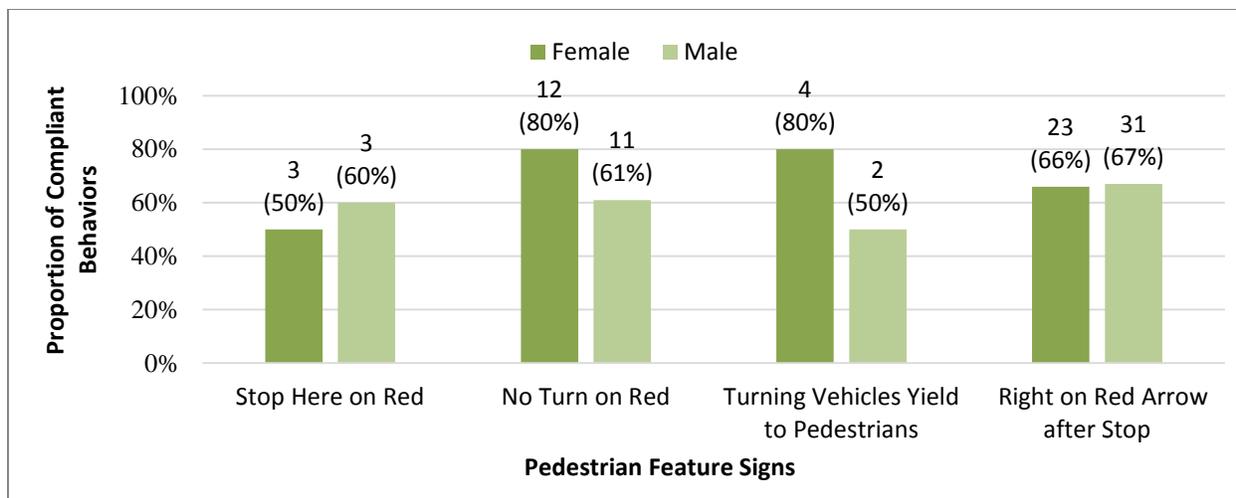
Pedestrian Feature Signs	Gender	Non-Compliant Counts	Compliant Counts	Total Counts	% Compliant Behaviors
STOP HERE ON RED	Female	3	3	6	50%
	Male	2	3	5	60%
NO TURN ON RED	Female	3	12	15	80%
	Male	7	11	18	61%
TURNING VEHICLES YIELD TO PEDESTRIANS	Female	1	4	5	80%
	Male	2	2	4	50%
RIGHT ON RED ARROW AFTER STOP	Female	12	23	35	66%
	Male	15	31	46	67%

Figure 15. Comparison of compliant behaviors by gender

4.3.5 Individual Analysis: Comparison of Compliant Behaviors by Age at Feature Sites

Figure 16 compares the driver compliant behaviors at feature sites by age.

- At sites with "NO TURN ON RED" and "TURNING VEHICLES YIELD TO PEDESTRIANS" signs, older drivers (age 60+) were more likely to comply with the feature (100%).
- At sites with "RIGHT ON RED ARROW AFTER STOP" signs, mid-aged drivers (25–59) showed the highest proportion of compliance (94%), followed by older drivers (63%) and younger drivers (60%).
- Only the comparison for "RIGHT ON RED ARROW AFTER STOP" sign is statistically significant.

*Statistically significant at a confidence level of 95%

Pedestrian Feature Signs	Age Group	Non-Compliant Counts	Compliant Counts	Total Counts	% Compliant Behaviors
STOP HERE ON RED	16-24	3	5	8	63%
	25-59	0	1	1	100%
	60+	2	0	2	0%
NO TURN ON RED	16-24	7	10	17	59%
	25-59	3	8	11	73%
	60+	0	5	5	100%
TURNING VEHICLES YIELD TO PEDESTRIANS	16-24	2	5	7	71%
	25-59	1	0	1	0%
	60+	0	1	1	100%
RIGHT ON RED ARROW AFTER STOP	16-24	23	34	57	60%
	25-59	1	15	16	94%
	60+	3	5	8	63%

Figure 16. Comparison of compliant behaviors by age

4.3.6 Overall Analysis: Impacts of Pedestrian Presence

Figure 17 shows the overall comparison of the compliant behaviors with/without pedestrians between feature and control groups.

- Drivers showed much higher compliance at the feature sites than that at the control sites (67% vs. 29%) when pedestrians were not present at intersections. The difference was statistically significant. This finding indicates that drivers will most likely comply with pedestrian features at feature sites even though there are no pedestrians present or drivers do not see them.
- Drivers were generally sensitive to pedestrian presence at both feature sites and control sites. The compliance percentages for both groups were higher when pedestrians were present than when pedestrians were absent.
- Drivers were more likely to comply with the feature at feature sites than at control sites when pedestrians were present (77% vs. 50%). However, there was no evidence to show the difference was statistically significant due to a small sample size.

Pedestrian Presence	Comparison Group	Non-Compliant Counts	Compliant Counts	Total Counts	% Compliant Behaviors
Without Pedestrians	Control Group	67	27	94	29%
	Feature Group	34	69	103	67%
With Pedestrians	Control Group	7	7	14	50%
	Feature Group	6	20	26	77%
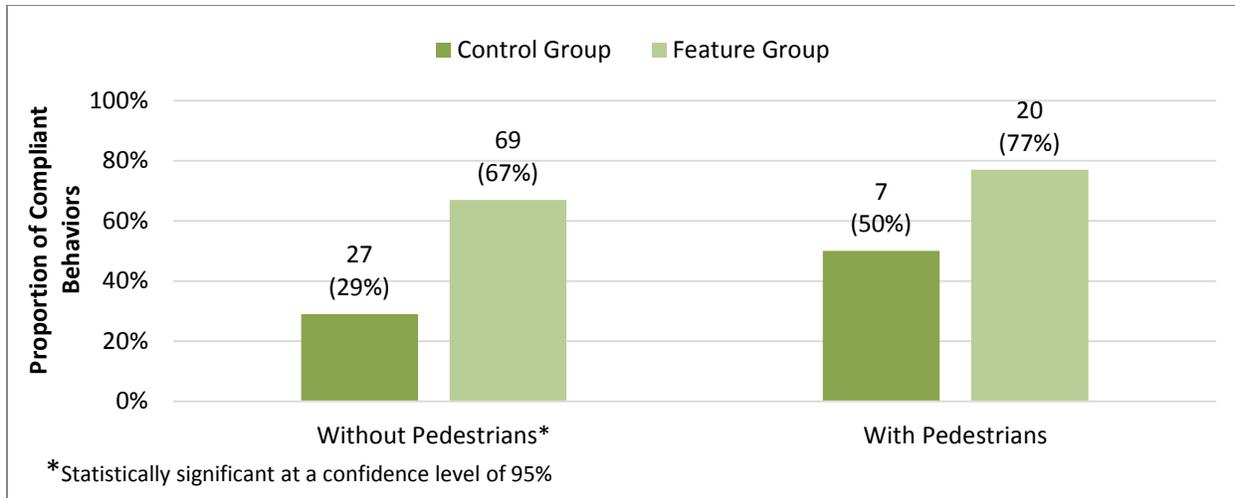
Figure 17. Comparison of compliant behaviors with/without pedestrian presence

4.3.7 Overall Analysis: Impacts of Driver Demographics at Feature Sites

Figure 18 shows the overall comparison of the driver compliant behaviors by gender and age.

- Female drivers showed a slightly higher percentage of compliance than male drivers at feature sites (69% vs. 64%).
- Mid-age drivers (25–59) showed the highest percentage of compliance at feature sites (83%), followed by older drivers (60+, 69%) and younger drivers (16–24, 61%). The differences were statistically significant at a confidence level of 90%.
- A possible explanation is that younger drivers take more risks and older drivers' detection/control abilities are reduced. Safety countermeasures at intersections should consider the specific needs for younger and older drivers.
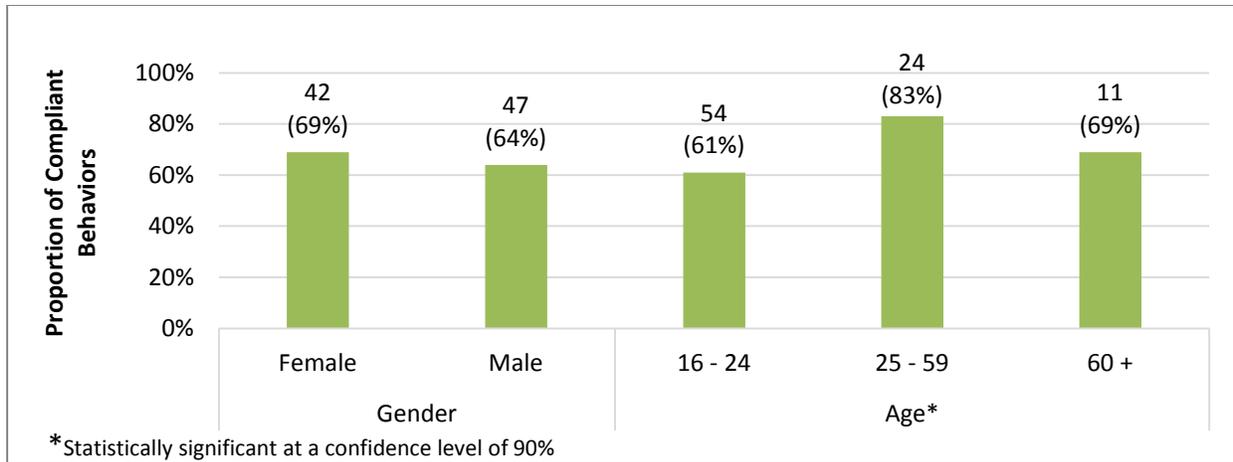
Driver Demographics		Non-compliant Counts	Compliant Counts	Total Counts	%Compliant Behaviors
Gender	Female	19	42	61	69%
	Male	26	47	73	64%
Age Group	16-24	35	54	89	61%
	25-59	5	24	29	83%
	60+	5	11	16	69%

Figure 18. Comparison of compliant behaviors by gender and age

4.3.8 Overall Analysis: Impacts of Driver Characteristics on Compliant Behaviors

The NDS dataset includes data from questionnaires of participants taken during intake in the driving study. These were general questions about their driving habits. Two questionnaires were used to determine risky behavior: the "Risk-Taking" and the "Driver Behavior" questionnaires. Ten questions were considered to determine the level of risk-taking, e.g., "Do you run red lights, fail to yield, make illegal turns, etc.?," and driver attention, e.g., "Do you conduct secondary tasks while driving?" "Do you adjust the CD player or pick up things?" "Do you take your eyes off the road to talk to your passenger?" Based on the replies to those questions, drivers were clustered into two groups according to a perceived risk level and distraction level. Chi-square tests were conducted to compare the percentage of drivers belonging to a group (based on self-evaluation) by driver characteristics, as shown in Figure 19.

- By self-evaluation, more female drivers were clustered in the groups of "more risky" and "more distracted" than male drivers. The difference was significant in terms of distraction.
- By self-evaluation, younger drivers (16–24) took significantly more risks than age groups 25–59 and 60+ drivers; younger drivers (16–24) and mid-age drivers (25–59) were significantly more likely to be distracted than older drivers (60+).

- By self-evaluation, older drivers (60+) took significantly fewer risks and were less likely to be distracted than other drivers.
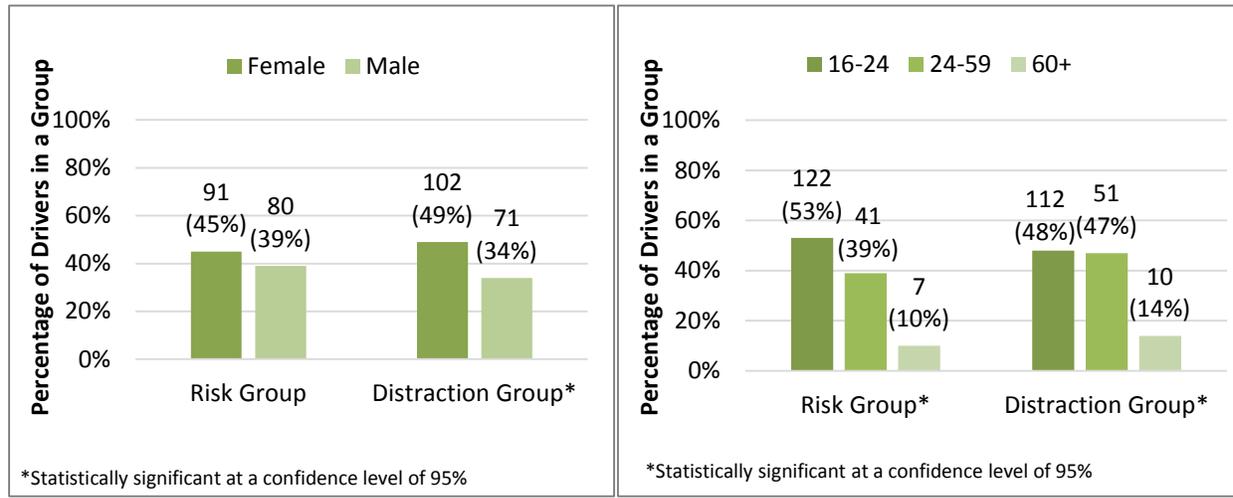
Driver Demographics		Risk Level			Distraction Level		
		Risk Counts	*Total Counts*	*% in Risk Group*	*Distraction Counts*	*Total Counts*	*% in Distraction Group*
Gender	Female	91	203	45%	102	209	49%
	Male	80	203	39%	71	209	34%
Age Group	16-24	122	231	53%	112	234	48%
	25-59	41	105	39%	51	109	47%
	60+	7	68	10%	10	73	14%

Figure 19. Comparison of risk and distraction levels by gender and age

To link the subjective risk to objective behavior observations, the compliance behaviors were compared by risk levels for "NO TURN ON RED" and "RIGHT ON RED ARROW AFTER STOP" signs. Due to limited sample size, the other feature signs were not compared. As shown in Figure 20, drivers in the "less risky" group were more likely to comply with the "NO TURN ON RED" sign than drivers in the "more risky" group.

Pedestrian Feature Signs	Comparison Group	Non-Compliant Counts	Compliant Counts	Total Counts	% Compliant Behaviors
NO TURN ON RED	More Risky	5	6	11	55%
	Less Risky	5	17	22	77%
RIGHT ON RED ARROW AFTER STOP	More Risky	14	28	42	67%
	Less Risky	13	26	39	67%
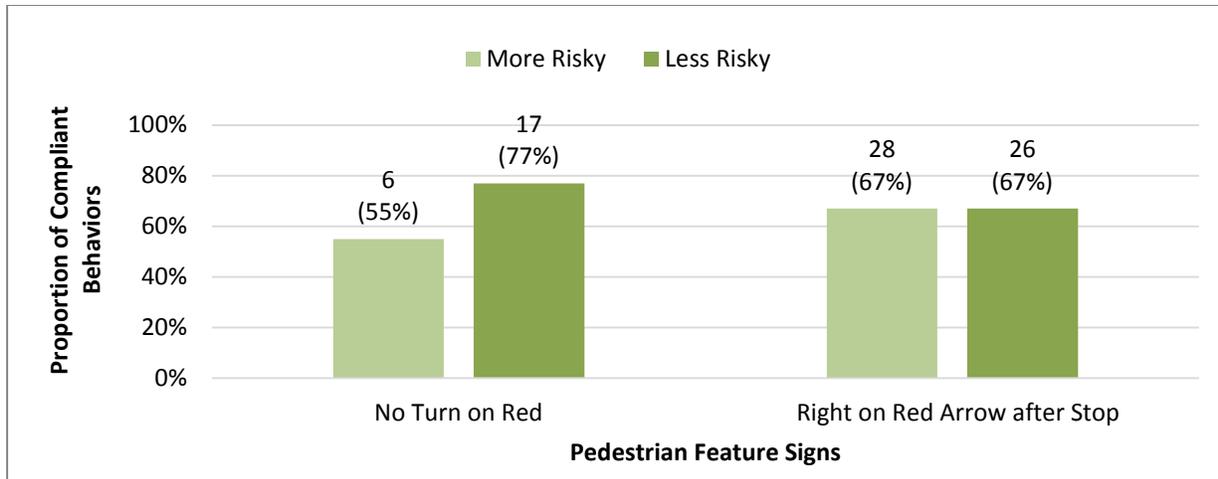
Figure 20. Comparison of compliant behaviors by risk levels

Figure 21 compares the consistency of compliant driver behaviors by gender and age groups.
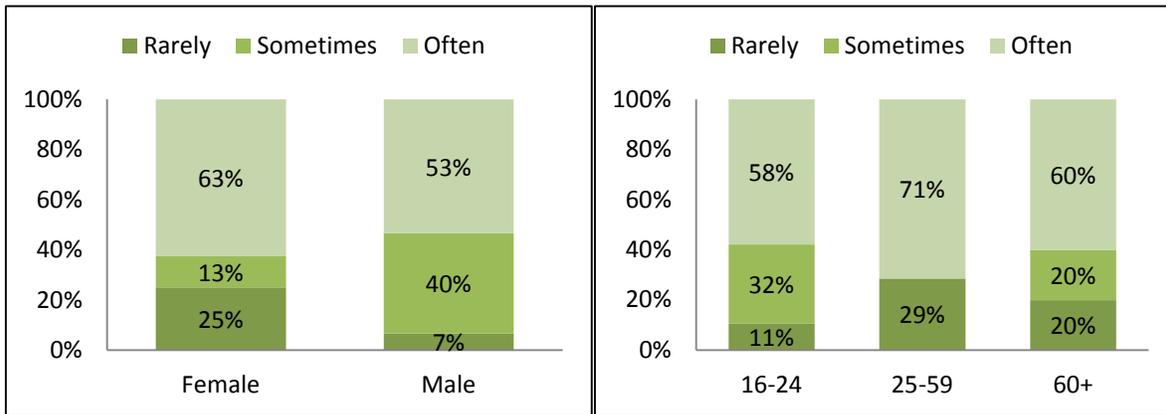
Driver Demographics		Counts				Percentages		
		Rarely	*Sometimes*	*Often*	*Total*	*Rarely*	*Sometimes*	*Often*
Gender	Female	4	2	10	16	25%	13%	63%
	Male	1	6	8	15	7%	40%	53%
Age Group	16-24	2	6	11	19	11%	32%	58%
	25-59	2	0	5	7	29%	0%	71%
	60+	1	1	3	5	20%	20%	60%

Rarely: frequency <= 20%; Sometimes: frequency = 20–60%; Often: frequency >= 60%

Figure 21. Compliance consistency by gender and age

The understanding of consistency of compliant driver behaviors by gender and age group can help identify demographics to focus educational outreach and law enforcement. Some initial observations about compliance consistency from this project are the following:

- Female drivers tended to be more consistent in complying with the feature than male drivers.
- Mid-age drivers tended to be more consistent in complying with the feature than others.
- Due to a small sample in this project, it is difficult to reach a confident conclusion on compliance patterns by driver characteristics and intersection features.

Chapter 5 – Summary of Findings and Future Direction

The ultimate goal of this research project was to use the SHRP2 NDS and RID datasets to better understand the interactions between drivers and pedestrian features at signalized intersections and to develop effective countermeasures to significantly increase pedestrian safety. Through this pilot project, researchers obtained initial research results and a preliminary understanding of interactions between drivers and pedestrian features at signalized intersections. In addition, the CUTR team built an NDS Automatic Video Processing Tool and a Data Reduction and Analysis Tool for managing and analyzing large NDS datasets. The research team also demonstrated the capability to effectively work with the NDS and RID databases. This project has built a solid foundation for future study towards achieving the final goal of this research project.

5.1 Summary of Findings

- The proportion of compliant driver behaviors, which is defined based on a specific feature intention, is an effective measure of the interactions between drivers and pedestrian features. The "NO TURN ON RED" sign had the highest rate of compliance (70%), followed by "RIGHT ON RED ARROW AFTER STOP" (67%), "TURNING VEHICLES YIELD TO PEDESTRIANS" (67%), and "STOP HERE ON RED" (55%).
- Three features ("STOP HERE ON RED," "NO TURN ON RED," and "RIGHT ON RED ARROW AFTER STOP" signs) increased the likelihood of compliant behaviors compared to the control groups.
- Drivers had a much higher compliance percentage at the feature sites than at the control sites (67% vs. 29%) when pedestrians were not present at intersections. The difference was statistically significant.
- Drivers were generally sensitive to pedestrian presence at both the feature sites and the control sites. Their compliance percentages for both groups were higher when pedestrians were present than those when pedestrians were absent.
- Drivers were more likely to comply with the feature at feature sites than at control sites when pedestrians were present (77% vs. 50%). However, there was no evidence to show the difference was statistically significant due to a small sample size.
- Based on self-evaluation, female drivers were significantly more likely to believe they are easily distracted when driving compared to male drivers. Older drivers (age 60+) believe they take significantly fewer risks and are less distracted than other drivers.
- Female drivers tended to comply more consistently with the feature than male drivers.
- Mid-age drivers tended to comply more consistently with the feature than others.

5.2 Summary of Lessons Learned

- The assessment of the pedestrian feature signs, especially "TURNING VEHICLES YIELD TO PEDESTRIANS," needs more pedestrian observations.

- The limited sample sizes may result in insignificant comparisons of compliant behaviors by driver characteristics (e.g., age, gender, risk and distraction levels). A larger sample size is expected to draw confident conclusions and obtain insight into compliance patterns by driver characteristics and intersection features.
- In this project, 2,700 videos were requested and provided by VTTI, but 16% were not usable for several reasons: (1) the video was obstructed by an object on the vehicle's windshield, the video resolution was so low that features could not be determined, (2) the video was blurred (out of focus), (3) there was no video (file was blank), or (4) the video segment provided started in the wrong place since the main interest was when a driver was passing through an intersection. VTTI may need to check closely to ensure the quality of the video data before sending it to researchers. The research team needs to find a way to quickly check the video data received from VTTI to make sure all are usable for the study. In this way, if there is any issue with the video data, the research team can contact VTTI to resolve the problem in the early stages of the study.
- The research team demonstrated the capabilities and methodologies to effectively use the SHRP 2 NDS and RID databases to study interactions between drivers and pedestrian features at signalized intersections. With larger datasets in future research, the research team can obtain the needed sample size and apply the approach proven in this project to conduct the research and obtain robust conclusions, which can result in effective countermeasure development to improve pedestrian and bicycle safety at signalized intersections.

5.3 Recommendations on Future Study

The initial research results and preliminary findings offer valuable insight into the effectiveness of specific pedestrian features and the effect of driver characteristics on their compliance with individual pedestrian features. A small sample size was used in this project to examine selected pedestrian features at signalized intersections, calibrate proposed methodologies for data analyses, and test the Automatic Video Processing Tool and the Data Reduction and Analysis Tool. A larger sample size is needed in future studies for researchers to conduct detailed qualitative and quantitative analyses to obtain a better understanding of the effectiveness of selected pedestrian features at signalized intersections and the effect of driver characteristics on their compliance with individual pedestrian features.

Based on the success and lessons learned from this project, the future research plan, NDS data request, analysis methodologies, and research tools are expected to be modified and enhanced on (1) interactions between drivers and pedestrian features at signalized intersections and (2) driver characteristics, behaviors, and performance with respect to studied pedestrian features. Based on the experience obtained in this project, the potential outcomes of future studies include the following:

1. Better understanding and detailed findings of the effectiveness of selected pedestrian features at signalized intersections with and without the presence of pedestrians.

2. Better understanding and detailed findings of driver behaviors and their compliance with studied pedestrian features at signalized intersection with respect to age, gender, and driving attitudes.
3. Development of countermeasures for implementation to effectively improve pedestrian and bicycle safety at signalized intersections based on the effectiveness of studied pedestrian features and driver characteristics.
4. Development of robust research tools to extract and analyze NDS data and recorded videos at signalized intersections to detect the presence of pedestrians, identify traffic signal indications, and organize NDS data for detailed analysis.

At present, FDOT and local traffic agencies do not have a clear understanding of the effectiveness of pedestrian features at signalized intersections, with and without the presence of pedestrians. They also do not know the population and demographics on which to focus for educational outreach and law enforcement that will result in significant improvement of their compliance with pedestrian features at signalized intersections. Future studies likely will result in important findings that will lead to the development of implementable countermeasures or changes in policy/practice, including engineering, education, and enforcement approaches. These improvements could lead to crash reductions and major safety improvements for pedestrians at signalized intersections in Florida. The research results on driving behaviors at signalized intersections will also result in new insights concerning crash causal mechanisms.

From the engineering perspective, the pedestrian features at signalized intersections with high effectiveness (high compliance from drivers) can be integrated into FDOT and local traffic agency policy/practice and widely implemented to improve pedestrian safety at little additional expense. For pedestrian features with low compliance, FDOT and local traffic agencies should reexamine their policies/practices for implementation or significantly reduce the number of these pedestrian features at signalized intersections.

From the education perspective, the understanding of driver behaviors and their non-compliance with specific pedestrian features with respect to age, gender, and driving attitudes can help FDOT and local traffic agencies develop educational outreach/campaigns to focus on specific demographics of drivers to improve their compliance.

From the law enforcement perspective, FDOT can coordinate with law enforcement agencies in Florida via existing high-visibility contracts for enforcing pedestrian and bicycle laws for the pedestrian features at signalized intersections with low compliance.

A combined engineering, education, and enforcement approach could produce many more benefits in reducing traffic-related fatalities, injuries, and crashes than implementation of any individual approach. Therefore, future studies likely will result in implementable safety improvements that can be effectively put into practice.

The direction of future studies can build on the foundation of this project produce tangible outcomes and detailed findings, which will lead to the development of implementable countermeasures. Future studies should continue to align with the American Association of State Highway and Transportation Officials (AASHTO) Safety Task Force's focus areas of (1)

driver speed, (2) roadway features and driver performance, (3) preceding contributory events, (4) vulnerable road users, and (5) intersections.

References

Fitzpatrick, K., V. Iragavarapu, et al. 2014. "Characteristics of Texas Pedestrian Crashes and Evaluation of Driver Yielding at Pedestrian Treatments" (No. FHWA/TX-13/0-6702-1). TxDOT Report FHWA/TX-13/0-6702-1.

Herman, H. 2000. "The Effects of No Turn on Red/Yield to PEDS: Variable Message Signs on Motorist and Pedestrian Behavior." University of North Carolina at Chapel Hill, Florida Department of Transportation, 15-20.

Karkee, G., S. S. Pulugurtha, and S. S. Nambisan. 2006. "Evaluating the Effectiveness of 'Turning Traffic Must Yield to Pedestrians (R 10-15)' Sign." *Applications of Advanced Technology in Transportation*, 400-405, ASCE.

Pecheux, K., J. Bauer, and P. McLeod. 2009. "Pedestrian Safety Engineering and ITS-Based Countermeasures Program for Reducing Pedestrian Fatalities, Injury Conflicts, and Other Surrogate Measures Final System Impact Report." Federal Highway Administration, Washington, DC.

Pulugurtha, S. S., S. S. Nambisan, et al. 2010. "Evaluation of Effectiveness of Traffic Signs to Enhance Pedestrian Safety." *Transportation Research Board 89th Annual Meeting (No. 10-1016)*.

Appendix A – IRB Approval Letter

USF
UNIVERSITY OF
SOUTH FLORIDA

RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-4799
(813) 974-5638 • FAX (813) 974-7091

March 9, 2015

Pei-Sung Lin, Ph.D., P.E., PTOE
CUTR - Center for Urban Transportation Research
4202 E. Fowler Ave, CUT 100
Tampa, FL 33620

RE: **NOT Human Research Activities Determination**
IRB#: Pro00021230
Title: Understanding Interactions between Drivers and Pedestrian Features at Signalized
Intersections

Dear Dr. Lin:

The Institutional Review Board (IRB) has reviewed the information you provided regarding the above referenced project and has determined the activities do not meet the definition of human subjects research. Therefore, IRB approval is not required. If, in the future, you change this activity such that it becomes human subjects research, IRB approval will be required. If you wish to obtain a determination about whether the activity, with the proposed changes, will be human subjects research, please contact the IRB for further guidance.

All research activities, regardless of the level of IRB oversight, must be conducted in a manner that is consistent with the ethical principles of your profession and the ethical guidelines for the protection of human subjects. As principal investigator, it is your responsibility to ensure subjects' rights and welfare are protected during the execution of this project

Also, please note that there may be requirements under the HIPAA Privacy Rule that apply to the information/data you will use in your activities. For further information about any existing HIPAA requirements for this project, please contact a HIPAA Program administrator at 813-974-5638.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

John Schinka, Ph.D., Chairperson
USF Institutional Review Board

Appendix B – IRB Protocol

*Title***: Understanding Interactions between Drivers and Pedestrian Features
at Signalized Intersections**

PI: Pei-Sung Lin   Co-PI: Achilleas Kourtellis

Rationale and Background

Florida experienced serious pedestrian safety problems and had the highest pedestrian fatality rate in the U.S. from 2008–2011 based on National Highway Traffic Safety Administration (NHTSA) Traffic Safety Facts annual reports. The 2014 edition of *Dangerous by Design* ranked four metropolitan areas in Florida as the top four most dangerous areas to walk in the U.S.— Metro Orlando, Tampa–St. Petersburg, Jacksonville, and Miami. The potential reasons were mostly due to the rapid spread of low-density neighborhoods that rely on wider streets with higher speeds to connect homes, shops, and schools—roads that tend to be more dangerous for people walking.

One of Florida's highest priorities is investigating major contributing causes for pedestrian fatalities and developing effective countermeasures to significantly improve pedestrian safety in the state. This proposed project intends to research and understand the interactions between drivers and pedestrian features (e.g., pedestrian signs, pedestrian signals, traffic signals, crosswalks, and pavement markings) at signalized intersections. Understanding these interactions can help the Florida Department of Transportation (FDOT) develop effective countermeasures to improve pedestrian safety. The Strategic Highway Research Program 2 (SHRP 2) Naturalistic Driving Study (NDS) recorded the driving behavior of a large sample of drivers in their personal vehicles, offering project researchers comprehensive naturalistic driving behavioral data for researching the interactions between drivers and various pedestrian features at selected signalized intersections through which they drove. This provides great and unique opportunities to research the proposed research question in this project.

Existing Research

This research is original and has no precedence, since the SHRP2 NDS database was created and completed in December 2014. Similar research has used other methods such as observations to aid in identifying how drivers might interact with features at intersections.

Research Objectives, Questions and Purpose

Our major proposed research question is: "How do drivers interact with pedestrian features at signalized intersections when pedestrians are or are not present?" These pedestrian features include pedestrian signs, pedestrian signals, traffic signals, crosswalks, and pavement markings.

Driver interactions with pedestrian features may be observed from driver responses to different pedestrian features, yielding behaviors to pedestrians, driver speeds, braking patterns, and attention and/or distraction. The proposed research question will cover four broad topics: Vulnerable Road Users, Roadway Features and Driver Performance, Intersections, and Driver Speed. Gender and age group will be included in the research.

The findings of the research can help FDOT to fully understand 1) driver interactions with various pedestrian features at signalized intersections, 2) the effectiveness of pedestrian features, 3) the impact of gender and age group on driver interactions, 4) specific interactions between drivers and pedestrians, and 5) the impact of driver attention and/or distraction on driver interactions. These understandings can assist FDOT in developing effective engineering, education, and enforcement strategies and countermeasures to reduce pedestrian fatalities and enhance pedestrian safety in Florida.

Project Objectives

The main objectives of this Phase I project are to:

1. Acquire knowledge and requested data from the SHRP2 NDS and RID datasets to conduct initial analysis on driver interactions with pedestrian features at signalized intersections.
2. Develop effective tools and identify specific parameters and factors that will aid in initial analysis in the Phase I project and full analysis in the Phase II project pertaining to the research question.
3. Conduct initial analysis using a more manageable dataset of acquired NDS data, provide initial findings on the research question, and offer recommendations that can be implemented by FDOT in a Phase II project.
4. Demonstrate the success from concept to countermeasures via the Phase I project to support a Phase II project.

Questions

These research questions are to be answered with the data acquired during the study. Specific questions are:

1. What are the driver interactions with different pedestrian features at signalized intersections?
2. What is the effectiveness of a specific pedestrian feature?
3. What are specific interactions between drivers and pedestrians?
4. Will drivers interact with pedestrian features differently when pedestrians are present?
5. What are the impacts of driver characteristics such as gender and age group on driver interactions?

6. What are the impacts of driver attention and/or distraction on driver interactions?

Study Design

The data were collected during the SHRP2 Naturalistic Driving Study (USF IRB#Pro00001238). The data are housed and shared by Virginia Tech Transportation Institute (VTTI) with a Data Sharing Agreement contract. The participants of the SHRP2 NDS study were healthy adults and minors from ages 16 and up with an eligible vehicle and residing in the study areas defined as counties of interest. The study had total of six sites at the following locations:

- USF, Tampa, FL
- CUBRC, Buffalo, NY
- Penn State, State College, PA
- Indiana University, Bloomington, IN
- Westat, Durham, NC
- Battelle, Seattle, WA

For the current study, VTTI will provide datasets related to traversals of SHRP2 NDS participants through intersections in the Tampa Area only, which the CUTR team will specify. VTTI will provide the number of trips, traversals, and participants traversing those intersections. The CUTR team will then make a final selection of intersections based on the data available.

For this pilot study, CUTR requires data for approximately 15 signalized intersections. CUTR wants data from 54 different drivers traversing these intersections. These drivers should each provide a minimum of 50 traversals through the chosen intersection. CUTR wants the drivers to be evenly distributed across age groups (9 different possibilities to be defined by CUTR) and gender. This implies that CUTR will receive data for approximately 2,700 signalized intersection traversals.

VTTI will provide CUTR with the following datasets based on the final selection of intersections. Note that VTTI will not be providing Roadway Information Database (RID) data to CUTR. Also note that the traversals of the selected intersections will not occur near the beginning or end of the trip (defined as a pre-determined distance from trip origin or destination; the distance contains a limited random noise element to further anonymize the trip).

Expected Results

The quantitative methods including statistical analysis will be applied to compare the impacts of different pedestrian features on driving behaviors with or without the presence of pedestrians. The effectiveness of specific pedestrian features on driving behaviors will be evaluated. For data that include interactions between drivers and pedestrians, further analysis will be conducted to understand how the pedestrian features at signalized intersections affect driver yield behaviors to

pedestrians. The impact of driver characteristics on driver interaction with pedestrian features also will be examined.

The initial data analysis in the Phase I project will help answer the major research question: How do drivers interact with pedestrian features at signalized intersections when pedestrians are or are not present? Specifically, the initial data analysis in Phase I intends to provide the initial answers to the following specific research questions:

1) What are the driver interactions with different pedestrian features at signalized intersections?
2) What is the effectiveness of a specific pedestrian feature?
3) What are specific interactions between drivers and pedestrians?
4) Will drivers interact with pedestrian features differently when pedestrians are present?
5) What are the impacts of driver characteristics such as gender and age group on driver interactions?
6) What are the impacts of driver attention and/or distraction on driver interactions?

The aim is to produce findings based on driver-infrastructure interaction and driver-pedestrian interaction.

Name of Principal Investigator

Pei-Sung Lin, Ph.D., P.E., PTOE, FITE, Program Director of the ITS, Traffic Operations and Safety Program at the Center for Urban Transportation Research (CUTR) at USF.

Potential Risks to Subjects

No risk is associated with analysis of these data. The data were collected and are stored with the highest importance on security and confidentiality. No identifiable information will be shared with the research team unless an additional agreement is in place to access the driver video which includes the driver's face. This can only occur if present at the VTTI secure data enclave, and no data will leave the site.

Potential Benefits to Subjects

No identified benefits to the subjects are available.

General information about the NDS can be found at www.drivingstudy.org.

Appendix C – VTTI Scope of Work

VTTI COST PROPOSAL

SHRP 2 NDS Data Support for CUTR, University of South Florida

Submitted to:

Achilleas Kourtellis

Prepared by:

Miguel Perez

Joel Kady

Virginia Tech Transportation Institute

3500 Transportation Research Plaza (0536)

Blacksburg, VA 24061

(540) 231-1537

February 14, 2015

General Statement of Work, Deliverable Schedule, and Budget

Objective

The purpose of this effort is to support the use of various components of the SHRP 2 NDS database by personnel from CUTR, who would like to assess the interactions between drivers and pedestrian features at signalized intersections. CUTR will use the requested SHRP2 NDS and RID datasets in Phase 1 of the Implementation Assistance Program (IAP) to develop data extraction and analysis tools.

Approach

The initial activity in this contract will be to provide CUTR with supporting materials as they generate and submit an Institutional Review Board (IRB) application for this project. Once the IRB application has been approved, the next activity will be to assist CUTR with the execution of a data sharing agreement for the SHRP2 NDS data required to complete this project.

CUTR will receive datasets related to traversals of SHRP2 NDS participants through intersections which CUTR specifies. When CUTR provides VTTI a list of intersections (preferably in the form of link IDs from the Roadway Information Database (RID)), VTTI will provide the number of trips, traversals, and participants traversing those intersections. CUTR may also want to understand the distribution of maneuvers at each of the intersections (e.g., number of left turns). CUTR will then make a final selection of intersections based on the data available.

VTTI understands that CUTR requires data for approximately 15 signalized intersections. CUTR wants data from 54 different drivers traversing these intersections. These drivers should each provide a minimum of 50 traversals through the chosen intersection. CUTR wants the drivers to be evenly distributed across age groups (9 different possibilities to be defined by CUTR) and gender. This implies that CUTR will receive data for approximately 2,700 signalized intersection traversals. A total of 10% of the trips from all drivers need to be a full trip and not a 30-second segment passing at the intersection. Also from those, a 5% sample needs to be during nighttime (9pm–5am).

VTTI will then provide CUTR with the following datasets based on the final selection of intersections. Note that VTTI will not be providing Roadway Information Database (RID) data to CUTR. Also note that the traversals of the selected intersections will not occur near the beginning or end of the trip (defined as a pre-determined distance from trip origin or destination; the distance contains a limited random noise element to further anonymize the trip).

Unless otherwise specified, VTTI will provide these datasets in a CSV (text) file format. When the files contain time series data, the timestamps will be reported on a 10 Hz frequency clock and measures will be aligned to the closest timestamp.

Trip Summary Measures. These measures will be for the trips in which the selected intersections are traversed. The variables will be:

- Brake Activations
- % CTRE Van Cov
- % HSIS Derived Rd Class
- % Other Class
- % Rur 2 Ln
- % Rur Frwy
- % Rur Frwy < 4 Lns
- % Rur Multi Div Non-Frwy
- % Rur Multi Undiv Non-Frwy
- % State Data Cov
- % Urb 2 Ln
- % Urb Frwy
- % Urb Frwy < 4 Lns
- % Urb Multi Div Non-Frwy
- % Urb Multi Undiv Non-Frwy
- % No Spd Lim Data
- % Spd Lim 35 or Less
- % Spd Lim 40-50
- % Spd Lim 55-65
- % Spd Lim 70 or Greater
- Trip Start Local Time Hour of Day
- Trip End Local Time Hour of Day
- ABS Available
- ABS Activation
- Mean Speed
- Max Speed
- Turn Signal Available
- Turn Signal Activations
- Cell Phone Flag

Events. These events will be near-crashes that occurred at the selected intersections (crashes cannot be provided because they could be used to identify the participants). The variables will be:

- Event Nature 1
- Event Nature 2

- Relation To Junction
- Incident Type 1
- Incident Type 2
- Intersection Influence
- Final Narrative
- Driver Behavior 1
- Driver Behavior 2
- Driver Behavior 3
- Secondary Task 1
- Secondary Task 1 Start Time
- Secondary Task 1 End Time
- Secondary Task 1 Outcome
- Secondary Task 2
- Secondary Task 2 Start Time
- Secondary Task 2 End Time
- Secondary Task 2 Outcome
- Secondary Task 3
- Secondary Task 3 Start Time
- Secondary Task 3 End Time
- Secondary Task 3 Outcome

Driver. These data will be provided for the participants represented in the sample. Note that some assessment data, or combinations of assessment data, are considered potentially PII and cannot be provided outside VTTI's secure data enclave. The variables will be:

- Age (provided in age bins)
- Gender
- Behavior Questionnaire (all available answers)
- Risk Taking Questionnaire (all available answers)
- Risk Perception Questionnaire (all available answers)
- Medical Conditions & Medications (all available answers)

Vehicle. These data will be provided for the vehicles represented in the sample. The variables will be:

- Make
- Model
- Year

Time Series. These data will be provided for the trip segments in the sample. A trip segment is defined as the time the participant is on the link IDs which define an intersection. The variables will be selected from the following list, when available for the events of interest:

- vtti.speed_network
- vtti.speed_gps
- vtti.accel_x
- vtti.accel_y
- vtti.accel_z
- vtti.pedal_gas_position
- vtti.head_confidence
- vtti.pedal_brake_state
- vtti.abs
- vtti.turn_signal
- steering wheel position
- wiper setting
- GPS heading
- Timestamp
- subjectID
- video, forward roadway
- latitude and longitude

Video. The video of the forward roadway will be provided for the events of interest. It will be provided in separate MP4-format files which will be linked by name to the time series data file.

The expected period of performance for this statement of work is three months.

In the event CUTR needs to access face video footage for the selected intersection traversals, considered PII, CUTR will need to access the secure data enclave at VTTI premises. A separate cost quote that includes this possibility is provided below. The cost quote assumes that CUTR will need to use the enclave for a week.

Deliverables

VTTI will deliver to CUTR the information and datasets described in the previous section. We will adhere to the planned period of performance of three months, but it is important to note that any subsequent changes to the statement of work may change the delivery period.

Budget

The expected estimated fixed-price cost if CUTR does not require the use of the enclave is $21,001. The corresponding cost including a week of enclave use is $24,084.

Data Sharing Agreement with VTTI

Onsite Use of Identifying Video and Driving Data

Offsite Use of Non-Identifying Driving, Vehicle, Participant, and Crash Data

Disclaimer: This data sharing agreement template has been developed in accordance with the terms specified in the consent forms that participants signed and thus represents a required minimal set of safeguards for participant data. Additional safeguards going above and beyond what the consent document requires may be specified by the individual Institutional Review Boards as they review requests for analyses of the data. Thus, any future modifications or additions to this template will provide additional protections for the use of participant data and will never reduce the protections accorded in the consent document.

Use of Identifiable Video and Driving Data in Secure Data Enclaves

When a researcher, research team, or research institution (hereafter referred to as the receiving agency) requests access to an existing SHRP 2 dataset containing identifying data, the data analysis shall be conducted in a designated secure data enclave within VTTI's facilities. Identifying data for the purposes of this agreement include face video, GPS coordinates, and any other data by which the identity of the participant may be revealed. In this situation, the client comes to the data warehouse site to run analyses in coordination/cooperation with VTTI researchers. The data enclave will be physically and securely separated from other data reduction and analysis efforts at VTTI. All work will be monitored and supported by VTTI staff and completed within the confines of the enclave. There will be an hourly all-inclusive fee for use of the enclave/data which will include the cost of VTTI support.

Release of Non-Identifying Driving, Vehicle, Participant, and Crash Data

Release of streamed data describing driving epochs requires thorough de-identification of data prior to release. De-identification activities (performed by VTTI personnel) and shipping costs will be paid for by the receiving agency. De-identification includes removing at a minimum:

- Dates and times (for example, March 15, 2010, 06:45am could be changed to March, Monday, 6am–12pm)
- Voiceprints
- Full face photos, videos, & comparable images
- De-identifying GPS coordinates
- Full trip files with starting and ending locations shown via forward video
- Files with identifiable highway signs and footage of a high-profile incident (such that research participant identity could be uncovered via news reports)
- Any other types of data that could be used to identify a research participant

Data Sharing Agreement

Use of the data enclave and offsite use of non-identifying driving epochs requires a data sharing agreement signed by the receiving agency. This document indicates agreement with the following:

- The receiving agency must provide a detailed proposal with researcher qualifications prior to beginning work with the dataset. Qualifications should indicate familiarity with and previous use of confidential or proprietary data using human research participants.

- The receiving agency must first obtain IRB permission to conduct the data analysis, and all parties who will be working with identifying data must undergo IRB training. The original research participant consent form will be shared with the receiving agency as part of this process (attached, with data sharing clauses highlighted).

- The receiving agency may not copy or remove files containing identifying data from the data enclave. Reduced, non-identifying files will be provided to the receiving agency by VTTI staff. To ensure data have been de-identified, it may be necessary for VTTI staff to further review the content of files before delivery.

- All personnel working with the data must agree to the working conditions such as leaving cell phones and cameras at the entrance of the data reduction laboratory.

- The receiving agency must agree not to attempt to learn the identity of research participants (e.g., using GPS and video data to locate the research participant's home or work address).

- If the receiving agency discovers identifying information or data in a dataset that was intended to be non-identifying, they must agree to provide that information to VTTI so that it can be properly de-identified for future use (for example, a pedestrian's face is visible and identifying in the forward view).

- The receiving agency must agree not to use data for purposes other than specified in the analysis plan; an additional data sharing agreement will be required for each new set of analyses.

- The receiving agency must agree not to show any identifying data at research conferences.

- The receiving agency agrees to properly acknowledge the source of the data in any reports or articles resulting from the analyses.

- Optional: The receiving agency agrees to return the reduced dataset to VTTI for to be made available to future researchers. In some cases the reduced dataset will have a proprietary nature and can be placed on hold for up to five years before it is provided to other researchers (for example, an OEM develops a crash avoidance algorithm that they hope to incorporate in their future fleet).

- All personnel who will be working with the data must agree not to release or share information leading to the identification of participants or to release or share non-identifying raw data.

Instructions – Please fill out the form and send it back to the Data Sharing Manager at VTTI (datasharing@vtti.vt.edu). The Data Sharing Manager will review the information and send it back to you. You may then sign it and either send a scanned copy of the signed form to datasharing@vtti.vt.edu or fax it to 540-231-1555, attn. Suzie Lee. The Data Sharing Manager will then sign the form and send it back to you, at which point the data sharing process will begin, assuming that the appropriate fiscal contracts are in place at that point.

<div align="center">

Data Sharing Agreement

between the Center for Urban Transportation Research at the University of South Florida
and Virginia Tech Transportation Institute

</div>

1. **Please describe the scope of the proposed analysis (1 paragraph). Please include the full project title and the research sponsor.**

   Project Title: Understanding Interactions between Drivers and Pedestrian Features at Signalized Intersections

   Sponsor: FHWA through FDOT

   Scope: Our major proposed research question is: "How do drivers interact with pedestrian features at signalized intersections when pedestrians are or are not present?" These pedestrian features include pedestrian signs, pedestrian signals, traffic signals, crosswalks, and pavement markings. Driver interactions with pedestrian features may be observed from driver responses to different pedestrian features, yielding behaviors to pedestrians, driver speeds, braking patterns, and attention and/or distraction. The proposed research question will cover four broad topics: Vulnerable Road Users, Roadway Features and Driver Performance, Intersections, and Driver Speed. Gender and age group will be included in the research. The findings of the research can help FDOT to fully understand 1) driver interactions with various pedestrian features at signalized intersections, 2) the effectiveness of pedestrian features, 3) the impact of gender and age group on driver interactions, 4) specific interactions between drivers and pedestrians, and 5) the impact of driver attention and/or distraction on driver interactions. These understandings can assist FDOT in developing effective engineering, education, and enforcement strategies and countermeasures to reduce pedestrian fatalities and enhance pedestrian safety in Florida.

2. **Please describe the dataset you expect to receive (1 paragraph).**

   Please see Appendix A, Data Specification, for full details of the data to be obtained.

   SHRP2 NDS data consist of two large datasets. The main dataset includes naturalistic data from instrumented vehicles and supplemental driver information; the second dataset includes roadway information collected separately. Since the research question targets pedestrian safety, during Phase I of the project, the research team will focus on acquiring the data

stream of vehicles passing from intersections obtained from a Tampa site with high pedestrian activity and/or crash frequency. This will provide a higher possibility of pedestrian encounters. The locations of these intersections will be identified in coordination with FDOT. To minimize the data required, the research team will use a driver sample size that is just sufficient for performing the analysis. This can be expanded to the whole database in Phase II. Since coordination with VTTI is required for the data acquisition, the specific data streams will be requested and filtered to include only a few seconds of video before and after drivers negotiate through the specified intersections. The data requested will include but not be limited to forward video; vehicle forward and lateral acceleration; roll, pitch, and yaw rates; braking; turn indications; headlights; GPS path for the sections; and driver assessment characteristics.

3. **Please describe the researcher qualifications (1 paragraph per researcher).**

Dr. Pei-Sung Lin, P.E., PTOE, FITE (Principal Investigator), is the Director of ITS, Traffic Operations, and Safety Program at the Center for Urban transportation Research (CUTR) at the University of South Florida (USF) and specializes in vulnerable road user safety, naturalistic driving study, behavior research and analysis, IRB process, traffic signal systems, traffic safety, traffic engineering and operations, resource allocation, and project management. He has served as PI for the Florida Comprehensive Pedestrian Safety Program grant for more than four years in support of FDOT to improve pedestrian and bicycle safety and reduce pedestrian- and bicycle-related crashes in Florida. From May 2010 to April 2014, he was Co-PI for SHRP2 Naturalistic Driving Study, Safety Project S07: In-Vehicle Driving Behavior Field Study, Tampa Site. Currently, he serves as PI for the FDOT Naturalistic Bicycling Behavior Pilot Study. His extensive knowledge, expertise, and experience on the SHRP2 Naturalistic Driving Study and Vulnerable Road User Safety grants will significantly benefit the proposed research project. In addition to his outstanding qualifications relevant to the proposed project, he has more than 23 years of work, research, and teaching experience in transportation areas. He has published more than 120 journal papers, conference papers, technical reports, and articles and has given more than 60 professional presentations at various statewide, national, and international conferences. His project management skills, human subject research and IRB experience, vulnerable road user safety knowledge, and traffic engineering and operations expertise will ensure the success of the proposed project. He will work closely with FDOT project managers and lead the CUTR research team to successfully demonstrate proof-of-concept to develop effective countermeasures to significantly improve pedestrian safety in Florida.

Dr. Achilleas Kourtellis (Co-Principal Investigator), is a Research Associate in the ITS, Traffic Operations, and Safety Program CUTR and specializes in naturalistic driving study, controlled driving tests, vehicle mechanisms, vulnerable road user safety, causal analysis,

crash data analysis, and advanced statistical analysis. He has outstanding and valuable experience as manager for the installation and maintenance of the Data Acquisition System (DAS) for the SHRP2 Naturalistic Driving Study, Safety Project S07: In-Vehicle Driving Behavior Field Study, Tampa Site, from January 2011 to October 2013 and is very familiar with the DAS instrument and NDS database. He also closely collaborated with VTTI during the SHRP2 Naturalistic Driving Study, Safety Project S07. In addition, he has served as PI for the FDOT Pedestrian Program Evaluation and Data Collection grants for two years and is the Co-PI for an ongoing FDOT Naturalistic Bicycling Behavior Pilot Study project. His expertise, knowledge, and experience on naturalistic driving study, NDS database, vulnerable road user safety, and casual analysis are essential and valuable to the proposed research project.

Dr. Zhenyu Wang (Researcher), is a Research Associate in the ITS, Traffic Operations and Safety Program at CUTR and specializes in traffic system modeling, transportation safety, development of application tools, software development, contributing factor analysis, crash data analysis, and advanced statistical analysis. He recently developed software and application tools for FDOT, including the Florida Straight-Line Diagram Online GIS Web Application, the Florida Safety Analyst Data Convertor, the Florida Work Zone Crash Database, and Prioritization of Intersections for Safety and Operational Improvements. His research work has been published in many leading scientific and transportation journals and compendia of technical papers. His knowledge and experience on application tool and software development and his excellent analytical capabilities will contribute to the success of the proposed research project.

4. **Please describe what you plan to do with the data when your analyses are complete**.

   The research team plans to publish a technical report to outline the work and findings of the project and analysis as part of the contractual requirements with FDOT. The team also plans to publish academic and technical papers in Journals and conferences related to naturalistic studies and transportation safety and driver behavior.

5. **Please provide proof of IRB permission to conduct the data analysis OR proof of an official exemption from IRB approval. As part of this, all researchers/analysts should provide proof of IRB training. These may be included as attachments.**

   IRB letter of approval and training certificates attached.

6. **In signing this data sharing agreement, the receiving agency agrees to delete the data no later than two years after project completion. Datasets will be archived and curated by the Virginia Tech Transportation Institute and exact duplicates can be obtained as needed for the same project once the two year retention period has passed (e.g., re-analysis in response to a journal reviewer).**

7. **In signing this data sharing agreement, the receiving agency agrees not to attempt to learn the identity of research participants.**

8. **In signing this data sharing agreement, the receiving agency agrees to not distribute the data to other entities or use it for purposes other than those specified in the scope of the proposed analysis. The receiving agency agrees to hold the data in reserve only to answer questions relating to the project described in this data sharing agreement, and to seek an additional data sharing agreement prior to using the data for any other purpose. An additional IRB approval will also be required for additional uses of the data.**

The receiving agency should not sign until all requested information has been received and the agreement has been approved and signed by the VTTI Data Sharing Manager.

Pei-Sung Lin
Name of researcher 1   Date

Signature of researcher 1

Achilleas Kourtellis
Name of researcher 2   Date

Signature of researcher 2

Zhenyu Wang
Name of researcher 3   Date

Signature of researcher 3

Suzanne Lee
Name of VTTI Data Sharing Manager   Date

Signature of VTTI Data Sharing Manager

NOTE: Language from the Primary Driver Information Consent Form related to data sharing is attached to this data sharing agreement.

Primary Driver Informed Consent Language from the
SHRP 2 Naturalistic Driving Study

HOW WILL MY DATA BE KEPT CONFIDENTIAL AND SECURE, AND WHO WILL HAVE ACCESS TO MY DATA?

Any data collected during this study that personally identifies you or that could be used to personally identify you will be treated with confidentiality. As soon as you begin participating in this study, your name and other identifying information will be separated from the raw data collected while you drive the vehicle and replaced with a number. That is, your raw data will not be attached to your name, but rather to a number (for example, Driver 0011). The raw data collected while you drive the vehicle will be encrypted (made unreadable) from the moment it is collected until it is transferred to one or more secure central storage locations. Your name also will be separated from any data about you, either provided by you in response to questionnaires or gathered by researchers during the study, including crash investigation data, and will be replaced by the same driver number (for example, Driver 0011).

Several types of information and data about you and the study vehicle will be collected during the study:

1. **Contact information** includes your name, address, email address, phone numbers, and similar information used to contact you when needed. It will be stored securely in electronic form during the course of the study and destroyed after the study is complete (unless you grant permission for us to keep your contact information when the study is over). This information will not be linked to or mingled with your study data, and will not be used in any research or analysis.

2. **Auxiliary study information** includes your Social Security Number, license plate number, bank account information (for those using direct deposit) and similar information. This information is used to verify your identity and to make payments for your participation. This information will be stored at the site in electronic form (securely encrypted) destroyed after the study is complete. This information will not be linked to or mingled with your study data, and will not be used in any research or analysis.

3. **Driver data** includes your answers to questionnaires, vision test results, and the results of the brief physical tests described above. This data will not contain your name or any identifying information and will be used in analyses, both on its own and in combination with the driving data, vehicle data, and additional crash data. This data will be stored securely in electronic form throughout the lifetime of the data (defined below).

4. **Vehicle data** includes the vehicle make and model, its condition, and how it is equipped. This data will not contain your name or any identifying information and will be used in

analyses, both on its own and in combination with the driver data, driving data, and additional crash data. This data will be stored securely in electronic form throughout the lifetime of the data (defined below).

5. **Driving data** includes the data we collect from the vehicle while you are driving, including video data and sensor data. This information will contain video of your face and GPS coordinates of your trips, both of which could be used to personally identify you. These data will be encrypted (stored in an unreadable format) from the moment of their creation until they are downloaded from the vehicle, transferred to a secure data storage facility, and verified. From this point on they will be decrypted (made readable) on as-needed basis for each analysis. These data will be used for analysis, both on their own and in combination with the driver data, the vehicle data, and the additional crash data. This data will be stored securely in electronic form throughout the lifetime of the data (defined below).

6. **Additional crash data** includes items we may collect after a crash, including answers to an interview with one of our researchers and the police accident report resulting from the crash. This data will not contain your name or any identifying information and will be used in analyses, both on its own and in combination with the driver data, vehicle data, and driving data. This data will be stored securely in electronic form throughout the lifetime of the data (defined below).

It is possible that an authorized Institutional Review Board (IRB) may view this study's collected data for auditing purposes. An IRB is responsible for the oversight of the protection of human subjects involved in research.

It is also possible that the study sponsors or investigators may view this study's driver data and driving data for quality control or administrative purposes; in this case, the study sponsors or investigators will be required to maintain the security and confidentiality of any data that personally identifies study participants or that could be used to personally identify study participants.

While driving the vehicle, a camera will videotape your face with some added space around the head to handle any head movements. An example is shown below. Also, video cameras will capture views of the forward view, the rear view, an external view to the right, as well as a dashboard/lap-belt view. A camera will also periodically take a permanently blurred snapshot of the vehicle interior which will allow researchers to count the number of passengers and make rough estimates of age, gender, and seatbelt use. Passenger identification will not be possible from these blurred snapshots. All video will be captured and stored in digital format (no tape copies will exist).

There will also be an ambient atmospheric analyzer that is capable of detecting the presence of alcohol in the passenger compartment under certain conditions. It may not be able to distinguish

whether the alcohol was imbibed or applied (as in hand sanitizer), and it will be unable to determine whether it is emanating from the driver or a passenger. However, this sensor will flag the data for possible indications of impaired driving.

If a safety-related incident or crash occurs, you are asked to press a button on the unit mounted near the rearview mirror. You will know this button is working if a red light appears when you press it. This will allow researchers to find the incident in the database after the data have been collected. Also, pressing the button starts a microphone for 30 seconds. During these 30-seconds, you can tell us what happened. No audio will be captured except when you press this incident button. Please note that pressing this button does NOT make a phone call, unlike OnStar™. It simply records your voice in an audio file that remains in the vehicle until the data is collected.

During the data collection phase of this study, all data collected from the vehicle will be encrypted (made unreadable) from the time of its creation and then stored in a specific password-protected project folder on a secure server; the driving data will only be decrypted (made readable) once it has been stored in this folder. At the conclusion of the collection phase of this study, the driver data, driving data, and additional crash data will be permanently housed at one or more highly secure data storage facilities. One set of data will be permanently housed at Virginia Tech under the supervision of the Virginia Tech Transportation Institute, the organization overseeing the data collection for the entire study. It is possible that, after data collection is complete, one copy of study data will be transferred to the U.S. Department of Transportation (or other secure facilities as determined by the Transportation Research Board) for permanent storage and oversight.

Only authorized project personnel and authorized employees of the research sponsors will have access to study data that personally identifies you or that could be used to personally identify

you. As explained below, other qualified research partners may be given limited access to your driver data, vehicle data, driving data, and additional crash data, solely for authorized research purposes and with the consent of an IRB. This limited access will be under the terms of a data sharing agreement or contract that, at a minimum, provides you with the same level of confidentiality and protection provided by this Consent Form. However, even these qualified researchers will not be permitted to copy raw study data that identifies you, or that could be used to identify you, or to remove it from the secure facilities in which it is stored without your consent.

Project personnel, the project sponsors and qualified, authorized research partners may show specific clips of video at research conferences. The project sponsors also may show specific clips of video to the media, driver's education teachers and students, and others involved in efforts to improve highway and road safety. The face portion of the video will be blurred, blacked out, or replaced with an animation for these purposes. Your name and other personally identifying information will never be associated with the showing of these video clips. Identifying location information will not be shown in association with these video clips.

It is expected that the data we capture throughout the course of the entire study, including that from all the approximately 3,100 primary participants, will be a valuable source of data on how drivers respond to certain situations and how the roadway and vehicle might be enhanced to improve driver safety. Researchers who study traffic congestion and traffic patterns may also find the data useful. Therefore, it is expected that there will be follow-on data analyses using all or part of the data for up to 30 years into the future. These follow-on analyses will be conducted by qualified researchers with IRB approval, as required by law, who may or may not be part of the original project team. In consenting to this study, you are consenting to future research uses of the information and videos we gather from you, consistent with the protections described above and elsewhere in this document.

If you are involved in a crash while participating in this study, the data collection equipment in the vehicle will likely capture the events leading up to the event. You are under NO LEGAL OBLIGATION to voluntarily mention the data collection equipment or your participation in this study at the time of a crash or traffic offense. We have provided a letter which you should keep in the glove box for these cases. The letter describes the vehicle's role in the study without identifying you as a participant in the study.

Because the vehicle camera system is storing continuous video, it may capture some incriminating evidence if an at-fault collision should occur. To help us protect your privacy, we have obtained a Certificate of Confidentiality from the U.S. Department of Health and Human Services National Institutes of Health. With this Certificate, neither the researchers nor study sponsors can be forced to disclose information that may identify you, even by a court subpoena, in any federal, state, or local civil, criminal, administrative, legislative, or other proceedings.

Identifying information for the purposes of this study includes your contact information, your auxiliary study information, your driving data (including video of your face and GPS coordinates which may identify your home, work, or school locations), or any information in your driver data, vehicle data, or additional crash data that could be used to personally identify you. While your confidentiality is protected in most cases by the Certificate, you should know that in some rare instances involving alleged improper conduct by you or others, you may be prevented by a court from raising certain claims or defenses unless you agree to waive the confidentiality protection. The researchers and study sponsors will use the Certificate to resist any demands for information that would identify you, except as explained below.

The Certificate cannot be used to resist a demand for information from personnel of the United States Government that is used for auditing or evaluation of federally funded projects or for information that must be disclosed in order to meet the requirements of the federal Food and Drug Administration (FDA).

This Certificate of Confidentiality does not mean that the Federal government endorses this study. You should understand that a Certificate of Confidentiality does not prevent you or a member of your family from voluntarily releasing information about yourself or your involvement in this research. If an insurer, employer, or other person obtains your written consent to receive research information, then the researchers may not use the Certificate to withhold that information. If you are not the vehicle owner, you should know that the vehicle owner will not have access to your data.

The Certificate of Confidentiality also does not prevent the researchers from disclosing voluntarily matters such as child abuse, or subject's threatened or actual harm to self or others. This could also include behaviors such as habitually driving under the influence of drugs or alcohol, allowing an unlicensed minor to drive the vehicle, or habitually running red lights at high speed. If this type of behavior is observed, we reserve the right to remove you from the study and inform the appropriate authorities of what we have observed. In most cases, we will notify you first of the behaviors we have observed prior to removing you from the study or informing others of our observations. If you are removed from the study, your compensation will be prorated based on the time you have already spent as a participant in the study.

The protections of the Certificate of Confidentiality described herein may not apply to passengers or drivers of the vehicle who have not consented to being in this study. For this reason, Informed Consent will be sought from all other adults who drive the vehicle, and these individuals will be protected by the Certificate of Confidentiality to the same degree as you are.

To summarize, your level of confidentiality in this study is as follows:

1. There will be video of your face and portions of your body. There will be audio recorded, but only for 30 seconds if you press the red incident button. The study also will collect health and

driving data about you. The video, audio, and other data that personally identifies you, or could be used to personally identify you, will be held under a high level of security at one or more data storage facilities. Your data will be identified with a code rather than your name.

2. All data collected from other drivers who have not signed a consent form will be deleted. No identifying information will be collected on passengers.

3. For the purposes of this project, only authorized project personnel, authorized employees of the project sponsors, and qualified research partners will have access to study data containing personally identifying information, or that could be used to personally identify you. The data, including face video which has been blurred, blacked out, or replaced by animation, may be shown at research conferences and by the research sponsors for the highway and road safety purposes identified above. Under no circumstances will your name and other personally identifying information be associated with the video clips.

4. The personally identifying data collected in this study may be analyzed in the future for other research purposes by this project team or by other qualified researchers in a secure environment. Such efforts will require those researchers to sign a data sharing agreement which will continue to protect your confidentiality, and will also require additional IRB approval. The confidentiality protection provided to you by these data sharing agreements will be as great as or greater than the level provided and described in this document. Research partners will not be permitted to copy raw data that identifies you, or that could be used to identify you, or to remove it from the secure facility in which it is stored except with your consent.

5. A Certificate of Confidentiality has been obtained from the National Institutes of Health. With this Certificate, the researchers and study sponsors cannot be forced to disclose information that may identify you, even by a court subpoena, in any federal, state, or local civil, criminal, administrative, legislative, or other proceedings. However, the Certificate of Confidentiality does not prevent the researchers from disclosing voluntarily matters such as child abuse, or a participant's threatened or actual harm to self or others. In terms of a vehicle, this could also include items such as driving under the influence of drugs or alcohol, allowing an unlicensed minor to drive the vehicle, or habitually running red lights at high speed. Such behaviors may result in your removal from the study and reporting of the behavior to the appropriate authorities. While your confidentiality is protected in most cases by the Certificate, you should know that in some rare instances involving alleged improper conduct by you or others, you may be prevented by a court from raising certain claims or defenses unless you agree to waive the confidentiality protection.

Data Specification

We require data for approximately 15 signalized intersections. We want data from 54 different drivers traversing these intersections. These drivers should each provide a minimum of 50 traversals through the chosen intersection. We want the drivers to be evenly distributed across age groups (9 different possibilities to be defined) and gender. This implies that we will receive data for approximately 2,700 signalized intersection traversals. A 10% of the trips from all drivers need to be the full trip and not the 30 second segment passing at the intersection. Also from those a 5% sample need to be during nighttime (9pm-5am).

VTTI will then provide us with the following datasets based on the final selection of intersections. Note that VTTI will not be providing Roadway Information Database (RID) data to CUTR. Also note that the traversals of the selected intersections will not occur near the beginning or end of the trip (defined as a pre-determined distance from trip origin or destination; the distance contains a limited random noise element to further anonymize the trip).

Unless otherwise specified, VTTI will provide these datasets in a CSV (text) file format. When the files contain time series data, the timestamps will be reported on a 10 Hz frequency clock and measures will be aligned to the closest timestamp.

Trip Summary Measures. These measures will be for the trips in which the selected intersections are traversed. The variables will be:

- Brake Activations
- % CTRE Van Cov
- % HSIS Derived Rd Class
- % Other Class
- % Rur 2 Ln
- % Rur Frwy
- % Rur Frwy < 4 Lns
- % Rur Multi Div Non-Frwy
- % Rur Multi Undiv Non-Frwy
- % State Data Cov
- % Urb 2 Ln
- % Urb Frwy
- % Urb Frwy < 4 Lns
- % Urb Multi Div Non-Frwy
- % Urb Multi Undiv Non-Frwy
- % No Spd Lim Data
- % Spd Lim 35 or Less

- % Spd Lim 40-50
- % Spd Lim 55-65
- % Spd Lim 70 or Greater
- Trip Start Local Time Hour of Day
- Trip End Local Time Hour of Day
- ABS Available
- ABS Activation
- Mean Speed
- Max Speed
- Turn Signal Available
- Turn Signal Activations
- Cell Phone Flag

Events. These events will be near-crashes that occurred at the selected intersections (crashes cannot be provided because they could be used to identify the participants). The variables will be:

- Event Nature 1
- Event Nature 2
- Relation To Junction
- Incident Type 1
- Incident Type 2
- Intersection Influence
- Final Narrative
- Driver Behavior 1
- Driver Behavior 2
- Driver Behavior 3
- Secondary Task 1
- Secondary Task 1 Start Time
- Secondary Task 1 End Time
- Secondary Task 1 Outcome
- Secondary Task 2
- Secondary Task 2 Start Time
- Secondary Task 2 End Time
- Secondary Task 2 Outcome
- Secondary Task 3
- Secondary Task 3 Start Time
- Secondary Task 3 End Time

- Secondary Task 3 Outcome

Driver. These data will be provided for the participants represented in the sample. Note that some assessment data, or combinations of assessment data, are considered potentially PII and cannot be provided outside VTTI's secure data enclave. The variables will be:

- Age (provided in age bins)
- Gender
- Behavior Questionnaire (all available answers)
- Risk Taking Questionnaire (all available answers)
- Risk Perception Questionnaire (all available answers)
- Medical Conditions & Medications (all available answers)

Vehicle. These data will be provided for the vehicles represented in the sample. The variables will be:

- Make
- Model
- Year

Time Series. These data will be provided for the trip segments in the sample. A trip segment is defined as the time the participant is on the link IDs which define an intersection. The variables will be selected from the following list, when available for the events of interest:

- vtti.speed_network
- vtti.speed_gps
- vtti.accel_x
- vtti.accel_y
- vtti.accel_z
- vtti.pedal_gas_position
- vtti.head_confidence
- vtti.pedal_brake_state
- vtti.abs
- vtti.turn_signal
- steering wheel position
- wiper setting
- GPS heading
- Timestamp
- subjectID
- video, forward roadway

- latitude and longitude

Video. *The video of the forward roadway will be provided for the events of interest. It will be provided in separate MP4-format files which will be linked by name to the time series data file.*

In the event CUTR needs to access face video footage for the selected intersection traversals, considered PII, CUTR will need to access the secure data enclave at VTTI premises. This will require upgrading the IRB approval from Exempt to Expedited (access to PII is what moves the requirement up to this level).