Final Report

EVALUATION OF DRIVER BEHAVIOR TO HYDROPLANING IN THE STATE OF FLORIDA USING DRIVING SIMULATION

Project No.: BDQ22 997-01

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: Volumes greater than 1000 l shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	l
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
psi	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	psi

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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16. Abstract

This project used a driving simulator to investigate patterns of drivers' behavior during various rainfall event using different roadway geometries. We conducted a literature review of previous transportation studies using driving simulators and selected and analyzed extensive field data on major highway sections throughout Florida. The data was broken into two major categories: light rain for rainfall intensity ranging from 0.01 to 0.24 inches/hour and heavy rain for rainfall intensity of greater than 0.25 inches/hour. The driving simulator at the University of Central Florida simulated the parameters, such as speed and rainfall intensity, observed in the field. Based on our analysis, we found that drivers are not affected by light rainfall event. However, heavy rainfall has a significant impact on their speed; on average, they reduced their speed by 6 to 12 mph. Also, there was no interaction between rainfall intensity and either gender or age group. The female participants appeared to drive faster as compared to their male counterparts, and the age group ranging from 16 to 21 year olds appeared to be the most aggressive drivers. Eighty percent (80%) of the participants reported on the survey that they have experienced some level of hydroplaning while driving on the road. The simulator appears to provide identical results to the field data analysis, lending credence to the validity of using a driving simulator to investigate the pattern of drivers' behavior during rainfall event. The researchers recommended further validation and refinement of this study. Continuation of this project may also help Florida Department of Transportation and other agencies with future decision making, such as variable message signs, determining appropriate corrective measures on existing roadway sections, and/or designing future roadway sections to reduce hydroplaning.

17. Key Word	18. Distribution Statement
Driving simulator, speed, light rainfall, heavy rainfall, hydroplaning, suburban, and highway	No restrictions.

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EXECUTIVE SUMMARY

The purpose of this study is to validate the use of a driving simulator to investigate the pattern of drivers' behaviors during rainfall event using different geometries. We conducted a thorough literature review using published materials from transportation studies using driving simulators. Data collected in the field as well as by the simulator were analyzed to meet the objectives of this research.

Field data was broken into two major categories: light rain for rainfall intensity ranging from 0.01 to 0.25 inches/hour and heavy rain for rainfall intensity of 0.25 inches/hour or greater. Based on the analysis conducted, it was found that the drivers reduced their speed by only 2 miles per hour during light rainfall event and up to 8 miles per hour during heavy rainfall event. The greatest decrease in speed occurred during nighttime and weekday peak hours. On average, the participants drove within the speed limit during dry conditions in the driving simulator. Similar to the field data, simulated light rainfall condition did not affect their driving behavior. However, they slowed down when heavy rainfall condition was simulated. On average, they slowed down by about 7 mph for rainfall event level 3 and by 9 mph for rainfall event level 4.

The results from the analysis of variance (ANOVA) support the hypothesis that the means of the drivers' speeds differs, based on the rainfall variation. On average, their speed dropped 13 mph when the drivers drove in rainfall intensity level 4 on the suburban route. Also, the drivers drove 6 and 12 mph slower when rainfall levels 3 and 4 were simulated on the highway route. Based on the results obtained from a two-way ANOVA, we found that the speeds recorded from the participants were not affected by gender on either road type. However, on the suburban route, the speed was significantly affected by age group; this was not true on the

highway route. Also, there was no interaction between gender and rainfall intensity. On average, females drove about 2 to 3 miles per hour faster as compared to their male counterparts.

In addition, no interaction was found between rainfall intensity and age group on either the suburban or highway routes. On the suburban route, the participants who were 16 to 21 year olds drove faster than any of the other participants. On average, they drove 3 mph and 6 mph faster as compared to the participants who were 22 to 33 year olds and participants who are 33 or more year olds, respectively. On either suburban or highway routes, it was found that the older participants drove slower as compared to the other participants. Their speeds were reduced 3 to 6 mph as compared to any of the other age groups.

The trend observed from the analysis of the simulator data matched the information provided by the participants in the survey. Also, ninety three percent (93%) of the participants reported that they drove slower during rainfall as compared to dry conditions. The amount of speed reduction was due to the rainfall intensity.

Field data analysis shows similar trends. These observations lend credence to the validity of utilizing a driving simulator to investigate the pattern of drivers' behaviors during rainfall event. The researchers recommend further validation and refinement of this approach. Continuation of this project may also help Florida Department of Transportation and other agencies with future decision making, such as determining appropriate corrective measures on existing roadway sections and designing future roadway sections to reduce the potential for hydroplaning. Findings from this type of research may be particularly useful at this time when many state agencies are implementing variable message signs into their driver information display program.

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CHAPTER 1
INTRODUCTION

1.1 Background

Automobile crashes are attributed to a number of causes, such as driver behavior, vehicle condition, roadway condition, and environmental conditions. During hydroplaning, a driver loses control of a vehicle when a film of water prevents contact between the tire and the pavement (Browne, 1975). As a result, the car slides and skids which may cause injury or fatality. One important cause of hydroplaning is driving speed (Glennon, 2006). The chance of hydroplaning grows as the driving speed increases. In this situation, it is desirable to know how fast drivers tend to drive in rainfall condition.

The purpose of this study is to utilize a driving simulator to investigate the pattern of drivers' behavior during various rainfall events, using different roadway geometries. In recent years, driving simulators have played an important role in traffic studies (Fitzpatrick et al. 2010; Fitzpatrick et al. 2011). They have also been used as a tool for studies and analysis related to driving behaviors. This research utilizes participants (drivers) of varying sex and age groups. Each participant drove the simulator in a virtual world ranging from suburban to highway routes, with and without rainfall. We recorded their driving speed and conducted a data analysis, including statistical analysis, to meet the objectives of this research.

1.2 Objectives

The primary objective of this research is to evaluate drivers' speed reduction during rainfall events.. The specific objectives are as follows:

- Collect and review all the pertinent literature and other information related to driving applications on roadways.

- Design and conduct a driving simulation with an experimental design to determine drivers' response during rainfall event.
- Conduct surveys to determine the perspective of the subjects used on this study while driving in rainfall event.
- Provide recommendations for speed reduction that will be used as a design parameter for the evaluation for hydroplaning potential.

1.3 Report Organization

This report has six (6) chapters. They are organized into these following topics:

- Chapter 1 **Introduction** – includes the objective of the project and the report organization.
- Chapter 2 **Literature Review** – includes a summary of previous transportation studies in driving simulators. The goal in this chapter is to identify the key elements required in successful driving simulation-based research.
- Chapter 3 **Field Traffic Data Analysis** – includes traffic data from Florida's Statewide 511 Website and Florida Department of Transportation (FDOT) STEWARD database. We also extracted rainfall data from the National Oceanic and Atmospheric Administration (NOAA) database. The goal is to determine the impact of rainfall event on drivers' behavior dealing with free flow speed and traffic volume. These data were also used to validate the results obtained from the diving simulation**.**
- Chapter 4 **Driving Simulator Pilot Study** – discusses the methodology and findings from the simulator pilot study using 6 subjects. This chapter is broken down into four (4)

major sections: Procedure, Experimental Design, Data Collection, and Analysis. Lessons learned from the pilot study were implemented into the full experiment.

- Chapter 5 **Driving Simulator** – discusses the methodology and findings from the simulator study of 30 participants.
- Chapter 6 **Summary and Conclusions** – provides the summary and key findings from each study along with a comparison of the study findings and the conclusions from the research.

CHAPTER 2
LITERATURE REVIEW

2.1 Overview

During hydroplaning, a driver loses control of a vehicle when a film of water prevents contact between the tire and the pavement (Browne 1975). As a result, the car slides and skids far too often, causing injury or fatality. One important cause of hydroplaning is driving speed (Glennon 2006). In 2009, more than 30,797 people died in traffic related accidents. Nearly one-half of all these fatal crashes occurred on roads with posted speed limits of 55 mph or greater (NHTSA 2009). The chance of hydroplaning grows as the driving speed increases. It is therefore desirable to know how fast drivers would drive in rainfall condition. On a dry surface, drivers may be more confident however the comfort level drops for most drivers during rainfall events when visibility is impacted. Very little information exists on how much drivers reduce their speeds when it rains. It is, therefore, of great importance to determine the safe speeds in rainfall condition.

In recent years, driving simulators have played an important role in traffic studies. They have also been used as tools for studies and analysis related to driving behaviors. The use of simulators is cost effective, safe and often the only viable method of analyzing driving behaviors, especially in situations that are difficult or impossible to reproduce in real life or on actual road conditions. Driving simulators offer advantages due to high-repeatability. Setting road and weather conditions in a simulator is relatively simple and economic (Maeda et al. 2005). The use of a modern advanced driving simulator for traffic safety and operation has many advantages over similar real world or on-road driving research, including experimental control, efficiency, expense, safety, and ease of data collection (Nilsson 1993).

2.2 Rainfall in Florida

The state's rainfall varies in annual amounts, seasonal distribution and location, with areas of high annual rainfall in the panhandle and in the southeastern Florida. The pattern of more frequent and high intensity rainfall, particularly during the summer season, puts vehicle drivers on roadway sections that may increase potential for hydroplaning because high rainfall intensity increases water film thickness on pavement.

2.3 Rainfall Impacts on Roadways and Traffic Operation

Research studies have been conducted to study the effect of rainfall event on roadway operation and traffic speed. Rainfall event affects driver behavior, roadway safety and mobility. The impact of rainfall on free flow speed may vary for different types of drivers and geographic location. It may also depend on the driver's confidence during rainfall event. However, a driver's confidence during rainfall event may be difficult to measure quantitatively. In general, rainfall can reduce pavement friction, decrease roadway capacity, and reduce visibility, all of which increase crash risk. On roads that have not had recent precipitation, light rain can mix with pavement contaminants (e.g., motor oil) decreasing pavement friction even further. Vehicles entering areas of heavy rain can hydroplane or encounter slow or stopped traffic. Heavy rain can produce very low visibility, lane submersion, flooded underpasses, and damage to roadbeds (Pisano and Goodwin 2002).

Some researchers have concluded that rainfall of any intensity will adversely impact traffic operation. Perrin et al. (2002) have concluded that speed and flow rate is reduced by 10% and 6% during rainfall event, respectively. This study was conducted on two arterial intersections in Salt Lake Valley, Utah. Smith et al. (2003) have conducted research to study the impact of rainfall on freeway traffic flow. They have concluded that light rain (intensity of 0.01 - 0.25 inches/hour) decreases freeway capacity by 4-10% and heavy rain (intensity of 0.25 inches/hour or greater) decreases freeway capacity by 25-30%. Also, they have noted that the presence of rain, regardless of intensity, results in approximately a 5.0-6.5% average decrease in operating speeds. On this study, traffic and weather data was collected in Hampton Roads, Virginia—an urban region in the southeast corner of the state.

However, the information reported by other researchers was not as consistent as described above. A research project conducted by Lamm, et al. (1990) on 322 curved roadway sections of two-lane rural highways in New York State have indicated that operating speeds are not affected by wet pavement until visibility is also impacted, and therefore light rain does not impact operating speeds, while heavy rain does. Saberi and Bertini (2010) have reported about 10 mph decreases in speed during daytime hours. However, the differences among measured speeds and flows in different rainfall condition for certain overnight and peak (congested) periods were not statistically significant, apparently due to the confounding effects of overnight loop detector speed errors and recurrent congestion during peak periods. They also observed a negligible decrease in free flow speed when precipitation increased. Saberi and Bertini never encountered rainfall intensities greater than 0.09 in/hr. In Florida, intensity of rainfall is at time greater than 1 in/hr, especially during the “rainy” season (Karl 2010).

2.4 Flexibility and Capability of Driving Simulator with Focus on Visual Databases

The virtual environment, implemented by created visual databases, is one of the most important factors deciding the fidelity of a driving simulator. The creation of visual databases for driving simulation is not significantly different from the same task for other purposes, such as computer games. It consists of the following steps:

1. Collecting data related to the dimensions of objects to be visualized in the simulator, including roads, buildings, landscapes, etc.
2. Creating computer graphics models, consisting of triangle meshes and textures, to implement the objects in the simulator.
3. Evaluating the computer graphics models. The outcome of this step may cause repetition of steps 1 and 2 until the computer graphics models are found to be accurate enough by the people with domain knowledge.

There have been studies in which users created visual databases for driving simulators. Orit et al. (2006) replicated an intersection in a driving simulator to study how drivers would respond to some improvements. Bella (2005) developed graphics models to visualize work zones in a driving simulator. The U.S. Federal Highway Administration developed visual databases of a proposed freeway interchange in order to evaluate and refine design features (Granda 2006). The creation of visual databases is performed by graphics modelers using software tools, such as Maya and 3D Studio Max (Maya 2012; 3D Studio Max 2012). The different software applications use their own format for graphic modeling and are often supported by graphics programming engines, such as DirectX and OpenGL (DirectX 2012; OpenGL 2012).

Some simulators, such as the one used by the University of Central Florida (UCF), use propriety formats, not available to the public. In reality, an important factor affecting the feasibility of creating visual databases in driving simulators is whether simulator vendors would disclose their digital formats of graphics models. If the vendor would not disclose or would only partly disclose their formats, it would be impossible or very difficult to create visual databases by the users.

2.5 Validation

Driving simulators have been adopted in many traffic studies because of the realistic driving experiences provided by the simulators. However, simulators' capability of duplicating reality differs. Some simulators, built with a great deal of investment, can achieve a high fidelity. However some other more inexpensive simulators have less fidelity. An important issue to be addressed in any simulator-based study is how closely the simulated driving experience is to the real world. Some studies address the validation of driving simulators. These studies all compare the data, collected from simulators, and data from the real world. Even via the same methodology, different results are found. Lee et al. (2003) reported that a driving simulator is validated by comparing how senior citizens respond to visual stimuli in the simulator to what previous studies, not based on a simulator, have found; they found consistent trends. Törnros (1998) compared the speed in a real tunnel to the replicated one in a simulator and found that people drove faster in the simulated tunnel than in the real tunnel. Interestingly, a study by Godley et al. (2002) showed that people drove faster in the real world than in a simulator. Two other studies by Harms (1994) and Alm (1995) found comparable speed in the simulated world and the real one.

The different driving behaviors found in the real and simulated worlds are due to the inherent limits of driving simulators. Espié et al. (2005) have identified the following three such limits:

- **Acceleration:** simulated car movements can be complex and demanding when they are to completely replicate the real driving experience;
- **Visualization:** the 70-Hz graphics system can create jerky movements in a driving simulator; and
- **Drivers:** car testers and professional drivers deliver more homogenous results.

Given these limits, it is necessary to identify reasonable expectations when validating a driving simulator. This is true in particular when the driving simulator being used does not have the moving base and a closed operating environment, such as a dome. Godley et al. (2002) found three types of validity related to driving simulators.

- **Absolute validity:** comparing data from the real world to simulated data;
- **Relative validity:** established when the differences between experimental conditions are in the same direction and have similar or identical magnitude in the real and simulated worlds; and
- **Interactive relative validity:** examines the similarity of drivers' dynamic reactions to stimuli, between experimental conditions

The UCF simulator may present physical limitation and inflexibility of modifying visual databases. In such a case, relative validity and/or interactive relative validity should be considered. These two types of validities are also consistent with the requirements of the hydroplaning project, which examines whether and how much people would reduce speed in rainfall event.

2.6 Summary

In general, rainfall event has an adverse effect on roadway operation and traffic speed. It impacts driver behavior, roadway safety, and mobility. Some researchers have concluded that rainfall event reduces free flow speed and flow rate by 10% and 6%, respectively. Other researchers have concluded that the effect is not that significant, especially for light rainfall event, congested periods, and at night.

The literature was not consistent as to drivers' speed response on a driving simulator as compared to real life. Another concern dealt with validation of the driving simulator. As to the UCF simulator, absolute validity should be verified, considering its physical limitation and inflexibility of modifying visual databases. In such cases, relative validity and/or interactive relative validity may be considered. These two types of validities are also consistent with the requirements of the hydroplaning project, which examines whether and how much people would reduce the speed during rainfall event. The researchers recommend the identification of external methods, such as analyzing real life data, to use for the validation of driving simulator.

CHAPTER 3
FIELD TRAFFIC DATA ANALYSIS

3.1 Overview

To investigate the impact of rainfall event on free flow speed and traffic volume, data was extracted from Florida's Statewide 511 Website, from the Florida Department of Transportation (FDOT) STEWARD database, and from the National Oceanic and Atmospheric Administration (NOAA). The NOAA database contains hourly rainfall data from multiple sites and airports in the nation, including the State of Florida. The data was analyzed to determine the impact of rainfall event on driver behavior dealing with free flow speed and traffic volume.

3.2 Roadway Sections Identification

For this study, major highway sections throughout the State of Florida were selected. These sections were carefully selected so that they were relatively close to airport locations for rainfall data availability. In addition, the literature has reported that the majority of traffic-related accidents occurred on roadways with posted speed limits of 55 mph or greater (NHTSA 2009). The locations were selected based on the following criteria:

- Posted speed limits of 55 mph or greater;
- Proximity to a NOAA rain gauge;
- Available on STEWARD database;
- Non-proximity to arenas, stadiums or other attractions; and
- Affected by a “peak” time.

The FDOT research team confirmed that the selected locations met their criteria for this research proposal. A total of six (6) sections, which cover a breadth of locations throughout the State of Florida, have been selected. The location, mile marker, and information about the weather station used for these sites are presented in Table 3-1. All of the locations were within 8 miles of an airport. The posted speed limit on these sites are 65 mph or greater. Rainfall data for the identified airport was used to complete the analysis.

Table 3-1 Roadway section used in the study

Project ID	City	District	Highway	Mile Marker	Airport	Distance from airport
2100814	Jacksonville	2	I-95	349.4	Jacksonville International Airport	8.12 miles
411002	Boca Raton	4	I-95	42.7	Boca Raton Airport	3.50 miles
420412	Ft Lauderdale	4	I-595	10.7	Ft Lauderdale-Hollywood International Airport	0.0 miles
510611	Orlando	5	I-4	75.8	Orlando International Airport	7.75 miles
640032	Miami	6	I-195	1.3	Miami International Airport	4.50 miles
700321	Tampa	7	I-275	33.8	Tampa	5.50 miles

3.3 Rainfall Data

At the request of the FDOT research team, effort was made to use rainfall data in 15-minute increments. The researchers gathered data from the National Oceanic and Atmospheric Administration (NOAA) and other sites. The following websites were used:

- http://gis.ncdc.noaa.gov/map/precip
- http://gis.ncdc.noaa.gov/map/precip/
- http://gis.ncdc.noaa.gov/map/ncs/?thm=themePrecip
- http://www.climate.gov/#dataServices/mapServices_us
- http://cdo.ncdc.noaa.gov/pls/plclimprod/poemain.cdobystn?dataset=DS3260&StnList=083322

Unfortunately, the 15-minute rainfall data are not available for every month through the year. These data are mainly located in rural areas which do not meet the section criteria illustrated in the previous section, and are also not located in close proximity to STEWARD monitoring stations. As a result, only hourly rainfall data were used in the analysis. Currently, the STEWARD database contains only traffic data starting in the second quarter of 2010. Rainfall data were allocated in NOAA system from May to August, 2010 – the rainy season in Florida (Day 2011).

3.4 Traffic Data

Traffic data were extracted from Florida's Statewide 511 Website, the Florida Department of Transportation (FDOT) STEWARD database. STEWARD contains daily summaries of traffic volumes, speeds, occupancies and travel times obtained from SunGuide Transportation Management Centers (TMCs) in Florida. The data are aggregated by 5, 15 and 60 minute periods. The STEWARD System is fairly new and contains limited data in Florida; traffic data are not currently available for every day. Traffic volume and speed were extracted on both dry and wet days from the STEWARD website. The analysis included the days when both traffic data and rainfall event were available.

3.5 Rainfall classification and analogy for comparison

Based on the information presented in the literature, the data were broken down into the following categories:

- **Weather** (Smith et al. 2003)
    - Light rain (intensity of 0.01 - 0.25 inches/hour)
    - Heavy rain (intensity greater than 0.25 inches/hour)

- Traffic
    - Weekday (daytime) conditions
        - Peak (congested) periods – 7:00 am to 10:00 am and 4:00 pm to 6:00 pm
        - Non-peak (non-congested) periods – 6:00 am to 9:00 pm excluding peak (congested) hours
    - Weekend conditions – Saturday and Sunday 6:00 am to 9:00 pm
    - Nighttime conditions – Monday to Sundays 9:00 pm to 7:00 am

The following analogy was established for comparison purposes with additional information provided in Table 3-2.

- Weekday conditions
    - The traffic data for a weekday rainfall event involved comparing the same hour of the average weekday traffic for four dry days for the same week as the rainfall event.
- Weekend conditions
    - When a rainfall event was observed on a weekend, the traffic data was compared to the same hour of the average weekend traffic (dry days) for the same weekend day of the entire month (up to 9 days) for the same month as the rainfall event.
- Nighttime conditions
    - Traffic data for a nighttime rainfall event was compared to the same hour of the average nighttime traffic for 6 dry days for the same week as the rainfall event.

Table 3-2 Rainfall classification and analogy for comparison

Rainfall condition	Non-Peak_WD [a]	Peak_WD	Weekend	Night
	Compared with			
Light Rain or Heavy Rain	4 other days of the week days		up to 9 other Saturdays and Sundays of the month	6 other days of the week

Note:
[a] WD = Week days

A significant amount of data was used for the analysis. The number of data points for all the six (6) sites are presented in Table 3-3. More information for each particular section can be found in Appendix A. The rainfalls used for light rain range from 0.01 to 0.24 and 0.26 to 4.33 for heavy rain.

Table 3-3 Data used for analysis of rainfall classification

Rainfall condition		Non-Peak_WD [a]				Peak_WD			
		# of Data Points	Range of Rainfalls b			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry days	322	N/A	N/A	N/A	355	N/A	N/A	N/A
	Wet Days	73	0.07	0.01	0.24	97	0.07	0.01	0.24
Heavy Rain	Dry days	72	N/A	N/A	N/A	86	N/A	N/A	N/A
	Wet Days	19	0.73	0.27	1.50	23	0.63	0.31	1.32

Table 3-3 Data used for analysis of rainfall classification (continued)

Rainfall condition		Weekend				Night			
		# of Data Points	Range of Rainfalls			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry days	244	N/A	N/A	N/A	561	N/A	N/A	N/A
	Wet Days	79	0.06	0.01	0.24	142	0.06	0.01	0.24
Heavy Rain	Dry days	74	N/A	N/A	N/A	162	N/A	N/A	N/A
	Wet Days	28	0.60	0.27	1.66	29	0.73	0.26	4.33

Note:
[a] WD = Week days
[b] Avg.= Average; Min= Minimum; Max= Maximum; N/A= Not applicable

3.6 Analysis

The data were analyzed for both dry and rainy days. The data were broken into two major categories: light rain for rainfall intensity ranging from 0.01 to 0.25 inches/hour and heavy rain for rainfall intensity of 0.25 inches/hour or greater. Each category was divided into weekday peak (congested) periods, weekday non-peak (non-congested) periods, weekend, and night conditions (see Table 3-2). The amount of data used for the analysis is presented in Table 3-3. The summary of traffic data for both light rain and heavy rain are presented in Figures 3-1 to 3-4. A 95% confidence interval error bars are also presented in the figures. More information for each particular section can be found in Appendices B and C.

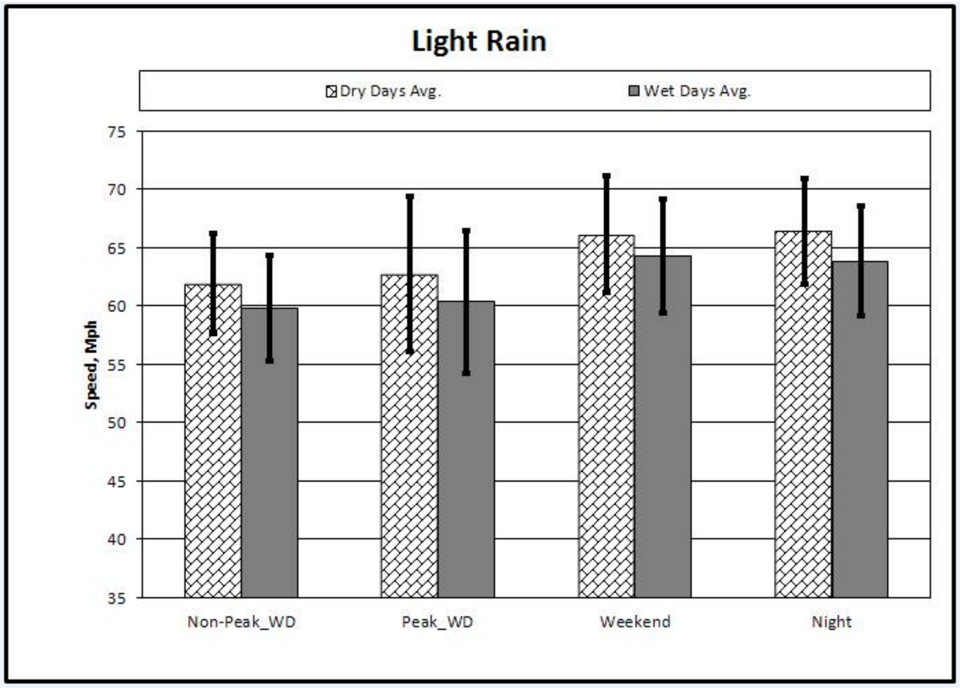

Figure 3-1 Average speed for statewide during light rain conditions with 95% confidence interval error bars.

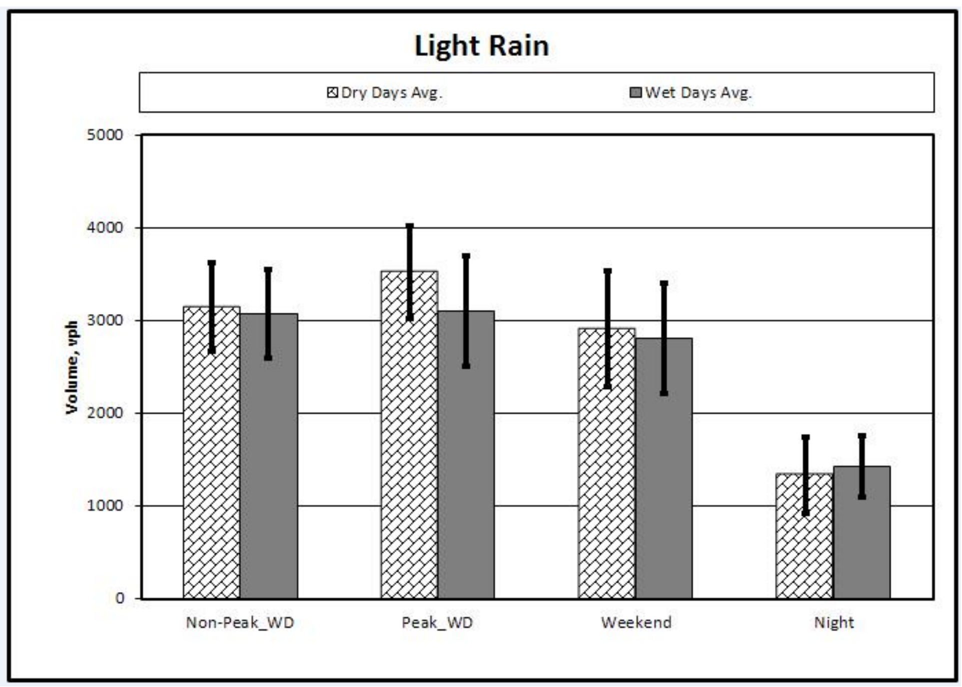

Figure 3-2 Average traffic volume for statewide during light rain conditions with 95% confidence interval error bars.

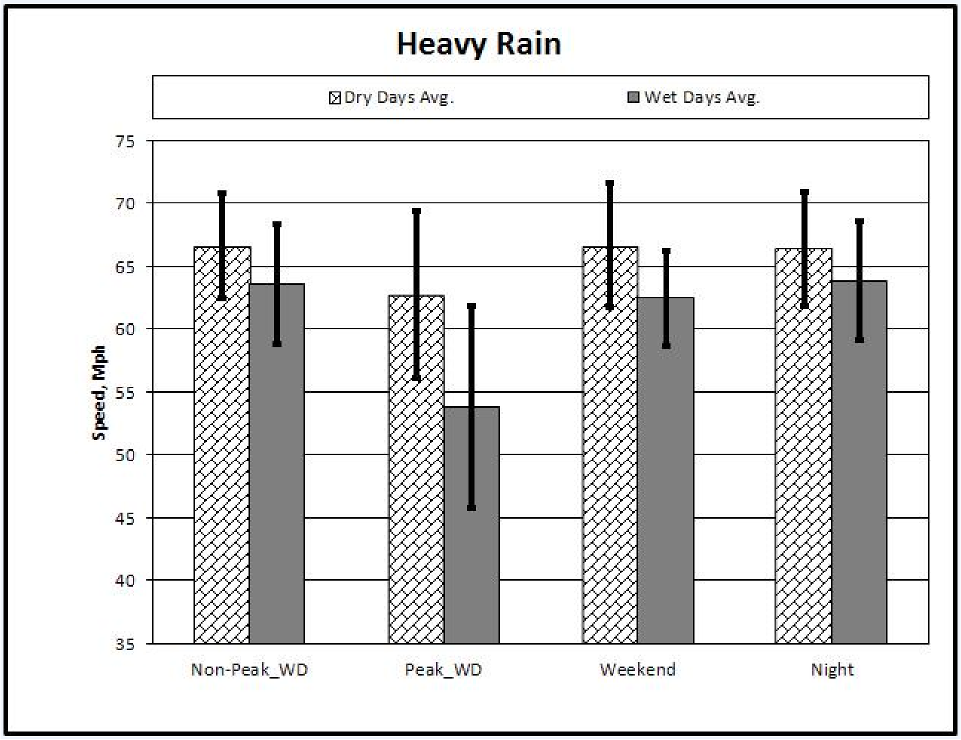

Figure 3-3 Average speed for statewide during heavy rain conditions with 95% confidence interval error bars.

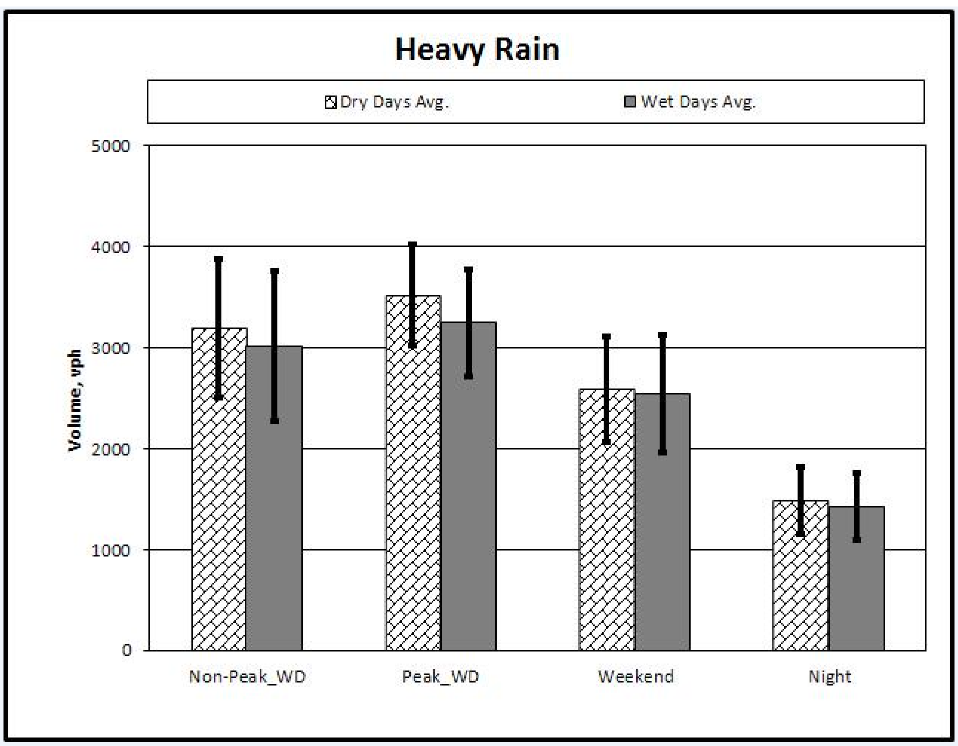

Figure 3-4 Average traffic volumes for statewide during heavy rain conditions with 95% confidence interval error bars.

Based on the data analyzed, it appears that the drivers slow down during rainfall event. Also, a reduction in traffic volume was observed (for the most part) during rainfall event. The data are summarized in Tables 3-4 and 3-5. More information for each particular section can be found in Appendices B and C. On average, drivers slow down by about two (2) mile per hour (mph) during light rainfall event and 5 mph during heavy rainfall event. The highest reduction in speed was observed during nighttime and peak hour week days (about 8 and 9 mph, respectively). Although a similar trend was observed for traffic volume, the reduction was only about 100 cars per hour.

Table 3-4 Speed difference for all the sections analyzed

	Speed difference, Mph			
Rainfall condition	Non-Peak_WD [a]	Peak_WD	Weekend	Night [b]
Light rain	-2.14	-2.32	-1.89	-2.58
Heavy rain	-3.01	-8.93	-4.16	-7.61

Note:
[a] WD = Week days
[b] N/A = Not applicable

Table 3-5 Flow difference for all the sections analyzed

Rainfall condition	**Volume difference, Vph**			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night [b]
Light rain	-66.3	-277.1	-104.4	18.9
Heavy rain	-179.3	-274.0	-45.4	-60.0

Note:
[a] WD = Week days
[b] N/A = Not applicable

3.7 Summary

This chapter focused on determining the impact of rainfall event on free flow speed and traffic volume. Significant data were obtained using six (6) roadway sections throughout the State of Florida. Due to limitation on the rainfall data from the NOAA and traffic data from the STEWARD database, no site was analyzed for District 3 (West Florida) at this time. Although many different avenues were explored to obtain the requested 15-minute rainfall data increment, this data could not be obtained for the selected roadway sections. Based on the conducted analysis, the following summary was made:

- There is a drop in speed (2 to 8 mile per hour) during rainfall event.
    - The greatest decrease occurs during nighttime and peak hours on weekdays.
- Traffic volume appears at this point to have little impact on free flow speed during rain events. Traffic volume decreases to about 100 cars per hour.

CHAPTER 4
DRIVING SIMULATOR PILOT STUDY

4.1 Overview

The purpose of this study is to utilize a driving simulator to investigate the pattern of drivers' behavior during rainfall event, using different levels of rainfall and different road geometries.

In order to meet these objectives, the following approach was used:

- Collect and review all the pertinent literature and other information related to driving applications on roadways.
- Design and conduct a driving simulation with an experimental design to determine the response of drivers in different sex and age groups, during rainfall event.
- Conduct surveys of participants' experience in the simulator.
- Provide recommendations that can be used to design roadway sections to accommodate for hydroplaning.

4.2 PatrolSim Driving Simulator

.. Since conducting experiments on actual roadways would be very difficult and unsafe, Florida Gulf Coast University (FGCU) and University of Central Florida (UCF) researchers proposed to design and conduct a driving simulation. Figure 4-1 is a picture of the driving simulator, "PatrolSim", used in this study, located in the RAPTER lab at UCF. Manufactured by L-3 Communications Inc., it is a fixed-base driving simulator, consisting of the following components:

- The Driving Cab is fully equipped with a glass dash to simulate different vehicles. The driver controls include steering wheel, gas pedal, brake pedal, head lights, and high beams. The dashboard includes fully functioning indicators, giving the driver a realistic vehicle startup.
- The visual system includes an image generator, visual graphic database and the display system to the driver. It consists of three 42-inch plasma TVs running a high resolution pixel image with a refresh rate of 70-Hz.
- The sound system uses high quality surround-sound including equalizer and speakers to simulate audio as well as vibration.

Figure 4-1 Photograph of the simulator used in the experiment – PatrolSim by L-3 Communications Inc.

Figure 4-2 presents a flowchart describing the components coordinated within the PatrolSim system. A scenario designer, using the Scenario Editor software, creates scenarios incorporating the events required in individual studies.

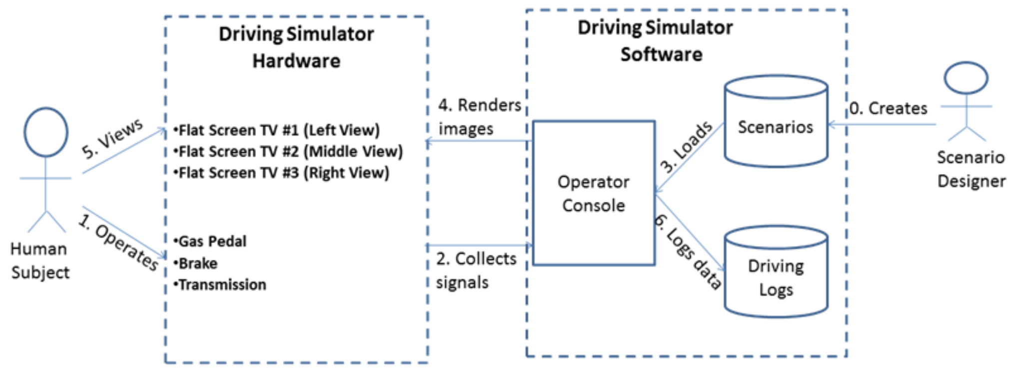

Figure 4-2 Data flow in the PatrolSim simulator

Figure 4-3 demonstrates examples of the rendered images obtained from this system. The simulation processes to be used in this study are summarized as follows:

1. The operator console loads the scenario (created offline).
2. The operator console finds what the subject should see on the three screens in the next cycle.
3. The operator console renders the images on the flat-screen TVs in front of the subject.
4. The subject sees the rendered images.
5. The subject operates the simulator’s gas pedal, brake and transmission as in a real car.
6. The subject’s operations are collected by the simulator as numerical values.
7. The simulator logs users’ inputs of positioning (X Y Z coordinates in the virtual world), steering, accelerating, braking, and MPH.

Steps 2-3 take place 70 times per second. With this rate of updating, the subject will perceive continuously updated views while driving.

Figure 4-3 Scenes from the driving simulator at the University of Central Florida - Suburban (left) and Highway (right)

The software component within this simulator system creates the rain effects. The simulator can create five rain levels (0-4), with level 0 being the dry condition and level 4 being the heaviest rain. From our observation, level 1 basically simulates drizzle and may not affect driving significantly. The other three levels, causing more noticeable changes, such as increased rainfall, increased fog density, and decreased road surface traction, were used in this experiment. The rain levels are parameterized by six coefficients as shown in Table 4-1. So far, the rain levels have not been translated to corresponding rain intensity. Examples of rain levels 0 and 2-4, used in this study, will be presented later.

Table 4-1 Rain levels used in scenario development in the UCF driving simulator

Rain Level State	Visibility Distance Level coefficient (feet)	Thunder/Lightning Coefficient	Fog Density Coefficient	Asphalt Friction Coefficient	Asphalt Adjustment Coefficient, μ	Visual Rain Drops Coefficient
0 Clear	-	1	0	0.95	0	None
2 Light	~1500	0.5	0.826	0.86	0.09	Slightly heavier
3 Medium	~700	0.5	0.95	0.81	0.14	Slightly heavier than light
4 Heavy	~150	0.5	0.99	0.75	0.20	Slightly heavier than medium

4.3 Process of Experiment Design

The process of experiment design resulted in the following major events:

1. The FGCU and UCF researchers developed the first-edition experiment plan. The FDOT researchers provided comments to which the researchers at UCF and FGCU responded. The outcome of this event will be referred to as the first-edition experiment plan.
2. The FGCU and UCF researchers met in the RAPTER lab to fine tune the driving scenario. We invited six people to drive the scenario while we observed their driving. The outcome of this event will be referred to as the second-edition experiment plan.
3. The FGCU, UCF, and FDOT researchers met in the RAPTER lab to review the second-edition scenario. Some major changes were made, which will be explained in detail later, and the experiment protocol was decided. During the meeting, we invited two people to drive the scenario and observed their driving. The outcome of this event will be referred to as the third-edition experiment plan.
4. After the meeting, the UCF researchers made some necessary changes in the third edition, the purpose of which will be explained later. Then we invited three people to drive the scenario and observed their driving patterns. The outcome of this event will be referred to as the final experiment plan.

During the scenario development, the research teams used information obtained from the literature review (Chapter 2), traffic analysis (Chapter 3), feedback/recommendations from FDOT research team, and project requirements to obtain performance requirements for the simulator. These were based on a negotiation of project needs, the simulator's capability and RAPTER's experience in conducting other studies. Several telephone meetings/conferences and coordination sessions were conducted between the FDOT sponsor and the research teams which lead to a major activity for the UCF - RAPTER team. In the next sections, these four editions of experiment plan will be discussed.

4.4 First Edition Experiment Plan

First, the UCF researchers found a path in the virtual database consisting of two road types: suburban and highway. The speed limits were 45mph and 65mph respectively. The scenario was designed to have six events, shown in Table 4-2. Each event was expected to run for 30-60 seconds, depending on the actual speed. The total running time would be approximately 4 to 5 minutes. This running time was fundamentally affected by the fact that human subjects tend to feel exhausted or sick in the L-3 driving simulator when using it for more than 5 minutes.

Table 4-2 Six events in the first edition experiment plan

Event #	Environment	Rain Type
1	Suburban (Speed Limit 45 mph)	No Rain/Dry
2		Light Rain
3		Heavy Rain
4	Freeway (Speed Limit 65 mph)	No Rain/Dry
5		Light Rain
6		Heavy Rain

A video showing how this scenario ran was submitted to the FDOT, who provided feedback. Below are the answers provided to some of their questions, which can be used to provide information about the first-edition experiment plan and the limitation of the PatrolSim simulator at UCF.

Question 1 - Is it possible to have the rain appear to be hitting the windshield? The appearance could be a splatter pattern or a distortion of the image; it currently appears to be a “Halo” effect as if the car had an umbrella over it.

Response 1 - <u>The current simulator software does not allow changes to the rain appearance. Simulation appearances may be changed by modifying the computer programs, but this must be done by the manufacturer, L-3 MPRI.</u>

Question 2 - Are windshield wipers operational in the model if the person elects to use them? Currently it probably isn't necessary due to the "halo" effect but if that could be changed it would be a nice feature.

Response 2 - <u>The windshield wiper feature is not operational because the current software does not respond to the windshield wiper. The simulated image would not change even if the wiper was operational.</u>

Question 3 - Would it be possible to have a "pace" car, perhaps at a specified distance ahead? It is good to have a reference and most people slow down when the car in front of them disappears but we don't want so many cars that chain-reaction breaking occurs.

Response 3 - <u>Technically, yes. The driver's visibility during the heavy rain is ~ 80 feet. The pacer needs to be within 80 feet (if it needs to be viewed at all times).</u>

Action: Some same direction traffic was added in the second-edition experiment plan, but no pace car was added in order to avoid collisions and unwanted braking.

Question 4 - Perhaps limiting the driving segment only to interstate since that gives us the greatest range in speed.

Response 4 - <u>We added the suburban area to the scenario to compare speed reduction patterns in rain on freeway vs. suburban roads. The scenario runs for about 4 minutes, a safe running time in regards to avoiding simulator sickness. It</u>

will take less time if the suburban area is dropped. From the safety perspective, it is even better. But it may be a little wasteful because subjects will be asked to test only on the interstate while they could test both interstate and suburban.

Question 5 - For the study, do we have speeds per lane for non-rain/rainy periods? Perhaps seeing the distribution by lane may shed a different picture since those drivers who are uncomfortable driving in rain may pull over to slower lanes which would free up the fast lane for those more comfortable driving in the rain.

Response 5 - Currently the speed limits are 45 MPH and 65 MPH for the suburban and interstate areas. Per our response to the third question, a baseline is needed to single out the rain as the only affecting factor, so the current scenario does not have any traffic in the same direction.

4.5 Second Edition of Experiment Plan

In another conversation, we were advised to ***change the speed limits to 55 mph in the suburban and 70 mph in the highway areas, respectively***, which we implemented in the second-edition experiment plan. Therefore, the events in Table 4-1 became the ones in Table 4-3.

Table 4-3 Six events in the second experiment plan

Event #	Environment	Rain Type
1	Suburban (Speed Limit 55 mph)	No Rain/Dry
2		Light Rain
3		Heavy Rain
4	Freeway (Speed Limit 70 mph)	No Rain/Dry
5		Light Rain
6		Heavy Rain

In November, 2011, the FGCU and UCF researchers met in the RAPTER lab, where the FGCU researchers experienced the scenario in the first-edition experiment plan. Several small changes, made according to discussions between the FGCU and UCF researchers, are listed here:

1. Additional traffic signs in the virtual database to better inform drivers about 90-degree turns ahead of time to avoid collisions.
2. Speed limit signs were posted so the drivers would better anticipate how fast they were supposed to drive.
3. Traffic in the adjacent lanes was reduced or removed. We agreed that opposing traffic should have little or no effect on the subjects while driving the simulator car.

After the changes were made, six drivers drove the scenario. Figure 4-4 shows a driver operating the simulator. Our observations of their driving behaviors, focusing on speeds, found that these people would mostly respond to the rain by lowering their speeds.

Figure 4-4 Photograph of the simulator during the experiment

4.6 Third Edition of Experiment Plan

In January, 2012, the FGCU, UCF, and FDOT researchers met in the RAPTER lab to evaluate the second-edition experiment plan. Our discussion identified another concern: drivers needed to make ***<u>three sharp turns</u>***, lowering their speed to nearly zero, which might confuse data analysis. It may be difficult to differentiate whether a lowered speed was due to rain or sharp turns. Since there was not a straight path in the simulator system long enough for this experiment, sharp turns were not avoidable in designing the experiment.

The solution we found was to rearrange the events in Table 4-2 so that subjects could make two out of three sharp turns when there is no rainfall simulated (dry condition). The subjects were to be asked to drive the same path without any rainfall condition. The consequence is twofold: first, drivers will experience less sharp turns in the rainfall condition; second, we could compare speeds from the same subjects driving in the same road geometry, ***<u>with or without</u>*** rainfall condition. At last, the rain levels used for this experiment were chosen to be rain levels 2 and 3, designated to be light and heavy rain, based on the advice from the FDOT researchers.

4.7 Final Edition of the Experiment Plan

Before the experiment plan was finalized, the UCF researchers found that rain levels 2 and 3 are not very differently perceived by the drivers. It was suggested that heavy rain be implemented as rain level 4 in the simulator. Figures 4-5 to 4-8 are screenshots of a dry environment, rain level 2, rain level 3, and rain level 4 in the simulator.

Figure 4-5 Dry environment from the driving simulator at the University of Central Florida

Figure 4-6 Rainfall level 2 from the driving simulator at the University of Central Florida

Figure 4-7 Rainfall level 3 from the driving simulator at the University of Central Florida

Figure 4-8 Rainfall level 4 from the driving simulator at the University of Central Florida

The experiment was finalized with four scenarios, in all of which the subject drove the same route, experiencing different rain conditions. The route consists of six segments. The first three segments are in a suburban area and the second three are in a highway area. Each segment took about 45 seconds to drive if rain occurred. The subject, within one segment, would experience one of three rain conditions: 1) no rain, 2) light rain, 3) heavy rain. The simulator is able to simulate five rain levels (0-4), with level 0 being the dry condition and level 4 being the heaviest rain. From our observation, level 1 basically simulates drizzle and may not affect driving significantly. The other three levels, causing more noticeable changes, such as increased rainfall, increased fog density, and decreased road surface traction, were used in this experiment. Below is a brief description of the four scenarios and Table 4-4 lists the rain conditions with respect to scenario and segment.

The subjects first drove an orientation scenario. The purpose was to familiarize the subjects with the simulator and with the route to be used for the real/actual experiment. It also helped familiarize the subjects with the road geometries, landscape, posted signs, and transition points, such as beginning of the highway. This scenario is not used for data analysis. In this scenario, the subjects did not experience any rainfall.

Then the subjects drove the orientation scenario again. This time the subjects' data, such as speed, braking, etc., were collected to be used as the baseline to compare with the data to be collected in the next two scenarios, in which the subjects would experience rain. This will be referred to as the *baseline scenario*.

The third scenario copied everything in the baseline scenario with the addition of rainfall condition. In this scenario, levels 2 and 3 were chosen to be the "light" and "heavy" rain, respectively. This scenario will be referred to as *rain scenario one*.

In the last scenario, the subject experienced the same as in rain scenario one, except that the heavy rain was implemented by rain level 4. This scenario will be referred to as *rain scenario two*. Tables 4-4 and 4-5 summarize these four scenarios.

Table 4-4 Final experiment plan: part 1

		Orientation Scenario	Baseline Scenario	Rain Scenario One	Rain Scenario Two
Suburban Area	Segment 1	No Rain	No Rain	Light Rain (Level 2)	Light Rain (Level 2)
	Segment 2			No Rain	No Rain
	Segment 3			Heavy Rain (Level 3)	Heavy Rain (Level 4)
Highway Area	Segment 4			No Rain	No Rain
	Segment 5			Light Rain (Level 2)	Light Rain (Level 2)
	Segment 6			Heavy Rain (Level 3)	Heavy Rain (Level 4)

Table 4-5 Final experiment plan: part 2

Scenario Name	Key Characteristics	Purpose
Orientation Scenario	• No rain condition • Data not collected	To familiarize subjects with the simulator.
Baseline Scenario	• No Rain Condition • Data collected to be used as the baseline	To record subjects' driving behaviors without rain.
Rain Scenario One	• Contains four stages (Table 1) • Light rain is implemented by level 2 in the simulator. • Heavy rain is implemented by level 3 in the simulator.	To record subjects' driving behaviors in the rain conditions.
Rain Scenario Two	• Contains four stages (Table 1) • Light rain is implemented by level 2 in the simulator. • Heavy rain is implemented by level 4 in the simulator.	To record subjects' driving behaviors in the rain conditions.

Five additional subjects drove the final edition (See Tables 4-4 and 4-5). This final experiment was considered a "Pilot Study." Subjects' maneuvers on the steering wheel, brake, and accelerator were logged. Table 4-6 shows the results of the pilot study.

Table 4-6 Pilot study results

Average Speed Reduction Due to Rain (mph)		
	Suburban	Highway
Light Rain (Level 2)	+0.4	-2.0
Heavy Rain (Level 3)	+2.7	-1.3
Heavy Rain (Level 4)	-4.7	-12.7

It is notable that subjects reduced their speed in the highway portion. On average, subjects raised their speed slightly during rain levels 2 and 3 in the suburban portion. This is consistent with some field observations, documented in Chapter 3. Subjects reduced their speed when the rain was the highest implemented by the simulator, which is also consistent with the field observations.

CHAPTER 5
DRIVING SIMULATOR

5.1 Overview

The purpose of this study is to utilize a driving simulator to investigate the patterns of drivers' behaviors during rainfall event, using different route geometries. This project utilized subjects (drivers) of varying gender and age groups. The pilot study information (see Chapter 4) was used to finalize the driving simulator experiment (also referred as *full experiment* or simply *the experiment*). The terms *participants*, *subjects*, and *drivers* are used interchangeably. When the FGCU Institutional Review Board approved our application to use this study's approach, the research experiment was cleared to proceed. In order to meet the objectives of this chapter, the following approach was used:

- Implement the key observations from the pilot study;
- Design and conduct a driving simulation with an experimental design to determine drivers' response during rainfall event;
- Conduct surveys to determine the subjects' perspectives while driving in rainfall event; and
- Provide recommendations that can be used to design roadway sections to reduce or accommodate for hydroplaning.

5.2 Driving Environment

The roadway environment used in this study consists of suburban and highway routes with rendered images as presented in Figures 4-5 and 4-6. Lessons learned from the pilot study improved the full experiment: The speed limits were set at 55 mph and 70 mph for suburban and highway, respectively. We made minor modifications, within the capacity of the simulator, so the participants could drive without disruption or significant drop in speed, as much as possible; the rain trigger was turned off at difficult-to-maneuver locations, such as sharp curves; and we increased the number of scenarios to greater familiarize the participants with the simulator. Each participant drove both roadway sections. The simulator used a passenger car and simulated traffic in the adjacent and oncoming lanes.

5.3 Study Participants

Thirty volunteer subjects participated in the study. The UCF research team recruited the participants through word of mouth and by posting flyers throughout the campus of the university. Participants were required to be at least16-years-old with some experience driving in the State of Florida. Similar to the pilot study, each participant was first given instructions about the simulator, signed a consent form, and also completed a questionnaire at the end of the experiment. Once the participants agreed to participate in the study and all the signed forms were in place, they were given a $10 compensation payment.

Table 5-1 gives a breakdown of participants' demography. The participant sample was composed of 15 males and 14 females. There was an additional male among the participants. However, he experienced a lot of difficulties while driving the simulator. As a result, that data was discarded from the analysis. The participant age group ranged from 16- to 55-years old and averaged 12 years of driving with a license. On average, the participants have been driving in Florida for 8 years. The participants drove about 223 miles per week. The standard deviation for this category was high (561.84 miles). Except for 1 participant, the participants reported in the questionnaire that they drove slower during rainfall event as compared to dry conditions. They also reported that the amount of speed reduction while driving is a response to rainfall intensity. Eighty percent (80%) of the participants reported on the survey that they have experienced some level of hydroplaning while driving on the road. This number is alarming. Accidents resulting from hydroplaning may be fatal. Other questions about participants experience on the simulator will be discussed later in the chapter.

Table 5-1 Participant demographics

Questions	Breakdown	Answer
Sex	Male Female	15 14
Age	16-21 22-33 33-more	8 13 8
Approximate number of hours you spend driving in typical week	Average Stdv. Max Min	9 6.88 30 1.5
Approximate number of miles you drive in typical week	Average Stdv. Max Min	223 561.84 3000 5
How many years have you had your driver's license?	Average Stdv. Max Min	12 9.730 34 1
How long have you been driving in Florida?	Average	8
	Stdv.	8.818
	Max.	34
	Min	0.2
Do you reduce your speed when driving in rainfall condition?	Yes	28
	No	1
Is the amount of your speed reduction related to the degree of the rain?	Yes	28
	No	1
Have you ever experienced hydroplaning condition?	Yes	23
	No	6
How many times has hydroplaning occurred to you?	Average	5
	Stdv.	7.107
	Max.	25
	Min	0

Note: Stdv= Standard deviation; Max= Maximum; Min= Minimum

5.4 Driving Simulation Scenario and Procedures

The full experiment was finalized with four scenarios:

1. The subjects first drove an **orientation scenario.** The purpose was to familiarize the subjects with the simulator's surrounding environment and with the route chosen for the real/actual experiment. It also helped familiarize the subjects with the road geometries, landscape, posted signs, and transition points (such as the beginning of the highway) that were part of the actual experiment. <u>This scenario was **not** used for data analysis.</u> In this scenario, the subjects did not experience any rainfall.
2. Then the subjects drove the orientation scenario again. This time the subjects' data, such as speed, brake, etc., were collected. The data became the baseline to compare with the data collected in the rainfall condition. In this document, this scenario will be referred to as the **baseline scenario** or **dry condition.**
3. The third scenario copied everything in the **baseline scenario** plus rainfall condition. The six stages in this scenario, as summarized in Table 5-2, were triggered to start when the drivers drove by specific locations. The adopted simulator can simulate four rain levels (1-4), with level 1 being the lightest and level 4 being the heaviest. From our observation, level 1 basically simulates drizzle and may not affect driving significantly. This level appeared not to be related to the type of rain conditions frequently encountered in the State of Florida; thus, it was not used in the experiment. The other three levels can cause more noticeable changes visually. In this scenario, levels 2 and 3 were chosen to be the "light" and "heavy" rain, respectively. More information about the different rainfall levels was presented in Chapter 4. In this document, this scenario will be referred to as **rain scenario one (1),** also referred **to as rainfall condition**.

4. In the last scenario, the subject experienced the same stages as in the **rain scenario one**, with heavy rain implemented by rain level 4 in the simulator. In this document, this scenario will be referred to as **rain scenario two**. Table 5-3 summarizes these four scenarios.

Table 5-2 Event order within each scenario

		Orientation Scenario	Baseline Scenario	Rain Scenario #1	Rain Scenario #2
Suburban 55 mph	Segment 1	No Rain	No Rain	Light Rain (Level 2)	Light Rain (Level 2)
	Segment 2			No Rain	No Rain
	Segment 3			Heavy Rain (Level 3)	Heavy Rain (Level 4)
Highway 70 mph	Segment 4			No Rain	No Rain
	Segment 5			Light Rain (Level 2)	Light Rain (Level 2)
	Segment 6			Heavy Rain (Level 3)	Heavy Rain (Level 4)

Table 5-3 Summary of the four scenarios

Scenario Name	Key Characteristics	Purpose
Orientation Scenario	• No rain condition • Data not collected	To familiarize subjects with the simulator.
Baseline Scenario	• No Rain Condition • Data collected to be used as the baseline	To record subjects' driving behaviors without rain.
Rain Scenario One	• Contains four stages (Table 5-2) • Light rain is implemented by level 2 in the simulator. • Heavy rain is implemented by level 3 in the simulator.	To record subjects' driving behaviors in the rain conditions.
Rain Scenario Two	• Contains four stages (Table 5-2) • Light rain is implemented by level 2 in the simulator. • Heavy rain is implemented by level 4 in the simulator.	To record subjects' driving behaviors in the rain conditions.

5.5 Research Experiment

Their driving maneuvers, including speed, acceleration, braking, and steering, were logged at 70-Hz. This frequency is unnecessarily high for data analysis. A computer program was written to down-sample the data to a frequency of about 12-Hz. In order to compare the subject's driving in the rain scenarios with those in the baseline scenario, another computer program was written to implement the following logic:

For each data point that is collected in the baseline scenario, do the following:

Find this subject's speed "s1"

Find his/her location point "p" in the road database

Find his/her speed "s2" when he/she drove by "p" in rain scenario one (1)

Find his/her speed "s3" when he/she drove by "p" in rain scenario two (2)

Each participant started the experiment in a parallel parked position in the suburban environment and proceeded through onto the freeway. The sections are built with curves, traffic lights, buildings, and traffic environments that simulate real life conditions. Additional information about the simulator was presented on Chapter 4.

For each subject, a figure was found to plot s1, s2, and s3 every one tenth second. Figure 5-1 is such an example. The six vertical lines (purple bar) in Figure 5-1 mark the ends of the six stages, as listed in Table 5-2. The thirty (30) subjects who have participated in the experiment to date have demonstrated a similar pattern in speed increase and decrease. Most of the significant increases and decreases are not responses to rain events. Instead, they are due to the geometry changes, such as 90-degree turns.

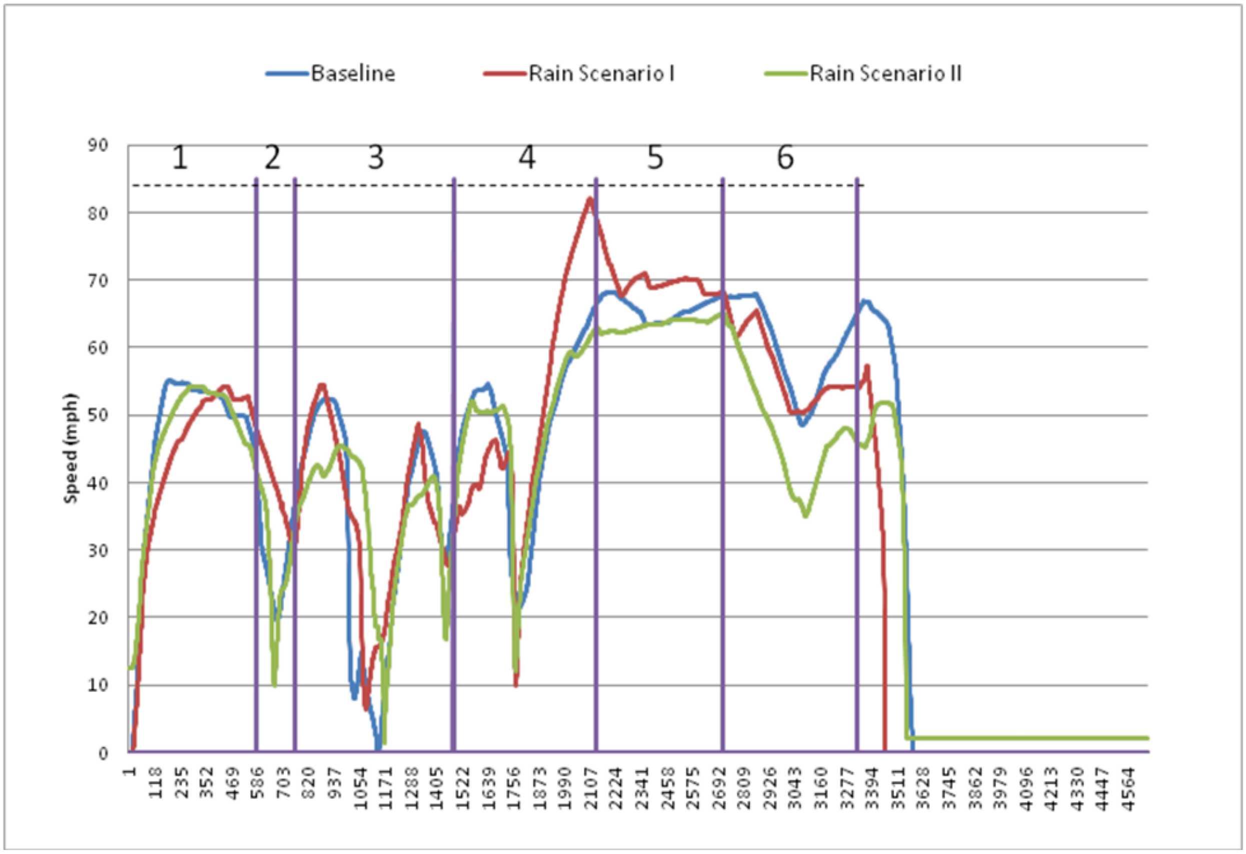

Figure 5-1 Speed recorded for Subject 1

As presented in Table 5-3, the first recorded data were the dry condition known as the "baseline". Each participant drove the full experiment a second time with rainfall level 2 (light rain) and rainfall level 3 (heavy rain). The final run included rainfall level 2 followed by rainfall level 4 (heavy rain). The rainfall intensity was increased on level 4 as compared to level 3. To match the same rain intensity as the field data (Chapter 3), level 2 will be referring to as "light rainfall". Since level 3 and level 4 were both used to simulate heavy rainfall in the field, they will be labeled as "heavy rainfall" throughout this document, respectively. Once the full experiment was completed, each participant completed a survey. The information provided will be used to correlate their experiences between the simulation and actual roadways.

5.6 Results

Once the full experiment was completed, the data were being stored in the simulator at the University of Central Florida. A computer program was generated to down-sample the data to a frequency of about 12-Hz. This computer program along with engineering judgment was used to eliminate the simulator locations depicting sharp curves and major transitions of road geometry because these conditions resulted in sharp drops in speed because of traffic signals and/or road curves. The participant ID 29 experienced difficulty maneuvering the simulator which resulted in many crashes. While this participant was allowed the full time and opportunity to complete the experiment, his/her data were not included in the analysis. The research team had predetermined that test results would be discarded when such conditions existed.

The data were analyzed for both suburban and highway roadway sections. As previously mentioned, the data were divided into four major categories: baseline (dry condition), level 2, level 3 and level 4. Figures 5-2 and 5-3 are actual speeds recorded for Driver ID 1 for suburban and highway sections, respectively. Appendix D presents the recorded speed for each participant. The vertical line (purple bar) in Figure 5-2 and Figure 5-3 marks the transition from rainfall levels 2 to 3 and levels 2 to 4, respectively.

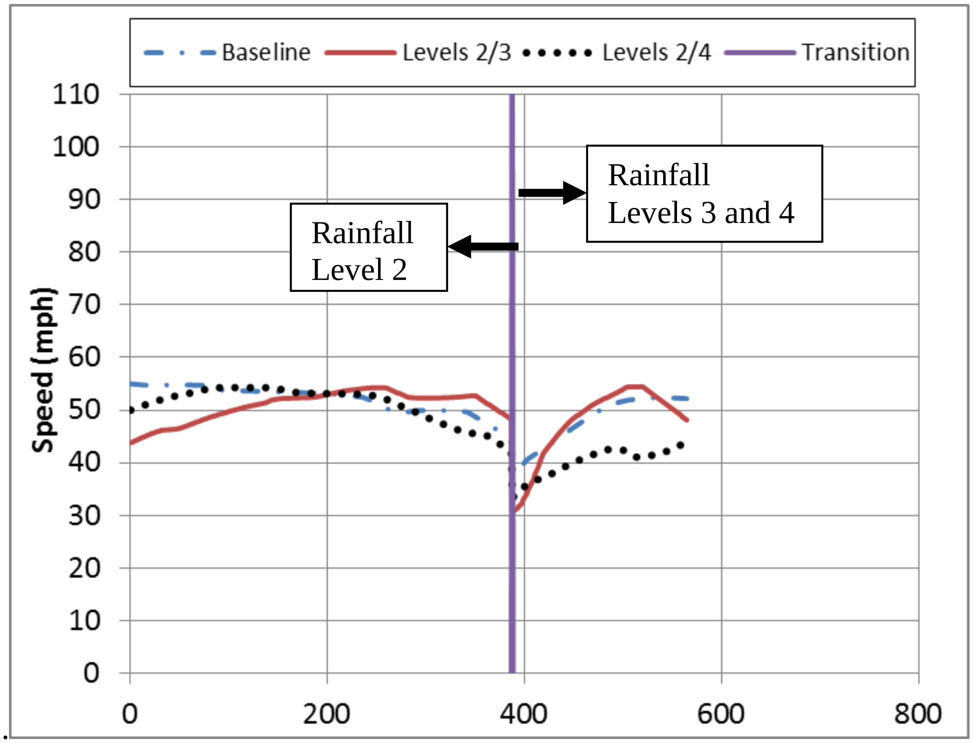

Figure 5-2 Speed recorded for Subject 1on suburban roadway section

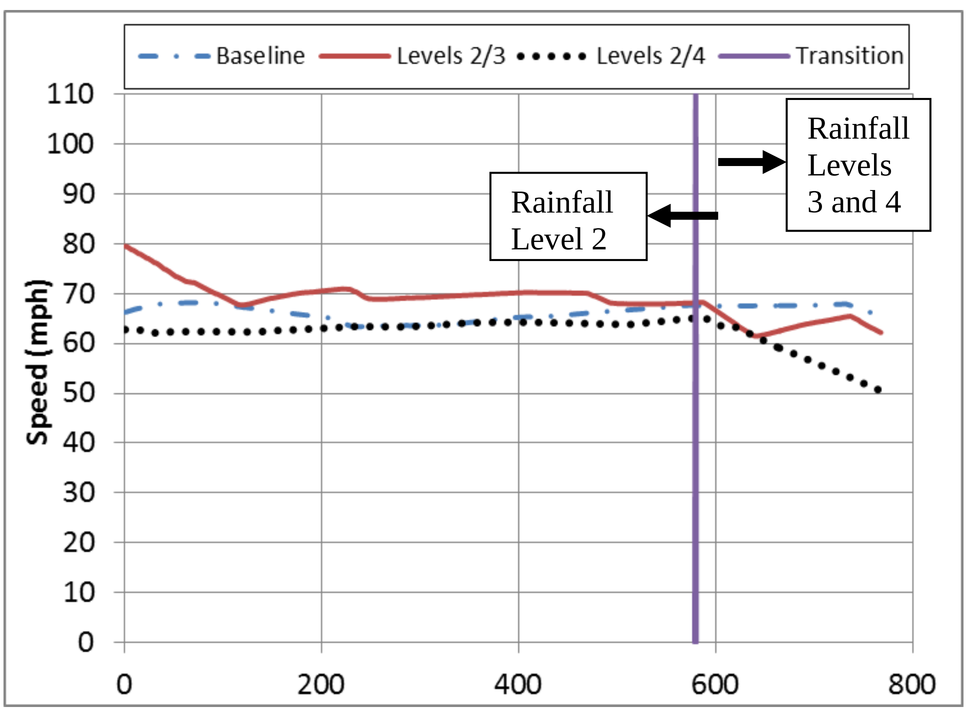

Figure 5-3 Speed recorded for Subject 1 on highway roadway section

On average, the drivers drove 50 mph and 70 mph on suburban and highway during dry conditions, respectively. With simulated light rain (level 2), it appears the drivers were not affected. They drove at equal speeds and many times slightly higher speeds (about 1 mph) as compared to dry conditions. A similar behavior was observed when actual field data were used to monitor speed reduction on highways; on average, the drivers slowed down only 2 mph during light rainfall event (Chapter 3). Figures 5-4 and 5-5 present the average speed for each roadway type along with 95% confidence interval error bars. Appendix E contains more information for each particular section. During heavy rainfall event, the drivers slowed down 7 mph and 9 mph for suburban and highway sections in the simulator, respectively. Analysis of the real (field) data revealed similar behavior; on average, drivers slowed down by5 mph during heavy rainfall event (Chapter 3). These observations lend credence to the validity of utilizing driving simulators to investigate the pattern of drivers' behavior during rainfall event.

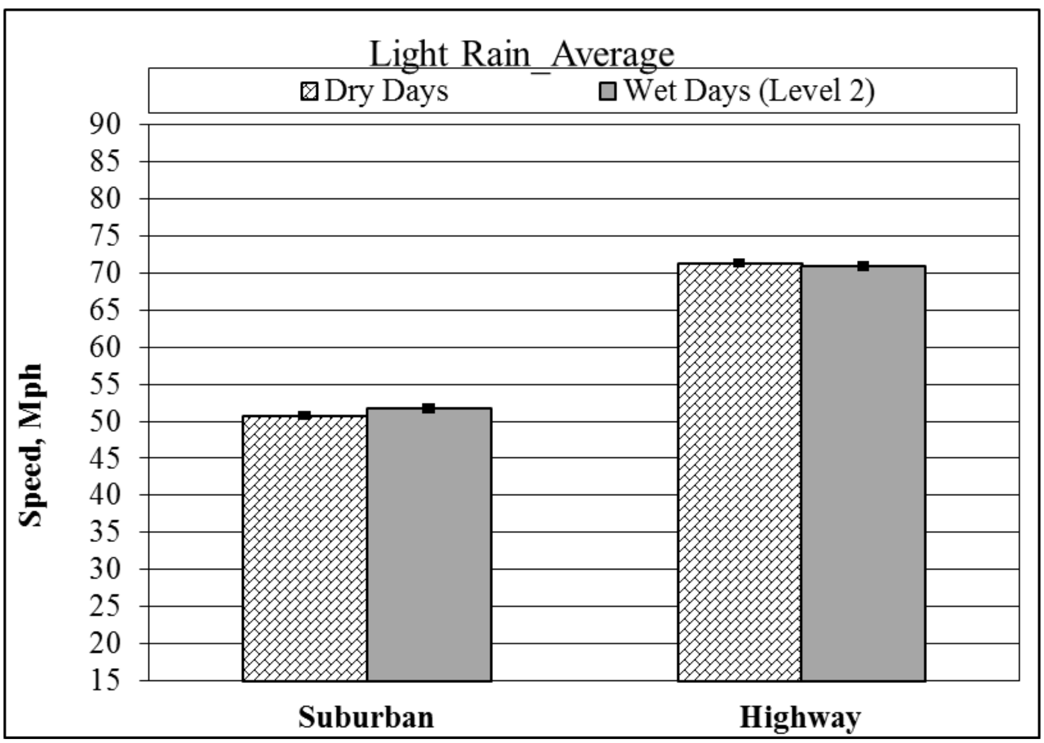

Figure 5-4 Average speed for all the participants during light rain conditions with 95% confidence interval error bars.

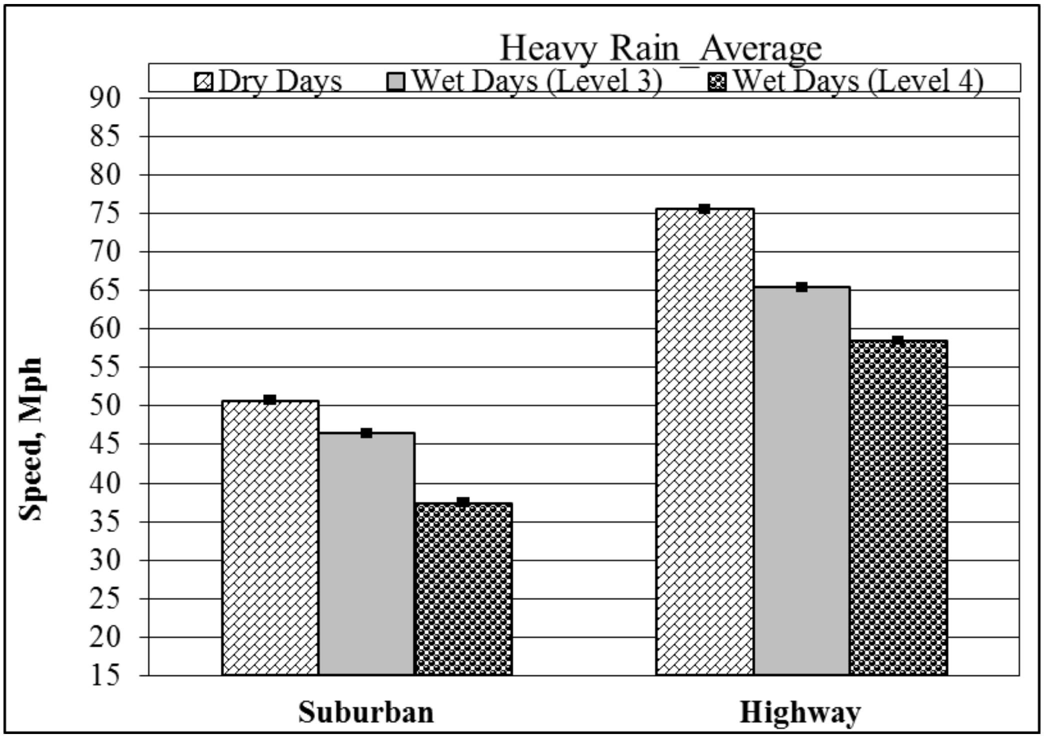

Figure 5-5 Average speed for all the participants during heavy rain conditions with 95% confidence interval error bars.

On average, the participants appeared to drive within the speed limit during dry conditions. The suburban speed recorded from the participants ranged from 43 mph to 57 mph and from 32 to 53 mph for light and heavy rainfall condition, respectively. On highway, these values ranged from 67 mph to 78 mph and 49 to 70 mph, respectively. Table 5-4 presents a summary of the data. Appendix F contains more information for each particular section. The variation in speed was about 2 to 5 mph. These values were pretty reliable. The 95% Confidence Interval Error Bars were very low.

Table 5-4 Speed (mph) data used for analysis of rainfall classification: Average of all Participants

		Dry	Level 2[a]	Level 3[b]	Level 4[c]
Suburban	Average	51	52	47	38
	Standard Deviation	4.071	3.407	4.713	2.972
	Minimum	41	43	36	32
	Maximum	56	57	53	43
Highway	Average	71	71	65	59
	Standard Deviation	2.985	2.804	3.358	6.027
	Minimum	65	67	59	49
	Maximum	76	78	70	70

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

5.7 Statistical Analysis

This section focused on performing a statistical analysis to determine the magnitude difference of the main effect: namely road types and rainfall condition on speed. Another analysis was also conducted to determine the effect on speed of drivers' sex and age and their interaction with rainfall condition.

5.7.1 Effect of Roadway Type on Drivers' Speeds

In order to compare the effect of roadway type on speed on a similar basis, the participants' actual speed was subtracted by 55 mph and 70 mph (posted speeds) while driving on suburban and highway sections, respectively. A one-way analysis of variance (ANOVA) was conducted on the speed difference on suburban versus highway. In other words, the authors were interested in testing the null hypotheses that the speed difference when the subjects were driving on suburban versus highway is equal. Low P-values (less than 0.01) imply that the data do not support the null hypothesis. The observations are illustrated by the linear statistical model as described in equation (1). The results are presented in Table 5-5.

$$\gamma_{ij} = \mu + \tau_i + \varepsilon_{ij} \tag{1}$$

Where:

γ_{ij} = observed response

μ = overall mean effect

τ_i = effect of roadway type (suburban and highway)

ε_{ijk} = a random error component

Table 5-5 Results of ANOVA for effect of roadway type on drivers' speeds

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F-Statistic	P-value	Significant at 95%
Road type	1425.11	1	1425.11	21.10	0.000	Yes
Error	15536.75	230	67.55			
Total	16961.86	231				

Based on the information presented in the table, the main effect (roadway type) was significant. In other words, the roadway type had a significant effect on the speed difference when the participants drove the simulator. As a result, the roadway type will be treated separately throughout the rest of the analysis. The P-values were less than 0.01.

5.7.2 Effect of Rainfall Intensity and Suburban Roadway Locations on Drivers' Speeds

A one-way analysis of variance (ANOVA) was conducted to determine the effect of rainfall intensity namely dry, level 2, level 3, and level 4 on the participants' speed on suburban roadways. A similar linear statistical model as described in equation (1) was used. The results are presented in Table 5-6. As presented in the table, the level of rainfall intensity affects the driver's speed. The P-values were less than 0.01.

Table 5-6 Results of ANOVA for effects of rainfall intensity and suburban roadway locations on drivers' speeds

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F-Statistic	P-value	Significant at 95%
Rainfall	3843.21	3	1281.07	49.93	0.000	Yes
Error	2873.59	112	25.66			
Total	6716.79	115				

Since the result from the ANOVA supports the hypothesis that the means of the rainfall intensity differs, it was of interest to determine the specific differences. In this study, Duncan's multiple range tests were used as they are quite powerful and widely used (Montgomery 1996). A comparison between the means of rainfall intensity shows that the speed between the dry conditions and rainfall levels 3 and 4 differs significantly (see Table 5-7). Also, the speed between rainfall levels 3 and 4 differs significantly. However, the drivers were not affected by light rainfall intensity. The effect of the rainfall intensity results in a substantial drop in speed, especially for rainfall level 4. On average, the speed dropped by 13 mph when the drivers drove in rainfall intensity level 4. The reduction in speed was 4 mph for rainfall level 3 (see Table 5-8). These data match the information provided by the participants in the survey. Ninety three (93%) of the participants have reported that they drove slower during rainfall as compared to dry conditions (Table 5-1). The amount of speed reduction is due to the rainfall intensity.

Table 5-7 Mean comparison between rainfall intensity and suburban roadway locations on drivers' speeds

Duncan's[a,b] Multiple Range Test

Road Types	Number of Data Points	Subset[c], mph		
		1	2	3
Rainfall Level 4	29	37.31		
Rainfall Level 3	29		46.48	
Rainfall Level 2	29			51.90
Dry Conditions	29			50.86
Significant		1.00	1.00	.438

[a]Uses Harmonic Mean Sample (Error) = 29; [b]Alpha = 0.5
[c]The factor levels that do not have significant effects are displayed in the same column

Table 5-8 Speed (mph) difference data used for analysis of rainfall classification

	Level 2[a]	Level 3[b]	Level 4[c]
Suburban	-1	-4	-13
Highway	0	-6	-12

Note: [a] Level 2 = Light Rainfall; [b] Level 3 = Heavy Rainfall; [c] Level 4 = Heaviest Rainfall
Negative values = Drivers drove slower when rainfall intensity was simulated as compared to dry conditions

5.7.3 Effect of Rainfall Intensity and Highway Roadway Locations on Drivers' Speeds

A similar approach (as described in the section above) evaluated the effect of rainfall intensity on drivers' speed while driving on the highway. ANOVA results (Table 5-9) showed that rainfall intensity has a significant effect on drivers' speed. Similar to suburban driving, drivers did not appear to be affected by light rainfall (see Table 5-10). However, both rainfall levels 3 and 4 have significant effect on speed reductions. On average, the drivers drove 6 and 12 mph slower when rainfall levels 3 and 4 were simulated (see Table 5-8).

Table 5-9 Results of ANOVA and differences for effect of roadway type on drivers' speed

Source of Variation	Sum of Squares	Degree of Freedom	Mean Square	F-Statistic	P-value	Significant at 95%
Rainfall	3104.99	3	1035.00	20.28	0.000	Yes
Error	5714.97	112	51.03			
Total	8819.96	115				

Table 5-10 Mean comparison between rainfall intensity and highway roadway locations on drivers' speeds

Duncan's[a,b] Multiple Range Test				
Road Types	Number of Data Points	Subset[c], mph		
		1	2	3
Rainfall Level 4	29	58.59		
Rainfall Level 3	29		65.48	
Rainfall Level 2	29			71.38
Dry Conditions	29			70.93
Significant		1.00	1.00	.8.12

[a]Uses Harmonic Mean Sample (Error) = 29; [b]Alpha = 0.5
[c]The factor levels that do not have significant effects are displayed in the same column

5.7.4 Effect of Gender on Drivers' Speeds

The one-way analyses indicated that roadway types and rainfall intensity had significant effect on speed on both suburban and highway driving. It was also found that drivers did not appear to be affected by light rainfall (Level 2). However, with visibility reduced by heavy rainfall intensity, namely level 3 and level 4, the drivers' speed was reduced substantially.

Other factors may also play a role in the speed reduction; the data were then analyzed utilizing a Univariate Analysis of Variance. It is a two-way ANOVA General Linear Model (GLM) with exactly two independent variables (e.g., fixed factors) (Montgomery 1996). The objective was to differentiate the rainfall intensity and compare their means to the dry conditions. The participants' genders were also factored into the ANOVA analysis to determine the effects that rainfall intensity and gender have on speed while the participants were driving on suburban and highway roads, respectively. In other words, the authors were interested in testing the null hypothesis that the effect of rainfall intensity and different gender groups were equal. An additional step was conducted to evaluate if interaction exits between rainfall intensity and different gender groups. Low P-values (less than 0.01) imply that the data do not support the null hypothesis. The observations are illustrated by the GLM as described in equation (2):

$$\gamma_{ij} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \varepsilon_{ij} \tag{2}$$

Where:

γ_{ijk} = observed response; μ = overall mean effect

τ_i = effect of the dry, levels 2, 3, 4 levels of the rainfall intensity

β_j = effect of male and female levels of sex group

$(\tau\beta)_{ij}$ = effect of the interaction between rainfall intensity and sex group

ε_{ijk} = a random error component

The results are presented in Tables 5-11 and 5-12 for suburban and highway driving, respectively. As presented in the previous sections, the main effect of the rainfall intensity was significant. However, based on the information presented in the tables, the speed was not significantly affected by gender on either road type. The P-values were 0.02 and 0.04 for suburban and highway, respectively. Also, there is no interaction between gender and rainfall intensity. The P-value was equal to 0.90 and 0.91 for suburban and highway driving, respectively. On average, females drove about 2 to 3 mph faster when compared to the male participants (see Table 5-13). Previous sections have already explained that the drivers' speed was not affected by light rainfall (Table 5-7).

Table 5-11 Results of ANOVA for effects of rainfall intensity, gender type, and suburban roadway locations on driver's speeds

Source of Variation	Type III Sum of Squares	Degree of Freedom	Mean Square	F-Statistic	P-value	Significant at 95%
Rainfall Intensity	3823.05	3	1274.35	50.66	0.000	Yes
Gender Type	142.63	1	142.63	5.67	0.02	No
Rainfall ∗ Gender	14.22	3	4.74	0.19	0.90	No
Error	2716.73	108	25.15			
Total	259028	116				
Corrected Total	6716.79	115				

Table 5-12 Results of ANOVA for effects of rainfall intensity, gender type, and highway roadway locations on driver's speeds

Source of Variation	Type III Sum of Squares	Degree of Freedom	Mean Square	F-Statistic	P-value	Significant at 95%
Rainfall Intensity	3086.81	3	1028.94	20.38	0.000	Yes
Gender Type	213.77	1	213.77	4.23	0. 04	No
Rainfall ∗ Gender	47.77	3	15.92	0. 32	0. 81	No
Error	5453.42	108	50.50			
Total	523265	116				
Corrected Total	8819.96	115				

Table 5-13. Speed recorded for male and female on the simulator

Road Type	Environment Conditions	Gender	Average Speed, mph
Suburban	Dry	Male	50
		Female	52
	Rain Level 2	Male	51
		Female	53
	Rain Level 3	Male	46
		Female	46
	Rain Level 4	Male	36
		Female	39
Highway	Dry	Male	71
		Female	72
	Rain Level 2	Male	70
		Female	72
	Rain Level 3	Male	63
		Female	63
	Rain Level 4	Male	57
		Female	60

5.7.5 Effect of Age Group on Drivers' Speeds

The purpose of this section is to determine the effect of age group and its interaction (if any) with rainfall intensity on drivers' speed. Similar to effect of gender analysis, a Univariate Analysis of Variance and process and model were used. Speed was used as the dependent variable and the factors were age and rainfall variation.

The results are presented in Tables 5-14 and 5-15 for suburban and highway driving, respectively. On the suburban drive, the speed was significantly affected by age. The P-value was less than 0.01. However, on the highway, the age did not have any effect on speed. The P-value was 0.11. No interaction between rainfall intensity and age existed on either suburban or highway driving, respectively.

Table 5-14 Results of ANOVA for effects of rainfall intensity, age group, and suburban roadway locations on drivers' speeds

Source of Variation	Type III Sum of Squares	Degree of Freedom	Mean Square	F-Statistic	P-value	Significant at 95%
Rainfall Intensity	3537.55	3	1179.18	54.44	0.000	Yes
Age Group	609.94	2	304.97	14.08	0.000	Yes
Rainfall ∗ Age	10.08	6	1.68	0. 08	1.00	No
Error	2252.86	104	21.66			
Total	258889	116				
Corrected Total	6611.63	115				

Table 5-15 Results of ANOVA for effects of rainfall intensity, age group, and highway roadway locations on drivers' speeds

Source of Variation	Type III Sum of Squares	Degree of Freedom	Mean Square	F-Statistic	P-value	Significant at 95%
Rainfall Intensity	2963.53	3	987.85	18.85	0.000	Yes
Age Group	236.37	2	118.18	2.26	0.11	No
Rainfall ∗ Age	40.53	6	6.76	0. 13	1.00	No
Error	5450.90	104	52.41			
Total	522766	116				
Corrected Total	8815.05	115				

Duncan's multiple range tests were used to determine the specific differences between age group on both suburban and highway roadways. The results are presented on Tables 5-16 and 5-17 for suburban and highway, respectively. A comparison between the means of every single age group category has a significant effect on speed when driving on suburban roads (Table 5-16). However, on highways no significant effect was found on the drivers' speed among the different age groups (Table 5-17). On suburban roads, the 16-to-21-year-old participants drove faster than any other participants. On average, they drove from 3 mph to 6 mph faster as compared to the 22-to-33-year-old participants and 33-or-more-year-old participants, respectively (Table 5-18). No specific pattern on speed reduction was found between the 16-to-21 and 22-to-33-year-old age groups when driving on highway. The 16-to-21 age group drove about 3 mph faster as compared to the participants that were 33 or older. On either suburban roads or highways, the 22-to-33 age bracket drove 3 mph faster than the participants that were 33 years old or more. Subsequently, it was found that the older participants drove slower as compared to the other participants. Their speeds were reduced 3 to 6 mph from any of the other age groups on either suburban roads or highways, respectively.

Table 5-16 Mean comparison between rainfall intensity, age group, and suburban roadway locations on drivers' speed

Duncan's[a,b] Multiple Range Test				
Road Types	Number of Data Points	Subset[c]		
		1	2	3
Age Group 33 or more	32	43.45		
Age Group 22 to 33	52		46.76	
Age Group 16 to 21	32			49.17
Significant		1.00	1.00	1.0

[a]Uses Harmonic Mean Sample (Error) = 36.71
[b]Alpha = 0.5
[c]The factor levels that do not have significant effects are displayed in the same column

Table 5-17 Mean comparison between rainfall intensity, age group, and highway roadway locations on drivers' speed

Duncan's[a,b] Multiple Range Test		
Road Types	Number of Data Points	Subset[c]
		1
Age Group 33 or more	32	64.28
Age Group 22 to 33	52	67.64
Age Group 16 to 21	32	67.10
Significant		0.062

[a]Uses Harmonic Mean Sample (Error) = 36.71
[b]Alpha = 0.5
[c]The factor levels that do not have significant effects are displayed in the same column

Table 5-18 Speed recorded for the drivers (as classified by age group) on the simulator

Road Type	Environment Conditions	Age Group	Average Speed, mph
Suburban	Dry	16-21	54
		22-33	51
		33 or more	48
	Rain Level 2	16-21	54
		22-33	52
		33 or more	48
	Rain Level 3	16-21	50
		22-33	46
		33 or more	43
	Rain Level 4	16-21	40
		22-33	38
		33 or more	34
Highway	Dry	16-21	73
		22-33	72
		33 or more	69
	Rain Level 2	16-21	71
		22-33	72
		33 or more	69
	Rain Level 3	16-21	66
		22-33	67
		33 or more	62
	Rain Level 4	16-21	58
		22-33	60
		33 or more	57

5.8 Experience of the Participants on the Simulator

As mentioned earlier, participants completed a survey after driving the simulator. Some of their answers have already been addressed in this report's previous sections. Their experiences are presented in Table 5-19; more information can be found in Appendix G. For the most part, the participants completed the experiment with no or only minor motion sickness caused by the simulator. Fewer than forty percent (40%) reported that they felt some level of discomfort mainly associated with dizziness. About ninety-six percent (96%) responded that their simulator experiences were close to reality. Also eighty-nine percent (89%) mentioned that their reaction times to the simulator's rainfall condition were closely or very closely related to how they would react to rain in real life.

This information provided a level of confidence on the validity of the data obtained from this study. Collection of field data related to vehicle speed is very difficult due to the associated safety issues. Driving simulators emerge as an alternative and cost effective method, allowing for experimental control, efficiency, low cost and ease of data collection. This study reinforces the information presented on the literature review.

Table 5-19. Participant experience in the simulator

Questions	Breakdown	Total	Percentage
Rate how realistic your driving experience was.	Very Unrealistic	1	3
	Unrealistic	0	0
	Realistic	16	55
	Very Realistic	12	41
Rate how much you think that your maneuver in the car was affected by the rainfall condition.	Not Affected	1	3
	Slightly Affected	7	24
	Affected	13	45
	Greatly Affected	8	28
Rate how much your reaction to the rainfall condition in the simulator was close to how you would react to rain in the real world.	Very Different	0	0
	Different	3	10
	Close	14	48
	Very Close	12	41
Did you experience any motion sickness during the experiment?	Yes	12	41
	No	17	59

5.9 Summary

This chapter focused on determining the impact of rainfall event on free flow speed. Significant data were obtained and analyzed for both dry and rainy days using thirty (30) participants driving on suburban and highway roadway sections in a driving simulator. The researchers have made the following observations:

- On average, the participants drove within the speed limit during dry conditions. Their driving ability was not affected when light rainfall condition was simulated, maintaining similar speeds during light rainfall and dry conditions. However, they slowed down about 7 mph and 9 mph when heavy rainfall condition (level 3 and level 4) was simulated, respectively.

- The results from the ANOVA support the hypothesis that the means of the rainfall intensity differs. A comparison between the means shows that the speed between the dry conditions and rainfall levels 3 and 4 differ significantly. However, the drivers were not affected by light rainfall intensity. On average, the speed dropped 13 mph when the drivers drove in rainfall intensity level 4 on suburban roads. On average, the drivers drove 6 and 12 mph slower on simulated highways with rainfall levels 3 and 4.
- Based on the results obtained from a two-way ANOVA, it was found that the participants' speeds were not affected by gender on either road type. The P-values were 0.02 and 0.04 for suburban and highway driving, respectively. Also, there was no interaction between gender type and rainfall intensity. On average, females drove about 2 to 3 mph faster as compared to their male counterparts.
- On suburban roads, the speed was significantly affected by age group. The P-value was less than 0.01. However, on highway, the age group did not have any effect on speed. In addition, no interaction was found between rainfall intensity and age group on either suburban roads or highways, respectively.
- On suburban roads, the participants that were 18-to 22-years-old drove faster than any of the other participants. On average, they drove 3 mph and 6 mph faster as compared to the participants that are 22-to-33-years-old and participants that are 33-or-more-years-old, respectively. On highways, no particular trend was observed on speed

reduction between the age groups. On either suburban roads or highways, the older participants drove slower, by 3 to 6 mph, as compared to the other participants.

- The trend observed from the analysis matched the information provided by the participants in the survey. Ninety-three percent (93%) of the participants reported that they drove slower during rainfall as compared to dry conditions. The amount of speed reduction was due to the rainfall intensity.
- Field data analysis shows similar trends. These observations lend credence to the validity of utilizing a driving simulator to investigate the pattern of drivers' behavior during rainfall event.
- The researchers recommend further validation and refinement of this approach. Continuation of this project may also help Florida Department of Transportation's future decision making when determining appropriate corrective measures on existing roadway sections and designing future roadway sections to reduce hydroplaning.

CHAPTER 6
FINDINGS AND CONCLUSIONS

6.1 Findings

The purpose of this study was to utilize a driving simulator to investigate the pattern of drivers' behaviors during rainfall event, using different geometries. A thorough literature review was conducted using published materials from transportation studies in driving simulators. Extensive field traffic data were extracted throughout the State of Florida from the Florida's Statewide 511 Website and FDOT's STEWARD database. In addition, rainfall data were extracted from the NOAA database. Technology advances have spurred studies in which users created visual databases in driving simulators. The "PatrolSim" simulator located in the RAPTER lab at UCF was selected for this study. It used proprietary formats, which are not open to the public; as a result, they limit the flexibility of the research study. Based on the discussions between the FGCU and UCF research teams, an initial scenario was developed and submitted to the FDOT sponsor, who provided feedback. A pilot study was developed using six (6) participants. Lessons learned from this pilot study and engineering judgments led to the development of a simulator experiment using 30 participants (drivers) of varying gender and age groups, all experienced drivers in the State of Florida, comfortable when driving the simulator, and driving in potential hydroplaning conditions. Their speed data were recorded and stored in a main frame computer and then analyzed to meet the objectives of this research. Based on the analysis, the following findings were discovered:

- There is a field data speed reduction of 2 mph during light rainfall event and of 8 mph during heavy rainfall event with the greatest speed decrease occurring during nighttime and weekday peak hours.
- No specific trend was observed for traffic volume during rainfall and it appeared to have little impact on free flow speed during rain events. Traffic volume decreased to about 100 cars per hour.
- On average, participants drove within the speed limit during dry conditions in the simulator. Similar to the field data, their driving ability was not affected when light rainfall condition was simulated. However, they slowed down when heavy rainfall condition was simulated. On average, they slowed down 7 mph for rainfall event level 3 and 9 mph for rainfall event level 4.
- On the simulator, the participants' speed was not affected during light rainfall condition. They maintained similar speeds during light rainfall and dry conditions. However, they slowed down about 7 mph and 9 mph when heavy rainfall condition (level 3 and level 4) was simulated, respectively.
- The results from the ANOVA support the hypothesis that the means of the rainfall variation differs; on average, speeds dropped 13 mph in rainfall intensity level 4 on suburban and 6 and 12 mph in highway-simulated rainfall levels 3 and 4.
- Based on the results obtained from a two-way ANOVA, the recorded speeds were not affected by gender on either road type. However, on suburban roads, the speed was significantly affected by age group, but not on highway.
- There was no interaction between gender type and rainfall intensity. On average, females drove 2 to 3 miles per hour faster as compared to their male counterparts.

- In addition, no interaction was found between rainfall intensity and age group on either suburban or highway driving. On suburban driving, the 16-to-21-year-old participants drove faster than any of the other participants. On average, they drove 3 mph and 6 mph faster as compared to the 22-to-33-year-old and 33-or-more-year-old participants, respectively. On either suburban or highway drives, older participants drove slower as compared to the other participants, with their speeds reduced by 3 to 6 mph below any of the other age groups.
- The trend observed from the analysis matched the information provided by the participants in the survey. Ninety-three percent (93%) of the participants have reported that they drove slower during rainfall as compared to dry conditions. The amount of speed reduction is due to the rainfall intensity.

6.2 Conclusions

Conclusions from this study may be summarized as follows:

- Drivers are not affected by light rainfall event. Heavy rainfall intensity has significant impact on their speed. On average they reduced their speed 6 to 12 mph.
- There is no interaction between rainfall intensity and either gender and age group. On the simulator, the female participants appeared to drive faster as compared to their male counterparts. The 16-to-21 year-old-age range was found to be the most aggressive.
- The UCF simulator appears to provide identical results when compared to the field data. These observations lend credence to the validity of utilizing a driving simulator to investigate the pattern of drivers' behaviors during rainfall event.

6.3 Recommendations

Evaluation of driver behavior to hydroplaning is a fairly new topic and has not been well studied. Although the study was limited, significant and quality data was obtained in this research which can be added to the existing literature. The researchers recommend further validation and refinement of this approach. Continuation of this project may also help FDOT's future decision making when determining appropriate corrective measures on existing roadway sections and designing future roadway sections to reduce hydroplaning. Specific recommendations include, but are not limited to the following:

- This research project used a fixed-base simulator, in which the driver response/behavior is directly affected by the visual representation of the driving environment. The researchers recommend the use of relationships between rain intensities and rainfall levels, used in the PatrolSim simulator. The simulated rainfall intensities should also be compared to that of real world. This relationship may be established using the visibility information along with statistical analysis using the data obtained from the simulator and field data. Once the visibility in the rain fall conditions is obtained, analysis can be conducted to obtain the corresponding rain intensity.
- This study was limited by the road geometries currently available in the virtual world in the PatrolSim simulator. Besides the suburban and highway roadways, this study should include a variety of roadway geometries including rural highways. The selected sections should also be structured in such way to minimize the effect of roadway geometry impact on hydroplaning. This may include eliminating locations with sharp curves and uncommon major transitions of road geometry.

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APPENDIX A
DATA USED FOR ANALYSIS OF RAINFALL CLASSIFICATION

Table A-1 Data used for analysis of rainfall classification for section 210084 - Jacksonville, FL

Rainfall Conditions		Non-Peak_WD [a]				Peak_WD			
		# of Data Points	Range of Rainfalls [b]			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry Days	28	N/A	N/A	N/A	26	N/A	N/A	N/A
	Wet Days	10	0.11	0.01	0.21	9	0.07	0.02	0.16
Heavy Rain	Dry Days	11	N/A	N/A	N/A	5	N/A	N/A	N/A
	Wet Days	5	0.79	0.36	1.66	2	0.53	0.31	0.75

Rainfall Conditions		Weekend				Night			
		# of Data Points	Range of Rainfalls			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry Days	18	N/A	N/A	N/A	28	N/A	N/A	N/A
	Wet Days	4	.12	.01	.21	8	0.04	0.01	0.11
Heavy Rain	Dry Days	11	N/A	N/A	N/A	0	N/A	N/A	N/A
	Wet Days	5	.79	.36	1.66	0	N/A	N/A	N/A

Note:
[a] WD = Week days
[b] Avg. = Average;
Min = Minimum;
Max = Maximum;
N/A = Not applicable

Table A-2 Data used for analysis of rainfall classification for section 411002 - Boca Raton, FL

Rainfall Conditions		Non-Peak_WD [a]				Peak_WD			
		# of Data Points	Range of Rainfalls [b]			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry Days	16	N/A	N/A	N/A	32	N/A	N/A	N/A
	Wet Days	4	0.11	0.03	0.20	9	0.11	0.10	0.20
Heavy Rain	Dry Days	15	N/A	N/A	N/A	0	N/A	N/A	N/A
	Wet Days	4	1.15	0.40	1.50	0	N/A	N/A	N/A

Rainfall Conditions		Weekend				Night			
		# of Data Points	Range of Rainfalls			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry Days	18	N/A	N/A	N/A	40	N/A	N/A	N/A
	Wet Days	6	0.13	0.03	0.10	10	0.14	0.10	0.20
Heavy Rain	Dry Days	3	N/A	N/A	N/A	17	N/A	N/A	N/A
	Wet Days	1	1.5	1.5	1.5	3	0.60	0.30	0.90

Note:
[a] WD = Week days
[b] Avg. = Average;
Min = Minimum;
Max = Maximum;
N/A = Not applicable

Table A-3 Data used for analysis of rainfall classification for section 420412 - Ft Lauderdale, FL

Rainfall Conditions		Non-Peak_WD [a]				Peak_WD			
		# of Data Points	Range of Rainfalls [b]			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry Days	70	N/A	N/A	N/A	78	N/A	N/A	N/A
	Wet Days	15	0.10	0.01	0.30	20	0.08	0.02	0.22
Heavy Rain	Dry Days	24	N/A	N/A	N/A	28	N/A	N/A	N/A
	Wet Days	6	0.50	0.27	0.71	7	0.76	0.37	1.32

Rainfall Conditions		Weekend				Night			
		# of Data Points	Range of Rainfalls			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry Days	48	N/A	N/A	N/A	156	N/A	N/A	N/A
	Wet Days	17	0.06	0.01	0.19	39	0.08	0.01	0.24
Heavy Rain	Dry Days	18	N/A	N/A	N/A	82	N/A	N/A	N/A
	Wet Days	7	0.53	0.31	0.94	14	0.76	0.26	4.33

Note:

[a] WD = Week days

[b] Avg. = Average;

Min = Minimum;

Max = Maximum;

N/A = Not applicable

Table A-4 Data used for analysis of rainfall classification for section 510611 - Orlando, FL

Rainfall Conditions		Non-Peak_WD [a]				Peak_WD			
		# of Data Points	Range of Rainfalls [b]			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry Days	56	N/A	N/A	N/A	34	N/A	N/A	N/A
	Wet Days	16	0.05	0.01	0.16	9	0.05	0.01	0.16
Heavy Rain	Dry Days	4	N/A	N/A	N/A	12	N/A	N/A	N/A
	Wet Days	1	1.06	1.06	1.06	3	0.55	0.32	0.78

Rainfall Conditions		Weekend				Night			
		# of Data Points	Range of Rainfalls			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry Days	59	N/A	N/A	N/A	94	N/A	N/A	N/A
	Wet Days	18	0.06	0.01	0.24	17	0.05	0.01	0.19
Heavy Rain	Dry Days	12	N/A	N/A	N/A	4	N/A	N/A	N/A
	Wet Days	4	0.59	0.33	1.26	1	0.43	0.43	0.43

Note:
[a] WD = Week days
[b] Avg. = Average;
Min = Minimum;
Max = Maximum;
N/A = Not applicable

Table A-5 Data used for analysis of rainfall classification for section 640032- Miami, FL

Rainfall Conditions		Non-Peak_WD [a] # of Data Points	Non-Peak_WD Range of Rainfalls [b] Avg.	Min	Max	Peak_WD # of Data Points	Peak_WD Range of Rainfalls Avg.	Min	Max
Light Rain	Dry Days	148	N/A	N/A	N/A	152	N/A	N/A	N/A
	Wet Days	41	0.06	0.01	0.21	41	0.06	0.01	0.22
Heavy Rain	Dry Days	18	N/A	N/A	N/A	34	N/A	N/A	N/A
	Wet Days	5	0.76	0.35	1.40	9	0.54	0.34	1.06

Rainfall Conditions		Weekend # of Data Points	Weekend Range of Rainfalls Avg.	Min	Max	Night # of Data Points	Night Range of Rainfalls Avg.	Min	Max
Light Rain	Dry Days	78	N/A	N/A	N/A	216	N/A	N/A	N/A
	Wet Days	26	0.05	0.01	0.21	54	0.04	0.01	0.22
Heavy Rain	Dry Days	26	N/A	N/A	N/A	28	N/A	N/A	N/A
	Wet Days	10	0.50	0.27	0.81	5	0.99	0.28	2.13

Note:
[a] WD = Week days
[b] Avg. = Average;
Min = Minimum;
Max = Maximum;
N/A = Not applicable

Table A-6 Data used for analysis of rainfall classification for section 700321 - Tampa, FL

Rainfall Conditions		Non-Peak_WD [a]				Peak_WD			
		# of Data Points	Range of Rainfalls [b]			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry Days	4	N/A	N/A	N/A	33	N/A	N/A	N/A
	Wet Days	1	0.06	0.06	0.06	9	0.04	0.01	0.12
Heavy Rain	Dry Days	4	N/A	N/A	N/A	7	N/A	N/A	N/A
	Wet Days	1	0.31	0.31	0.31	2	0.81	0.57	1.05

Rainfall Conditions		Weekend				Night			
		# of Data Points	Range of Rainfalls			# of Data Points	Range of Rainfalls		
			Avg.	Min	Max		Avg.	Min	Max
Light Rain	Dry Days	23	N/A	N/A	N/A	71	N/A	N/A	N/A
	Wet Days	8	0.06	0.01	0.16	14	0.07	0.01	0.16
Heavy Rain	Dry Days	4	N/A	N/A	N/A	31	N/A	N/A	N/A
	Wet Days	1	0.34	0.34	0.34	6	0.54	0.29	0.75

Note:
[a] WD = Week days
[b] Avg. = Average;
Min = Minimum;
Max = Maximum;
N/A = Not applicable

APPENDIX B

AVERAGE SPEED FOR INDIVIDUAL SECTION SELECTED

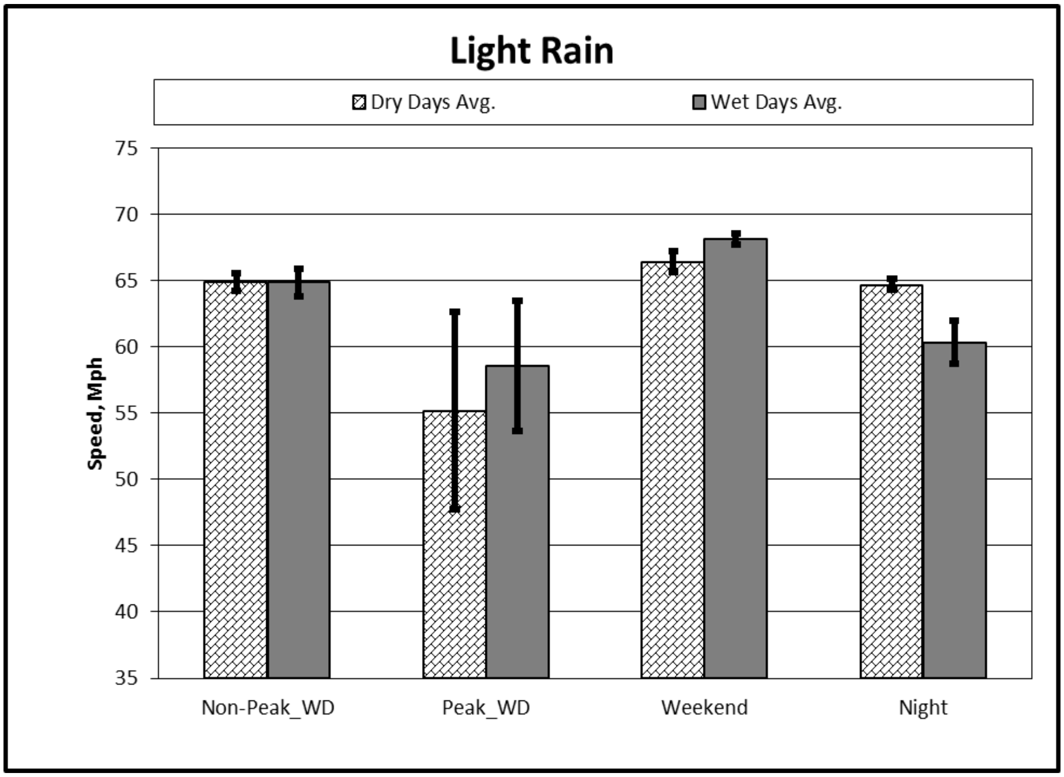

Figure B-1 Average speed during light rain conditions with 95% confidence interval error bars for section 2100814 - Jacksonville, FL

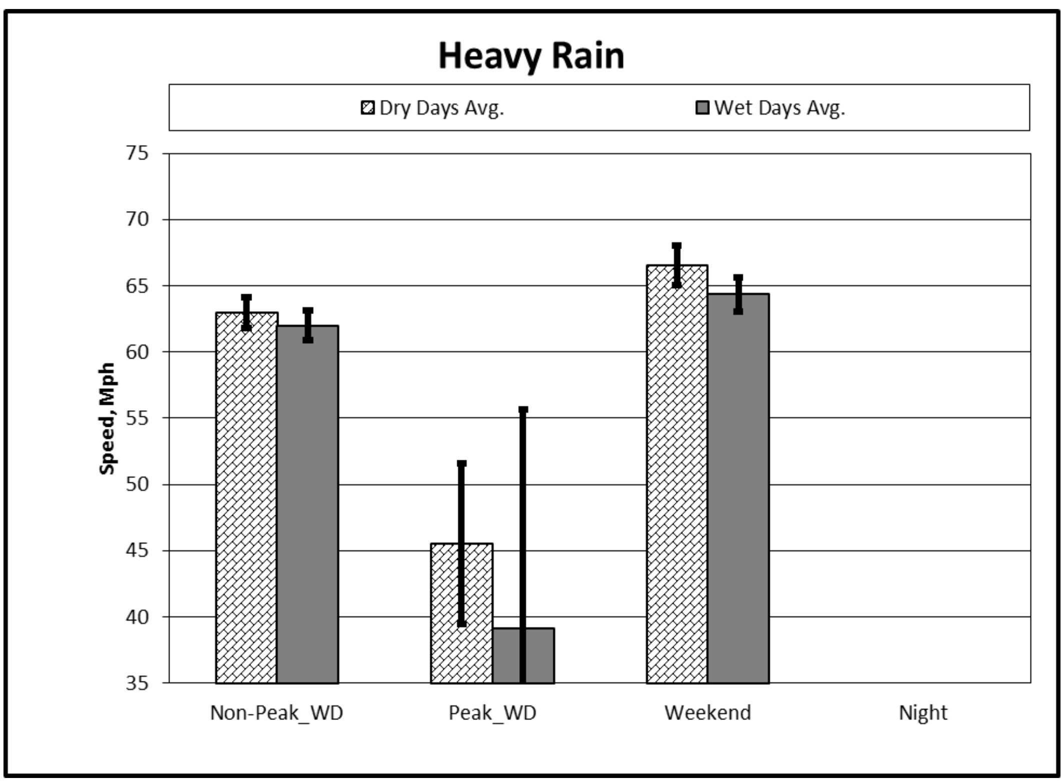

Figure B-2 Average speed during heavy rain conditions with 95% confidence interval error bars for section 2100814 - Jacksonville, FL

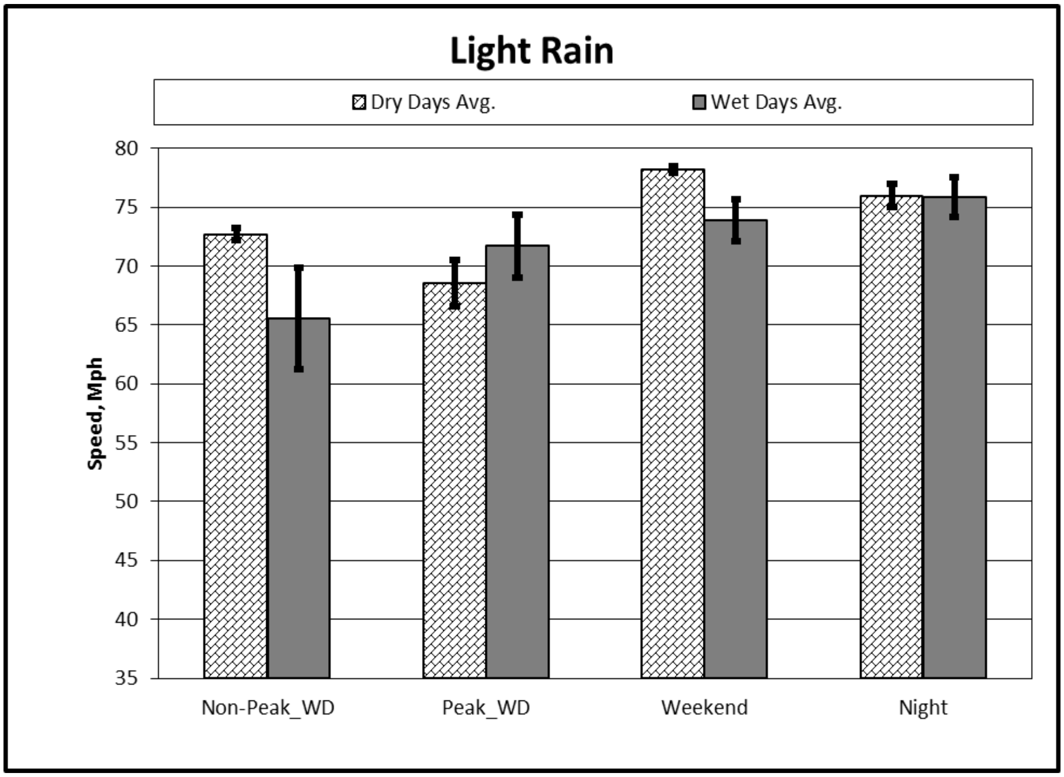

Figure B-3 Average speed during light rain conditions with 95% confidence interval error bars for section 411002 - Boca Raton, FL

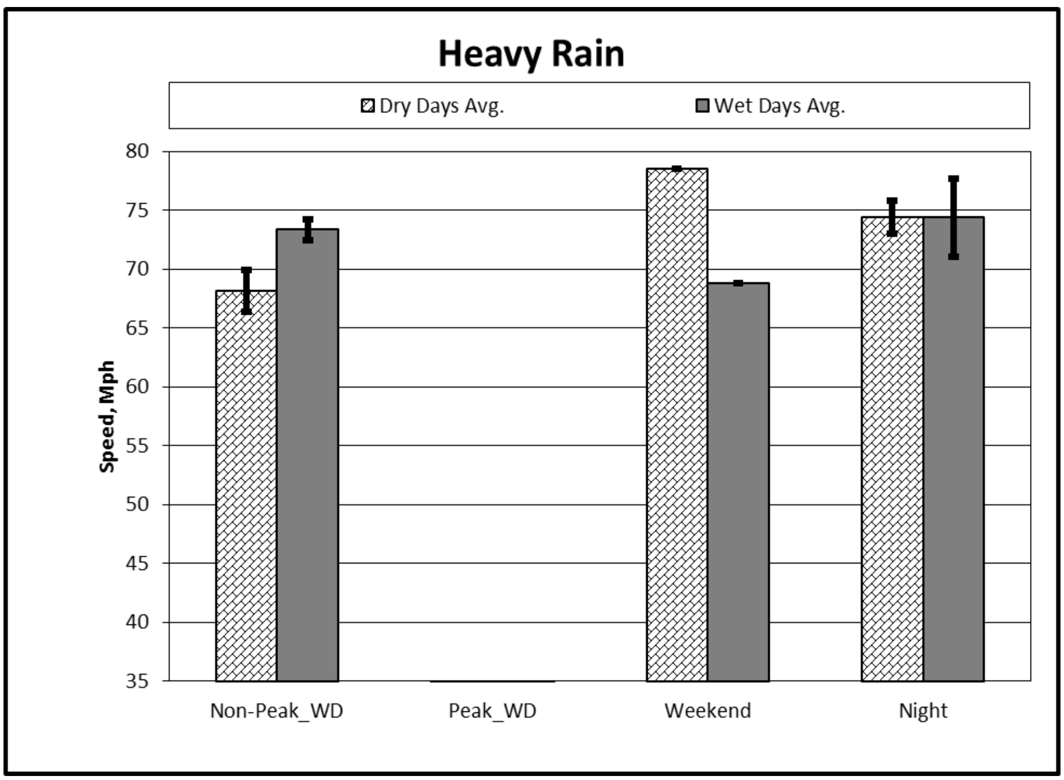

Figure B-4 Average speed during heavy rain conditions with 95% confidence interval error bars for section 411002 - Boca Raton, FL

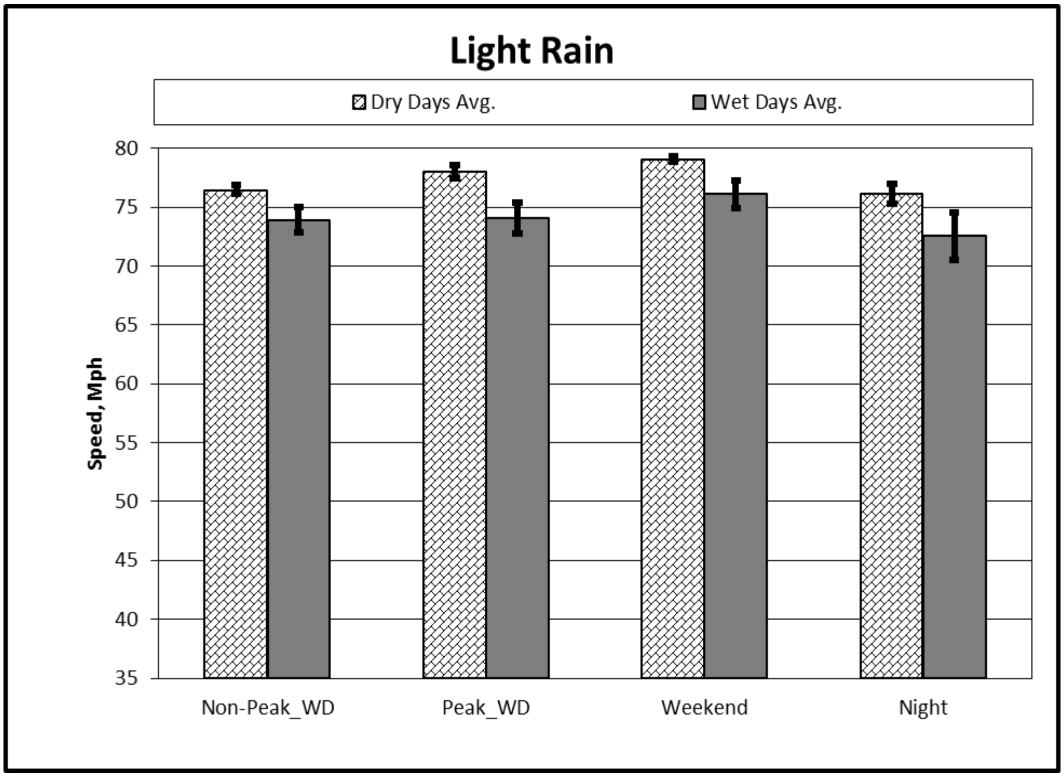

Figure B-5 Average speed during light rain conditions with 95% confidence interval error bars for section 420412 - Ft Lauderdale, FL

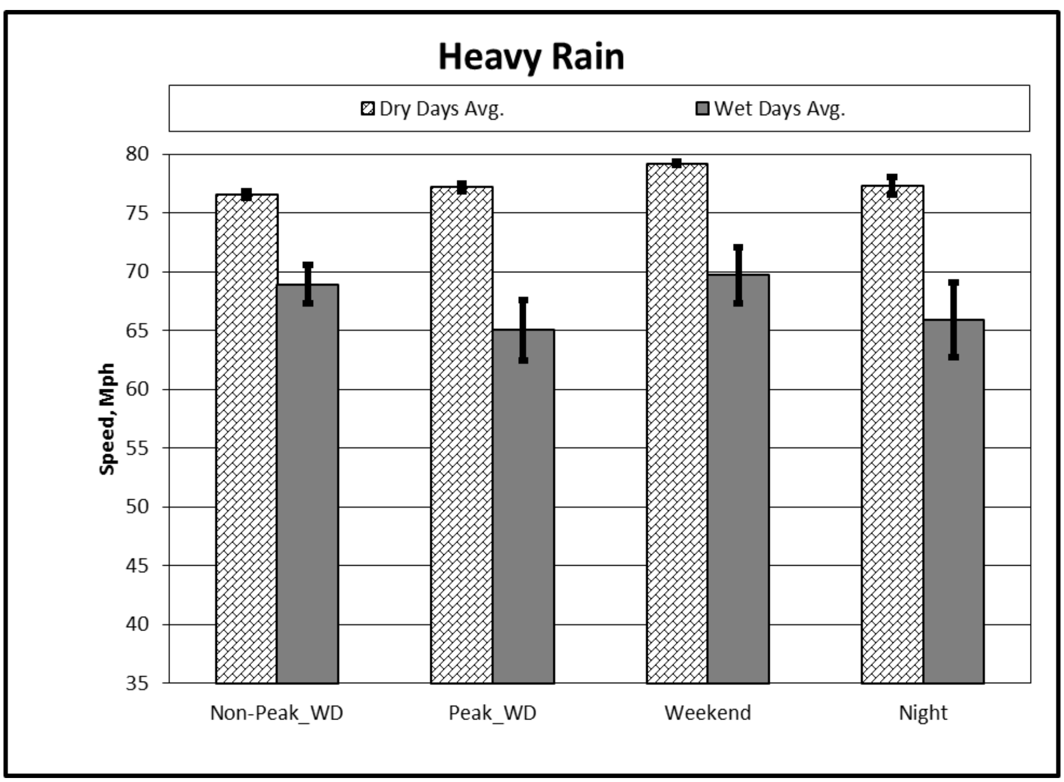

Figure B-6 Average speed during heavy rain conditions with 95% confidence interval error bars for section 420412 - Ft Lauderdale, FL

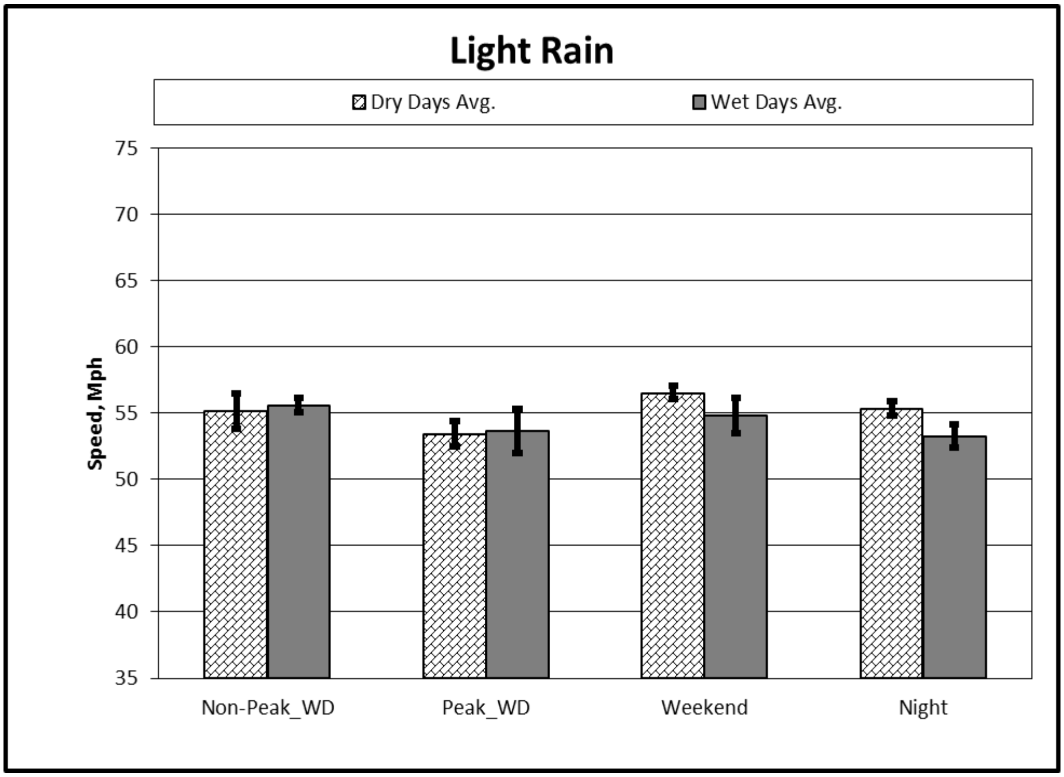

Figure B-7 Average speed during light rain conditions with 95% confidence interval error bars for section 510611 - Orlando, FL

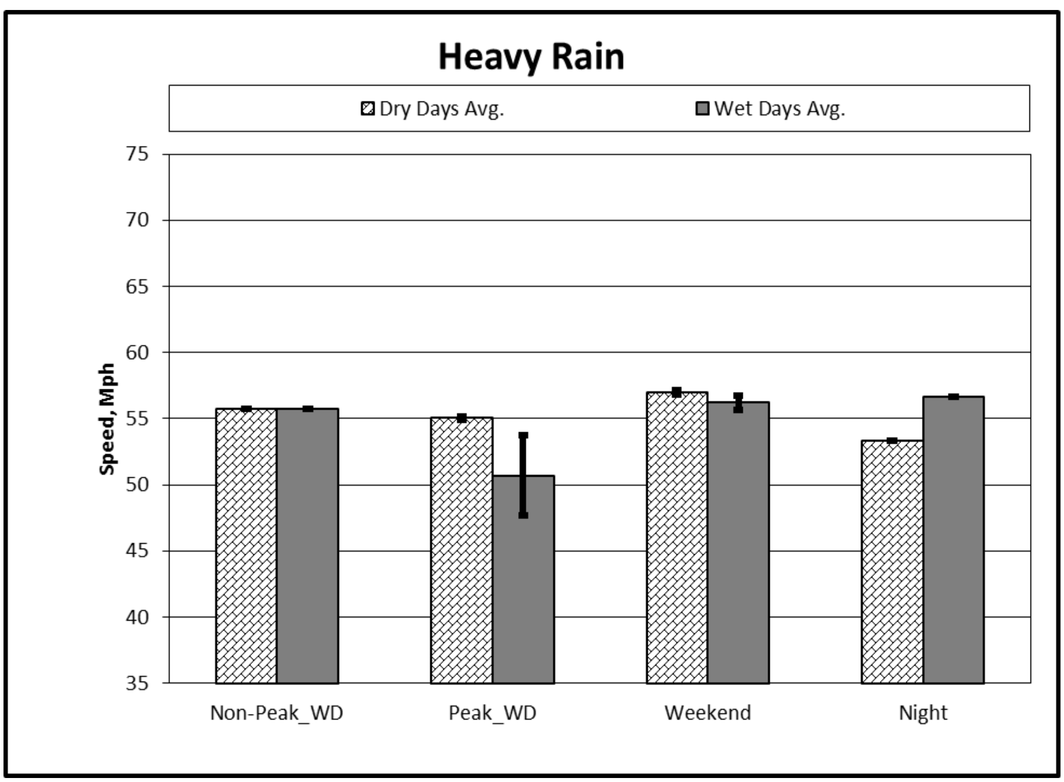

Figure B-8 Average speed during heavy rain conditions with 95% confidence interval error bars for section 510611 - Orlando, FL

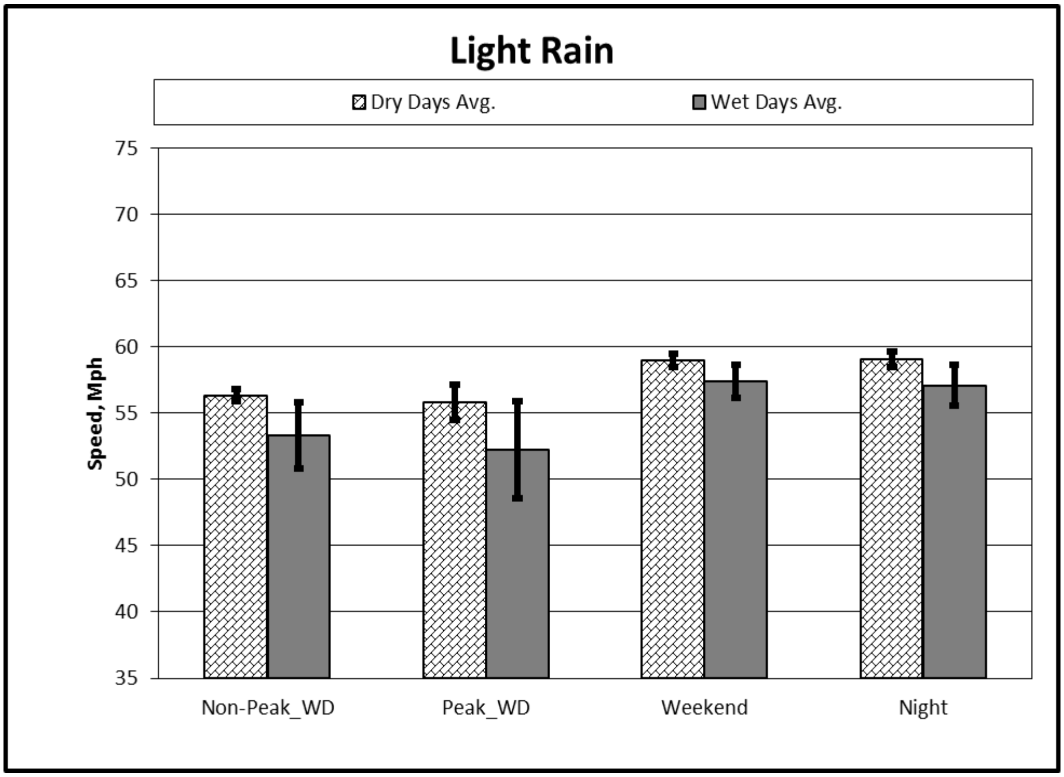

Figure B-9 Average speed during light rain conditions with 95% confidence interval error bars for section 640032 - Miami, FL

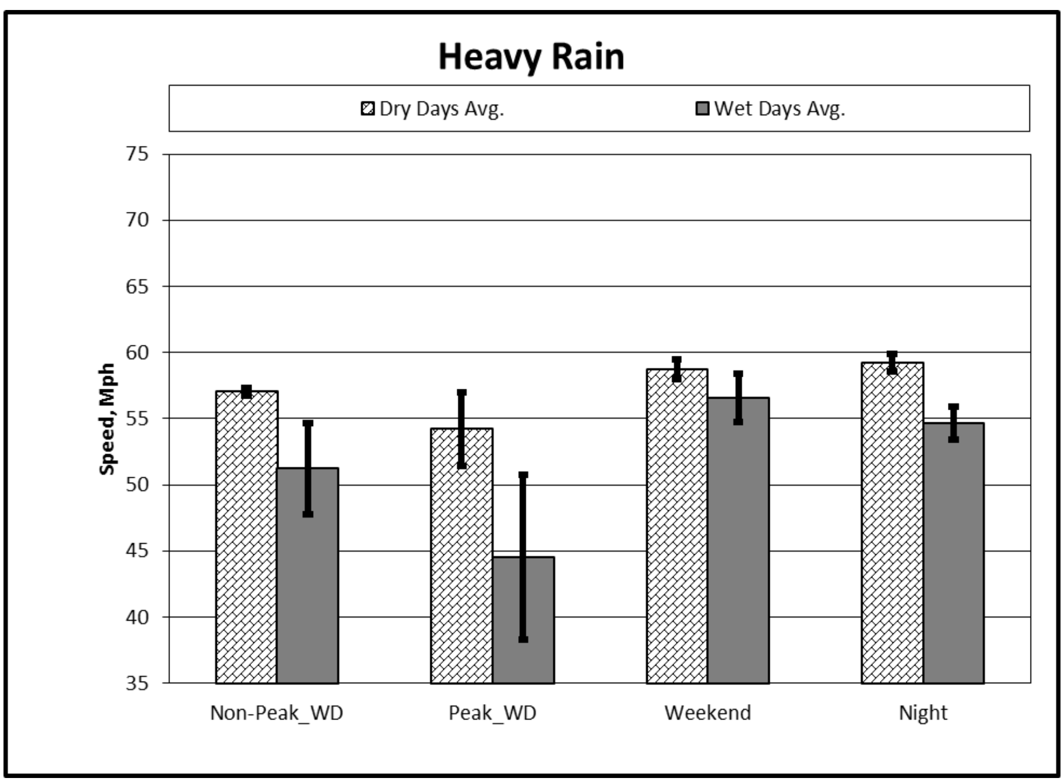

Figure B-10 Average speed during heavy rain conditions with 95% confidence interval error bars for section 640032 - Miami, FL

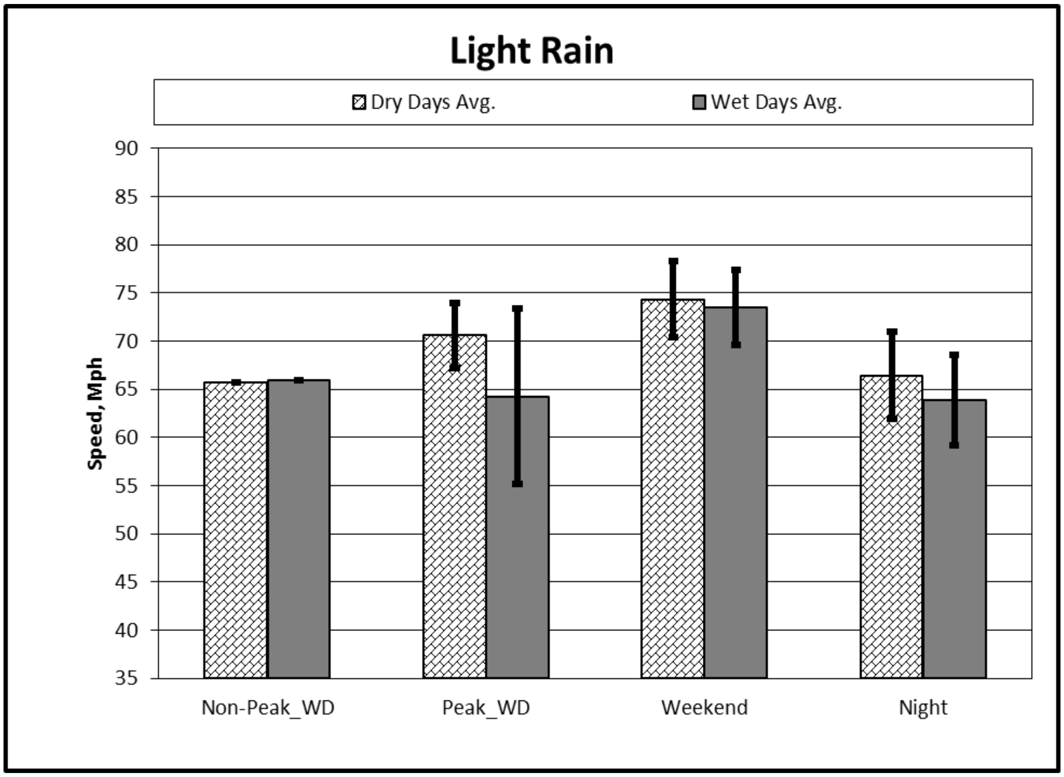

Figure B-11 Average speed during light rain conditions with 95% confidence interval error bars for section 700321 - Tampa, FL

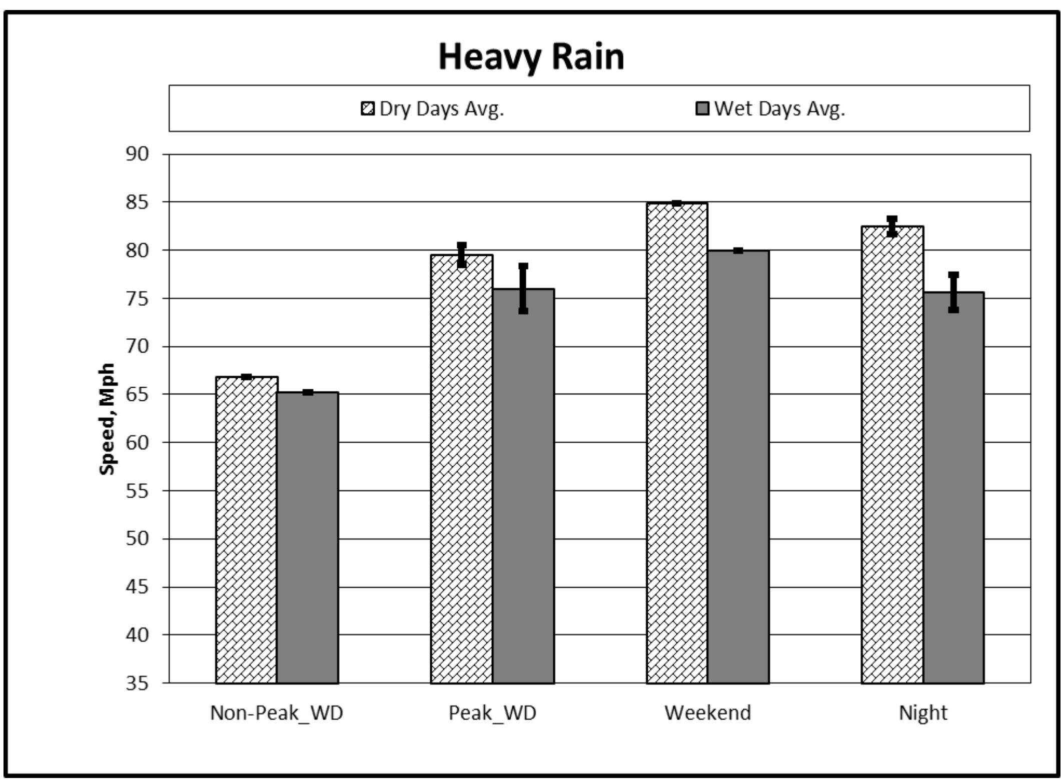

Figure B-12 Average speed during heavy rain conditions with 95% confidence interval error bars for section 700321 - Tampa, FL

Table B-1 Speed difference for section 2100814 - Jacksonville, FL

Rainfall Conditions	Speed difference, Mph			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	-0.02	3.36	1.71	-4.36
Heavy rain	-0.97	-6.42	-2.17	N/A

Note:
[a] WD = Week days
[b] N/A = Not applicable

Table B-2 Speed difference for section 411002 - Boca Raton, FL

Rainfall Conditions	Speed difference, Mph			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	-7.16	3.12	-4.32	-0.12
Heavy rain	5.21	0.00	-9.74	-0.04

Note:
[a] WD = Week days

Table B-3 Speed difference for section 420412 - Ft Lauderdale, FL

Rainfall Conditions	Speed difference, Mph			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	-2.57	-4.15	-3.01	-3.60
Heavy rain	-7.62	-12.15	-9.50	-11.39

Note:
[a] WD = Week days

Table B-4 Speed difference for section 510611 - Orlando, FL

Rainfall Conditions	Speed difference, Mph			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	0.46	.017	-1.75	-2.09
Heavy rain	0.01	-4.33	.0.74	3.36

Note:
[a] WD = Week days

Table B-5 Speed difference for section 640032 - Miami, FL

Rainfall Conditions	Speed difference, Mph			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	-3.04	-3.36	-1.57	-1.99
Heavy rain	-582	-9.71	-2.16	-4.56

Note:
[a] WD = Week days

Table B-6 Speed difference for section 700321 - Tampa, FL

Rainfall Conditions	Speed difference, Mph			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	0.18	-6.37	-0.86	-2.58
Heavy rain	-1.60	-3.51	-4.84	-6.92

Note:
[a] WD = Week days

APPENDIX C
AVERAGE VOLUME FOR INDIVIDUAL SECTION SELECTED

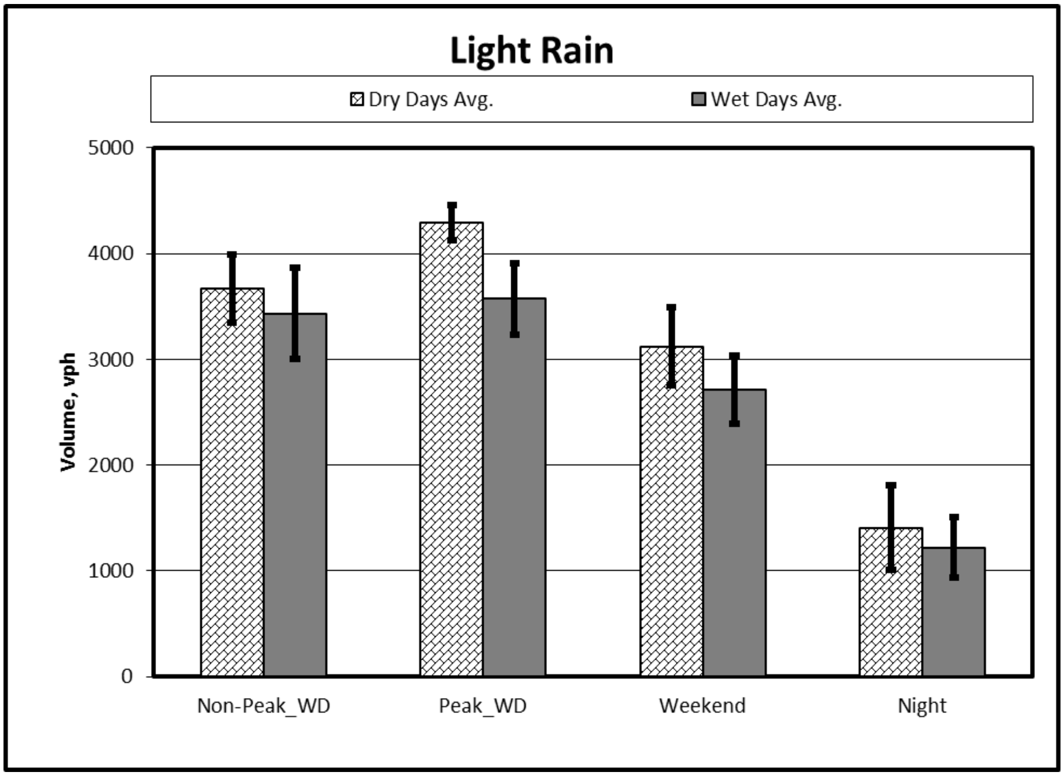

Figure C-1 Average volume during light rain conditions with 95% confidence interval error bars for section 2100814 - Jacksonville, FL

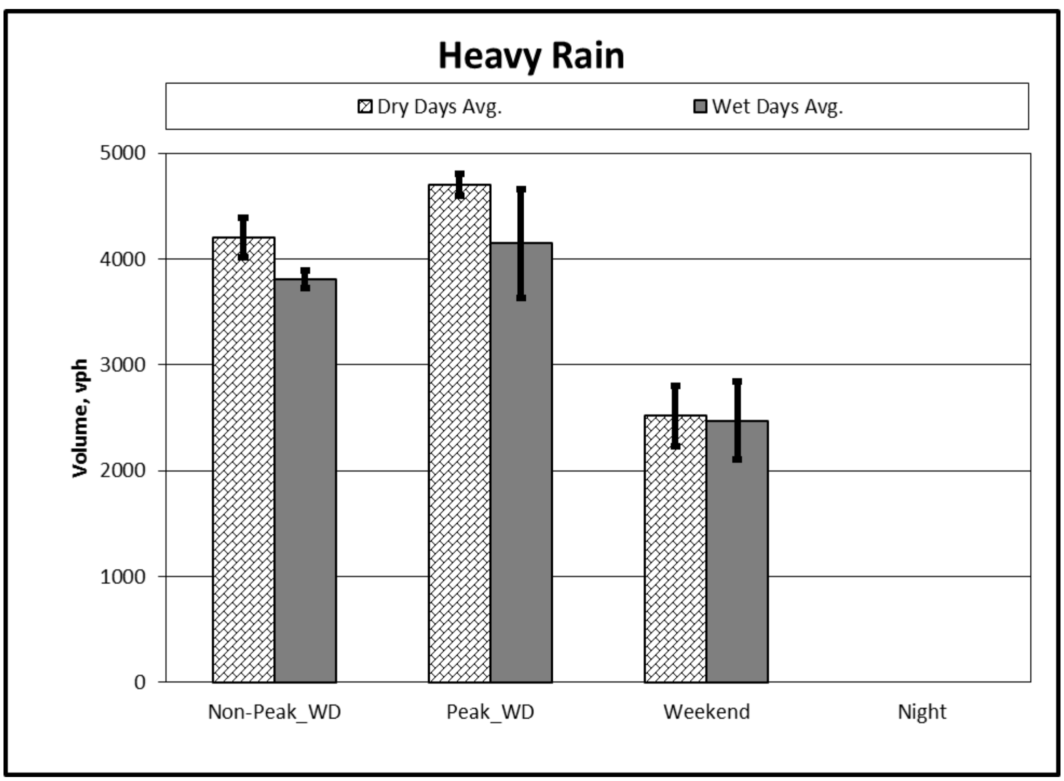

Figure C-2 Average volume during heavy rain conditions with 95% confidence interval error bars for section 2100814 - Jacksonville, FL

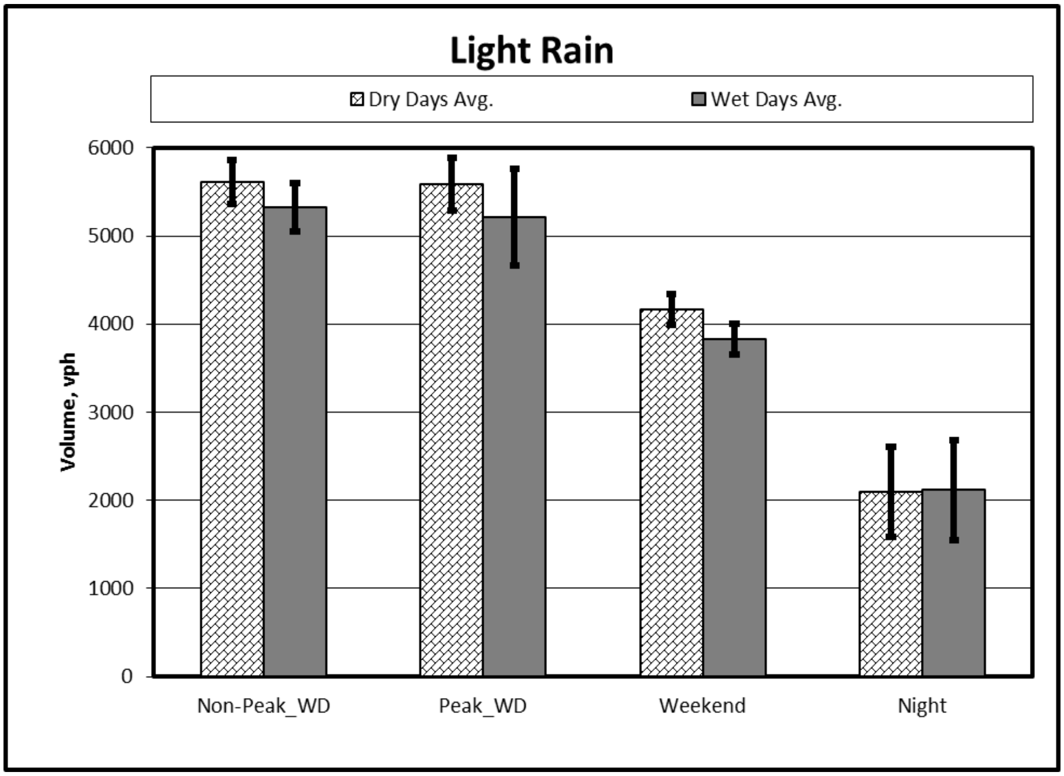

Figure C-3 Average volume during light rain conditions with 95% confidence interval error bars for section 411002 - Boca Raton, FL

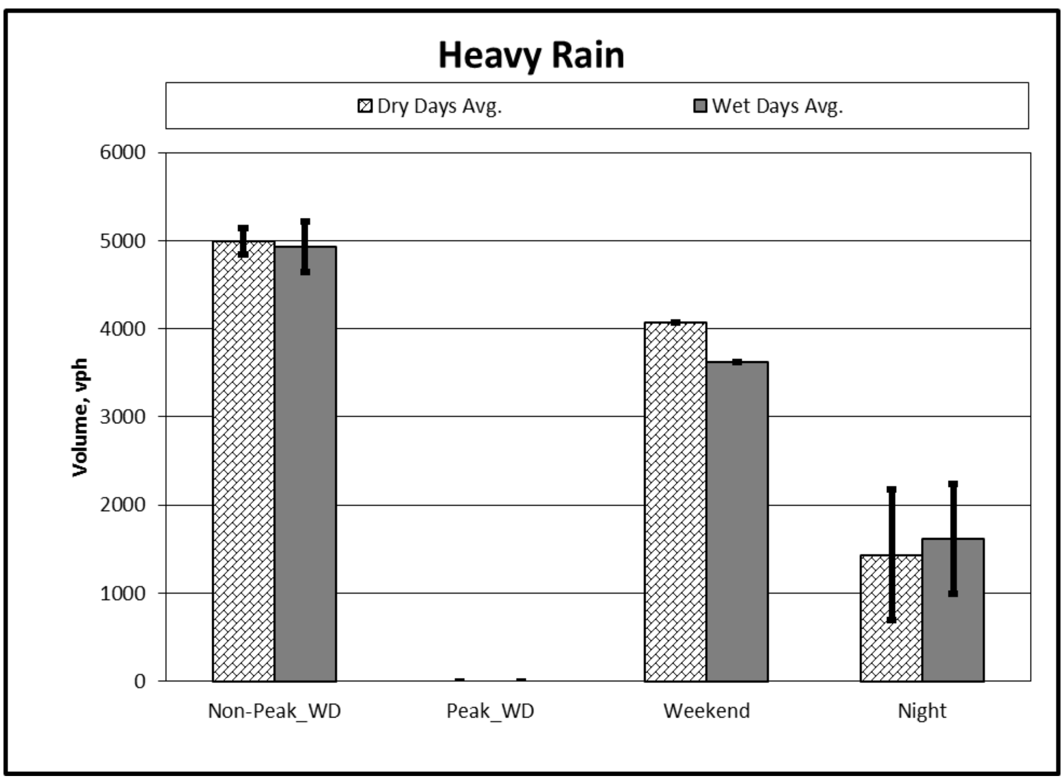

Figure C-4 Average volume during heavy rain conditions with 95% confidence interval error bars for section -411002 Boca Raton, FL

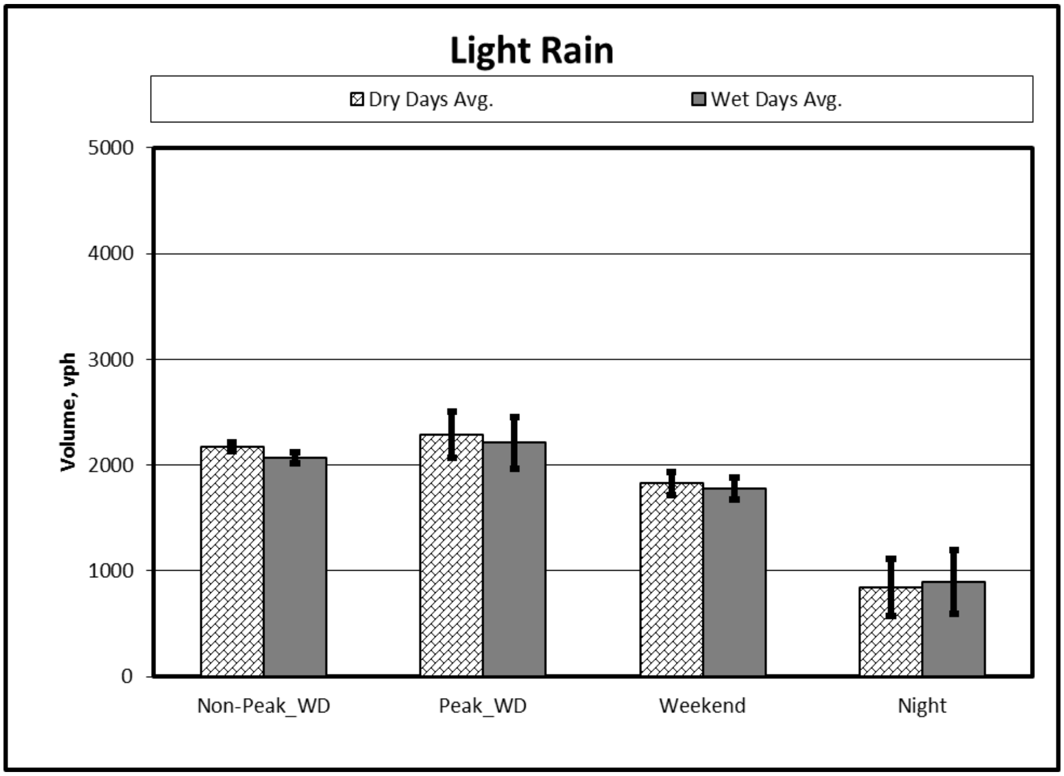

Figure C-5 Average volume during light rain conditions with 95% confidence interval error bars for section 420412 - Ft Lauderdale, FL

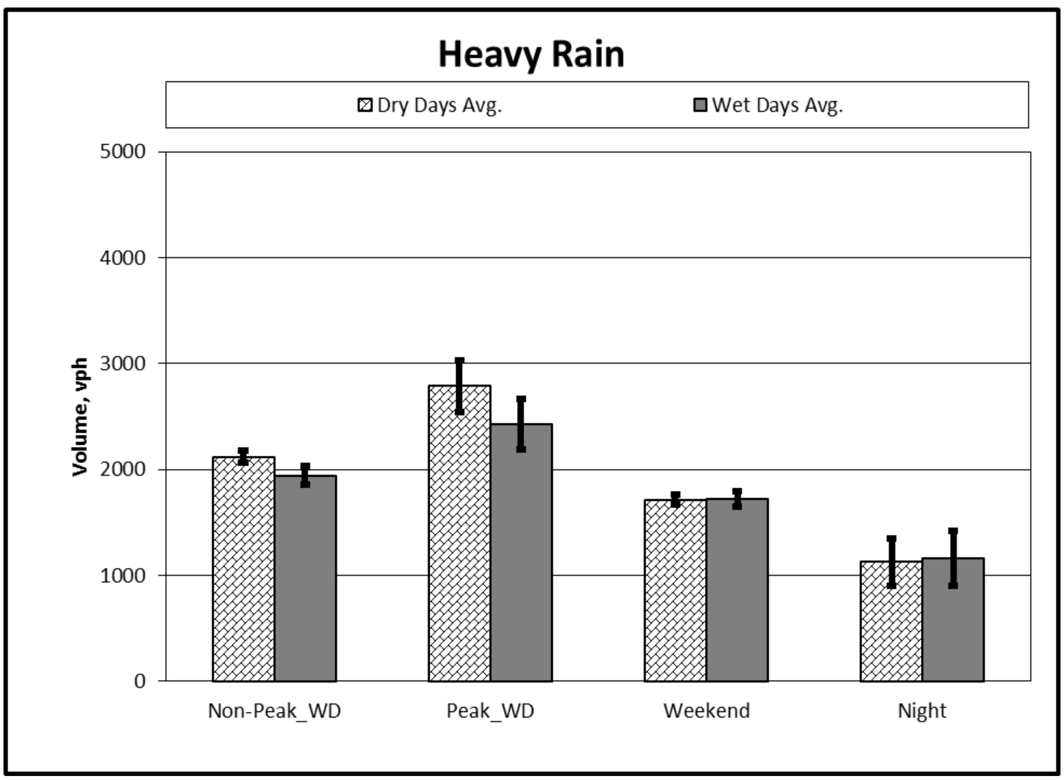

Figure C-6 Average volume during heavy rain conditions with 95% confidence interval error bars for section 420412 - Ft Lauderdale, FL

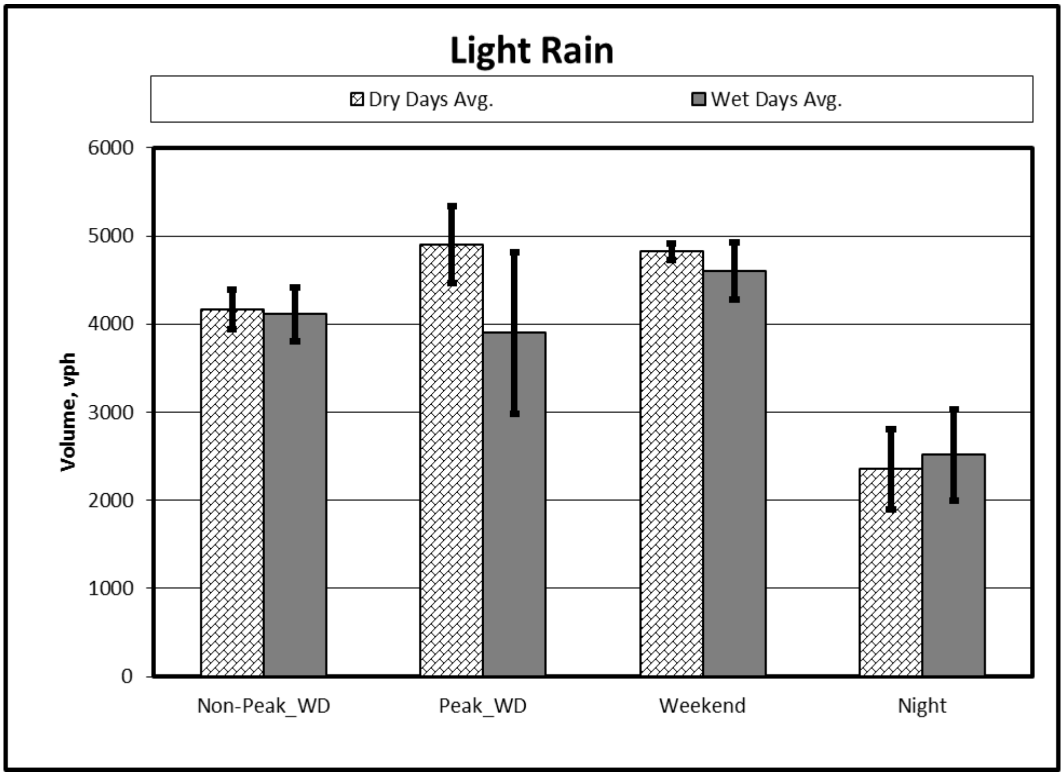

Figure C-7 Average volume during light rain conditions with 95% confidence interval error bars for section 510611 - Orlando, FL

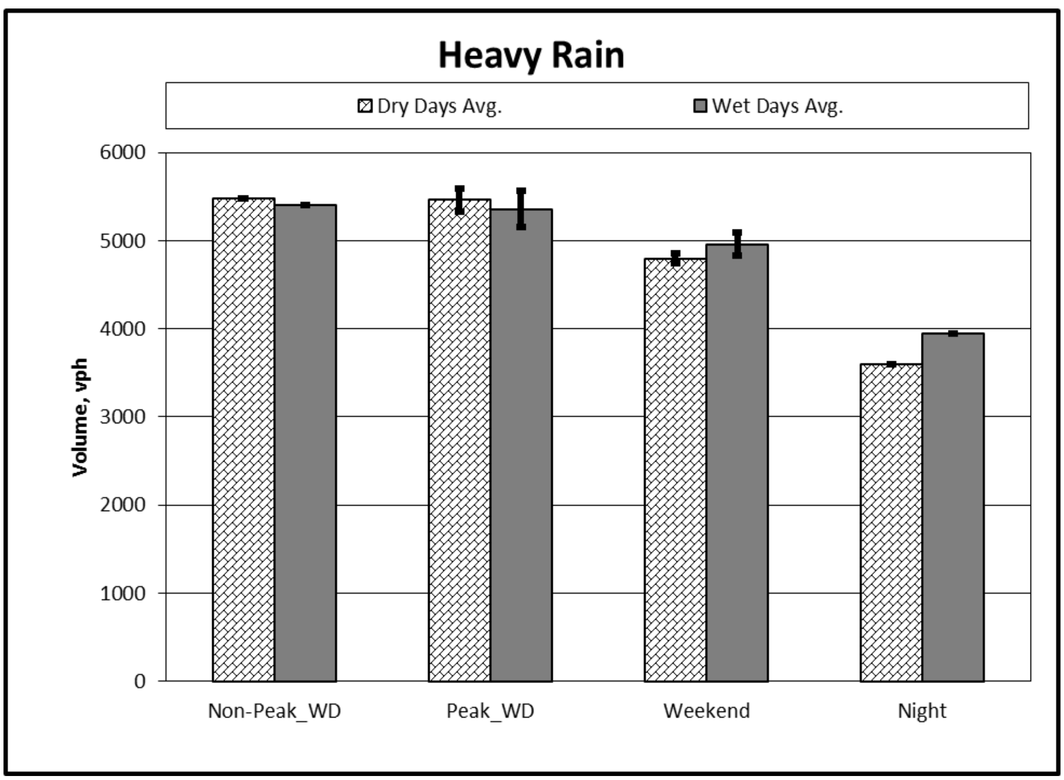

Figure C-8 Average volume during heavy rain conditions with 95% confidence interval error bars for section 510611 - Orlando, FL

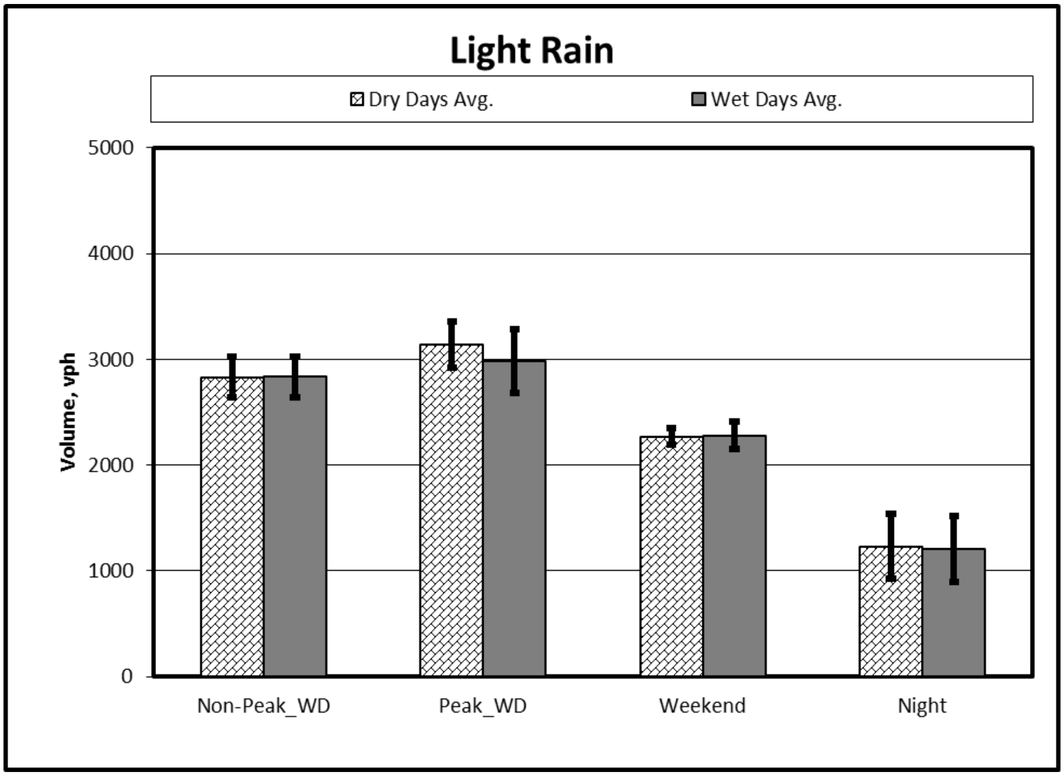

Figure C-9 Average volume during light rain conditions with 95% confidence interval error bars for section 640032 - Miami, FL

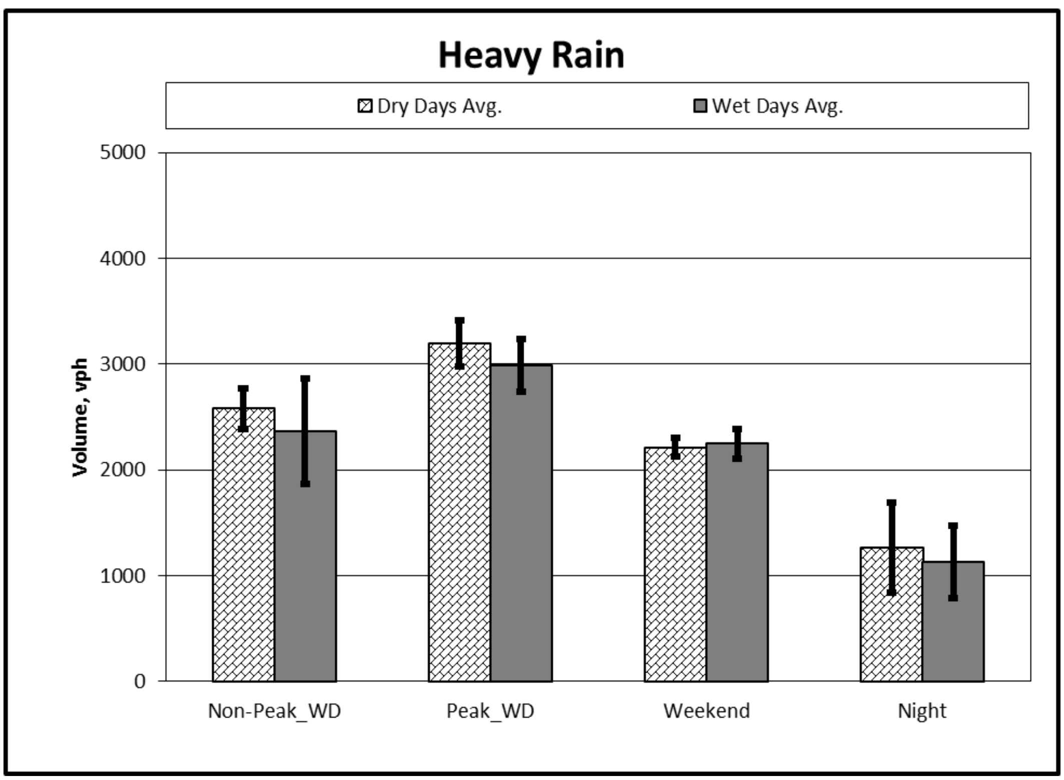

Figure C-10 Average volume during heavy rain conditions with 95% confidence interval error bars for section 640032 - Miami, FL in heavy rain

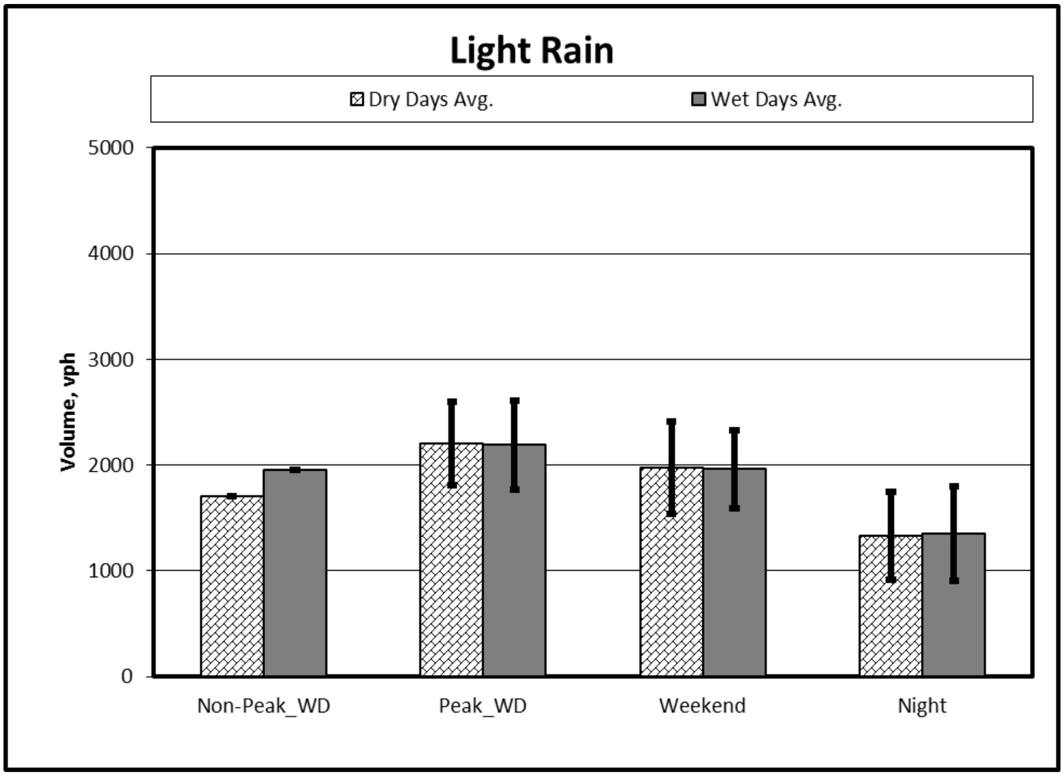

Figure C-11 Average volume during light rain conditions with 95% confidence interval error bars for section 700321 - Tampa, FL

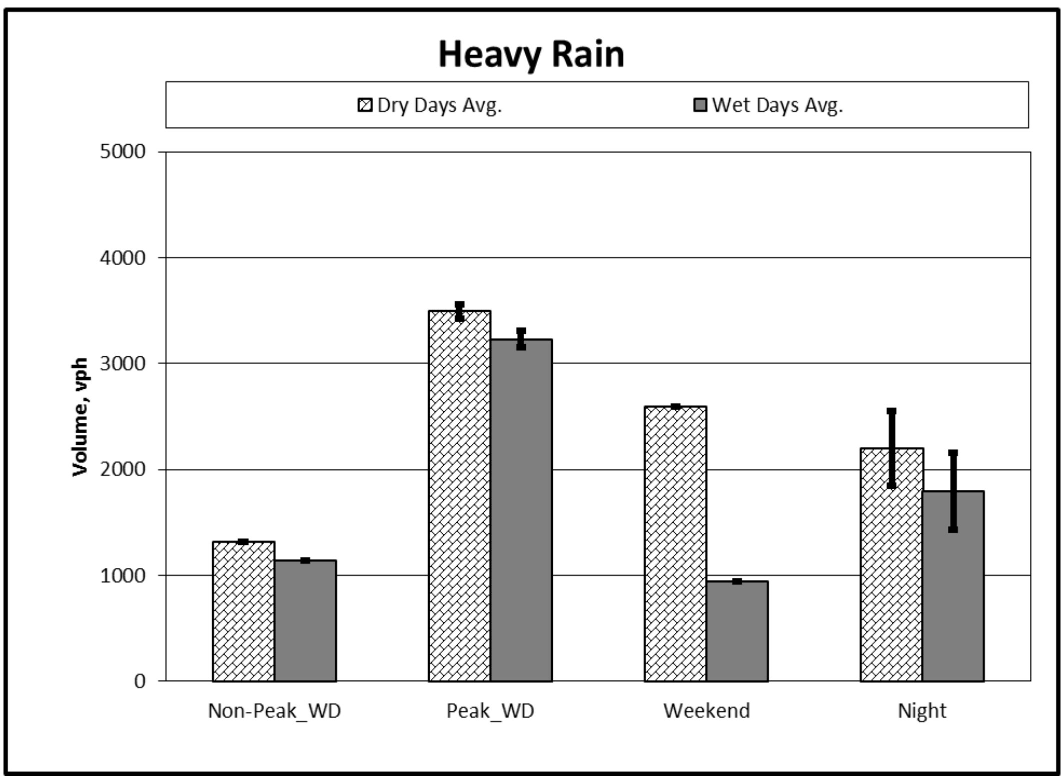

Figure C-12 Average volume during heavy rain conditions with 95% confidence interval error bars for section 700321 - Tampa, FL

Table C-1 Volume difference for section 2100814 - Jacksonville, FL

Rainfall Conditions	**Volume difference, Mph**			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	-233.4	-718.2	-407.3	-186.0
Heavy rain	-393.6	-552.8	-46.6	0.0

Note:
[a] WD = Week days

Table C-2 Volume difference for section 411002 - Boca Raton, FL

Rainfall Conditions	**Volume difference, Mph**			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	-288.4	-377.7	-335.3	18.6
Heavy rain	-62.7	0.0	-444.3	182.1

Note:
[a] WD = Week days

Table C-3 Volume difference for section 420412 - Ft Lauderdale, FL

Rainfall Conditions	**Volume difference, Mph**			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	-108.9	-77.8	-45.3	49.7
Heavy rain	-174.6	-355.2	8.8	35.4

Note:
[a] WD = Week days

Table C-4 Volume difference for section 510611 - Orlando, FL

Rainfall Conditions	**Volume difference, Mph**			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	-60.0	-1004.1	-222.4	161.1
Heavy rain	-70.3	-106.4	165.1	358.3

Note:
[a] WD = Week days

Table C-5 Volume difference for section 640032 - Miami, FL

Rainfall Conditions	**Volume difference, Mph**			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	4.6	-152.6	9.4	-25.1
Heavy rain	-215.1	-207.8	33.8	-137.0

Note:
[a] WD = Week days

Table C-6 Volume difference for section 700321 - Tampa, FL

Rainfall Conditions	**Volume difference, Mph**			
	Non-Peak_WD [a]	Peak_WD	Weekend	Night
Light rain	249.5	-18.3	-9.6	18.9
Heavy rain	-175.3	-260.5	-1653.8	-409.0

Note:
[a] WD = Week days

APPENDIX D

SPEED RECORDED FOR PARTICIPANT ON SUBURBAN AND HIGHWAY

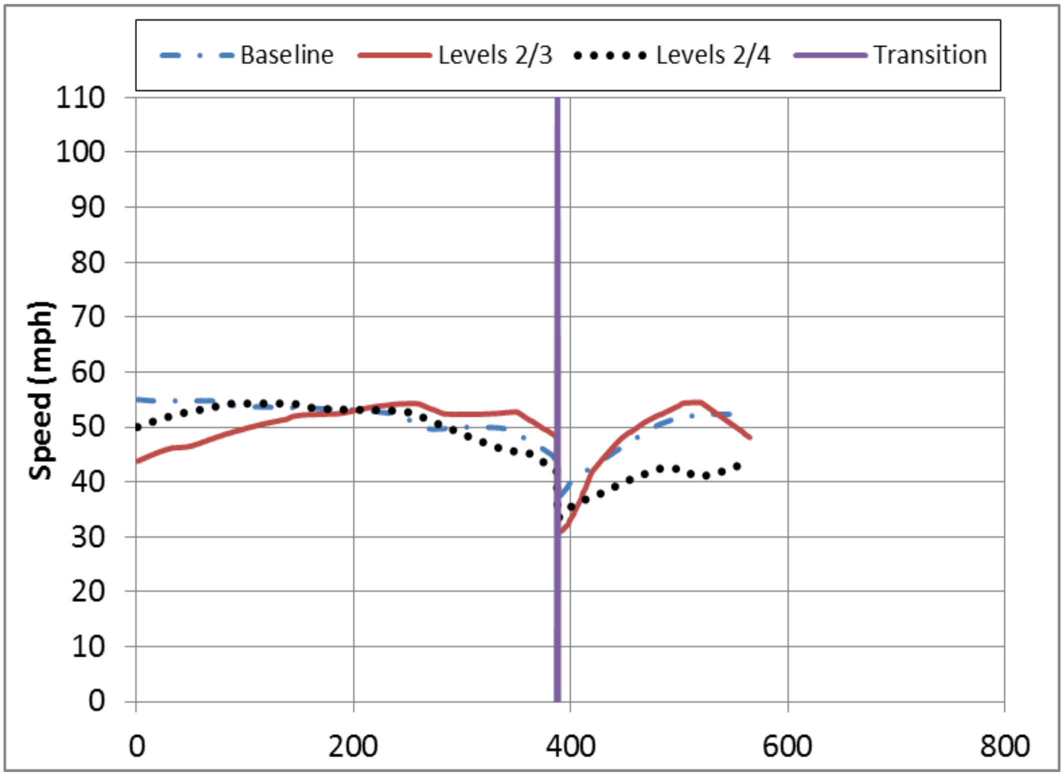

Figure D-1 Speed recorded for Participant 1 on Suburban Roadway Profile

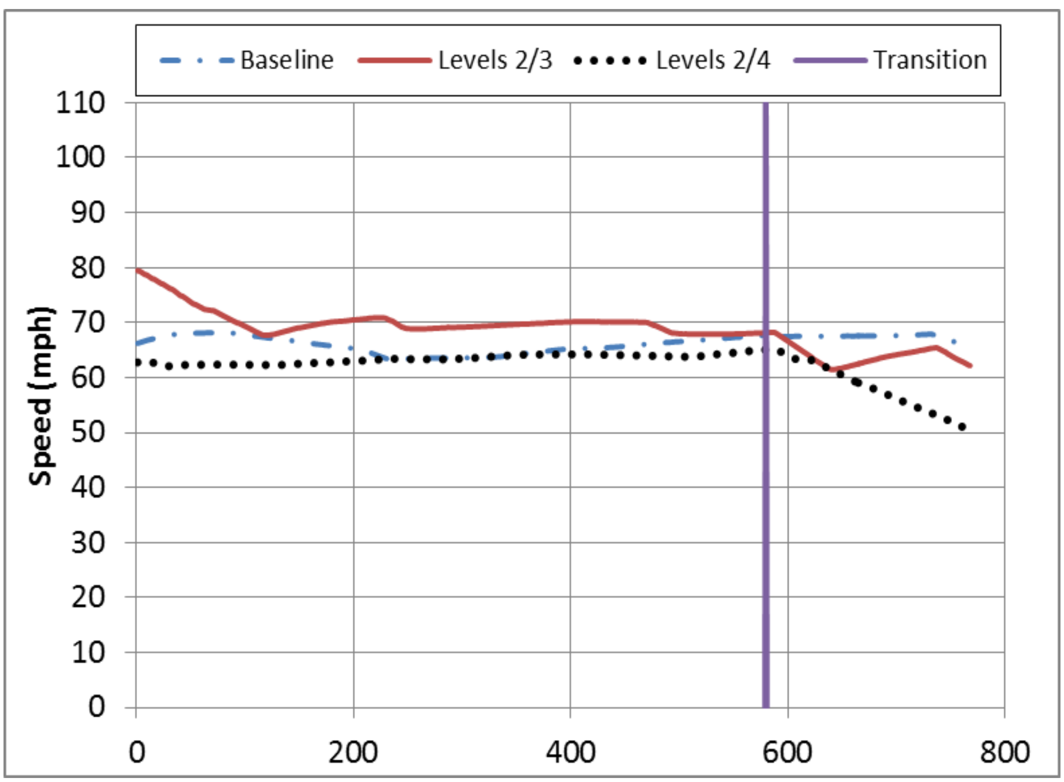

Figure D-2 Speed recorded for Participant 1 on Highway Roadway Profile

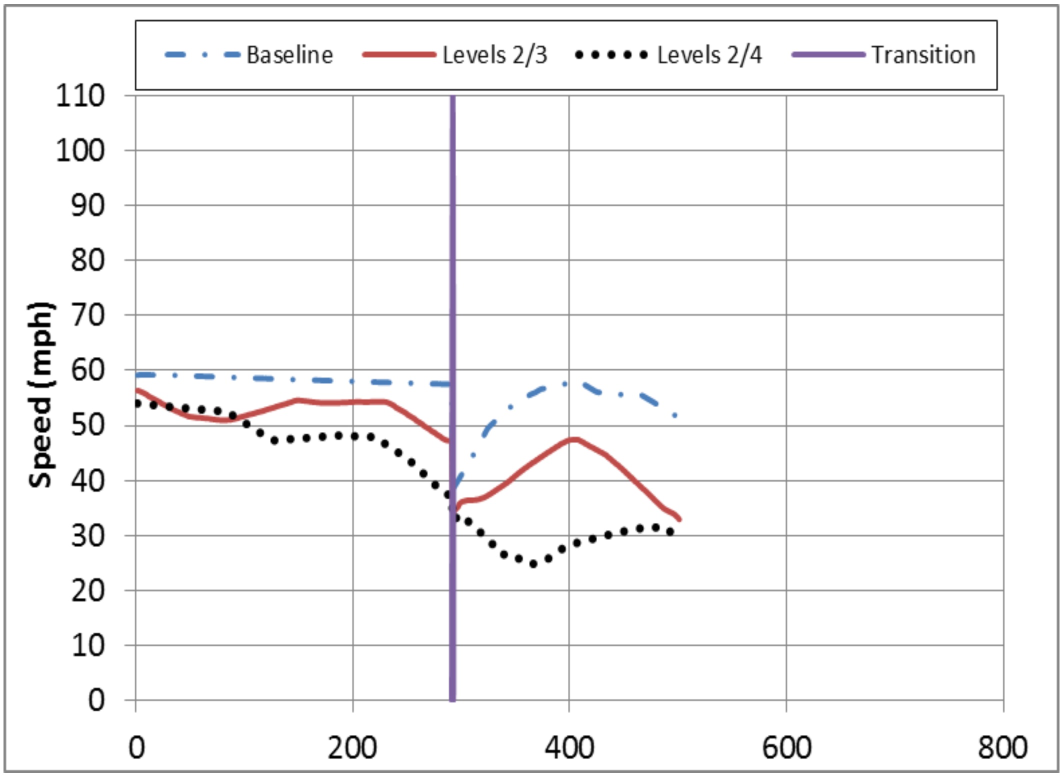

Figure D-3 Speed recorded for Participant 2 on Suburban Roadway Profile

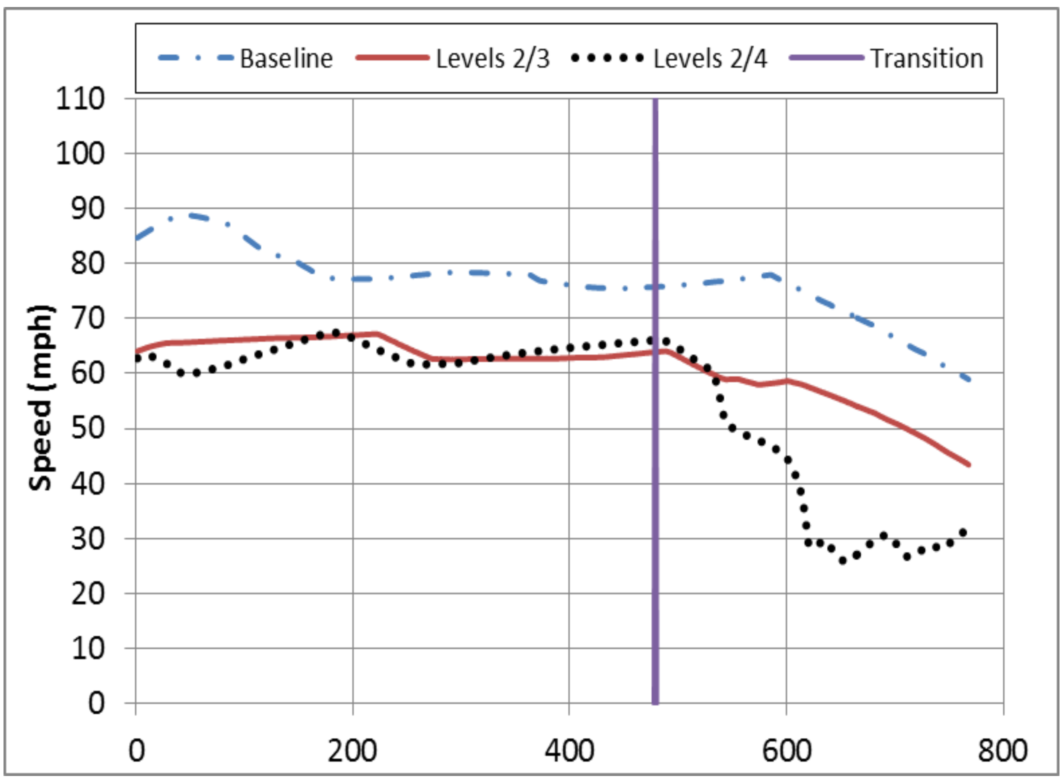

Figure D-4 Speed recorded for Participant 2 on Highway Roadway Profile

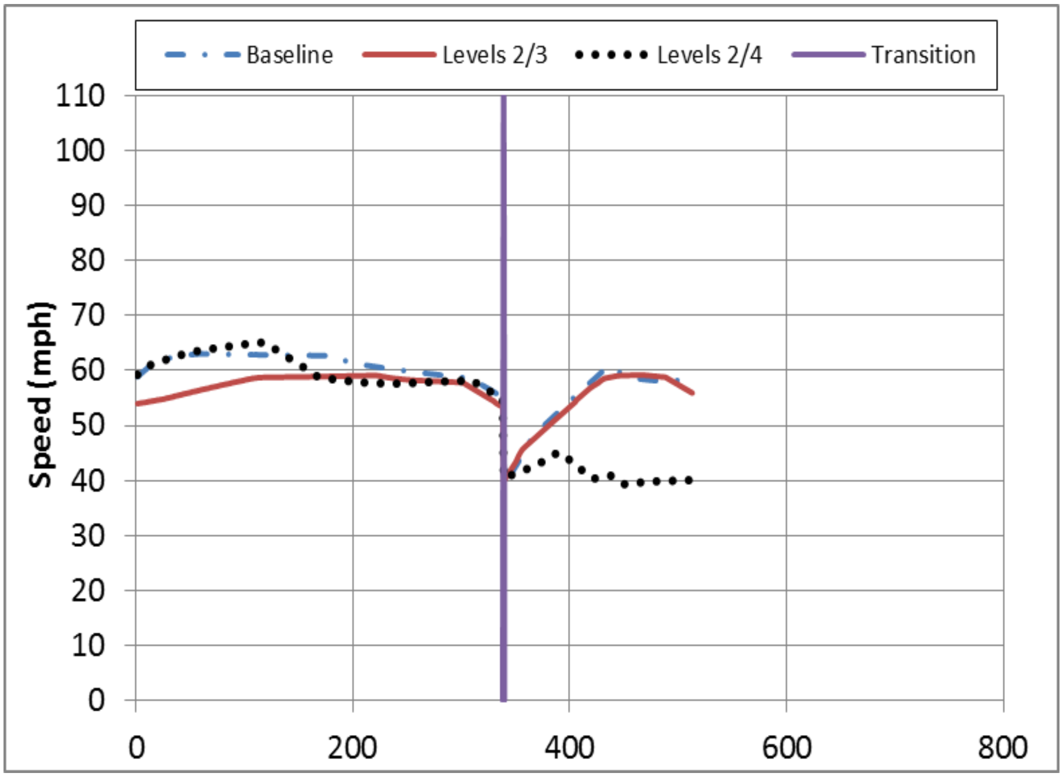

Figure D-5 Speed recorded for Participant 3 on Suburban Roadway Profile

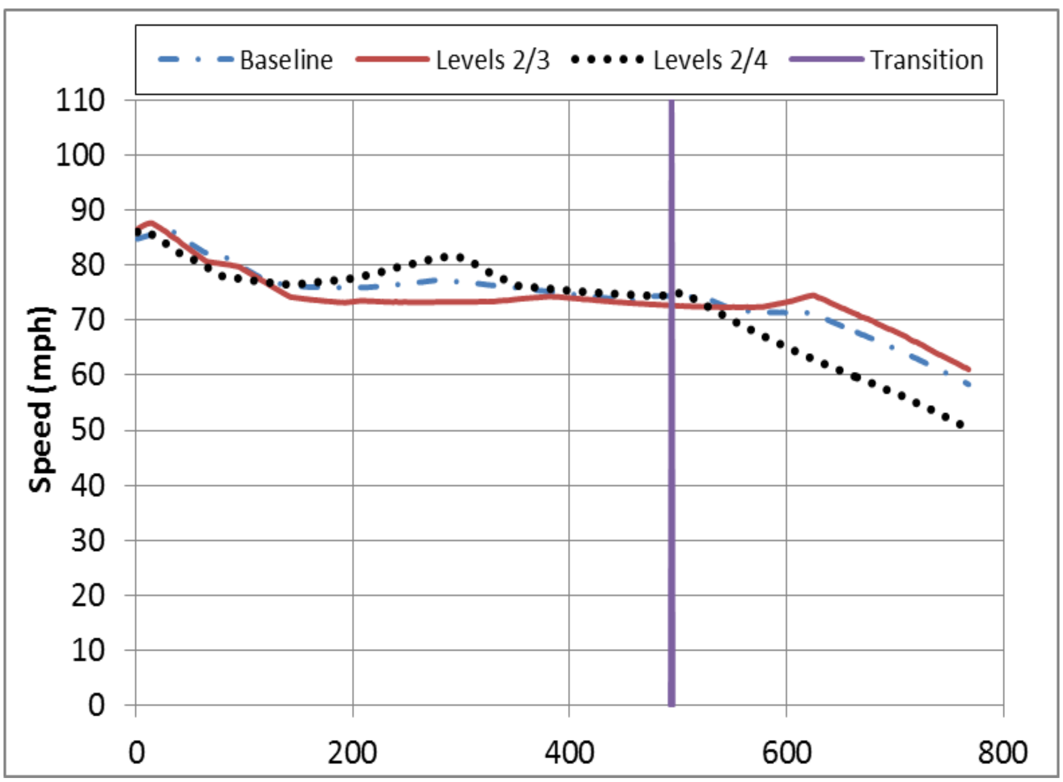

Figure D-6 Speed recorded for Participant 3 on Highway Roadway Profile

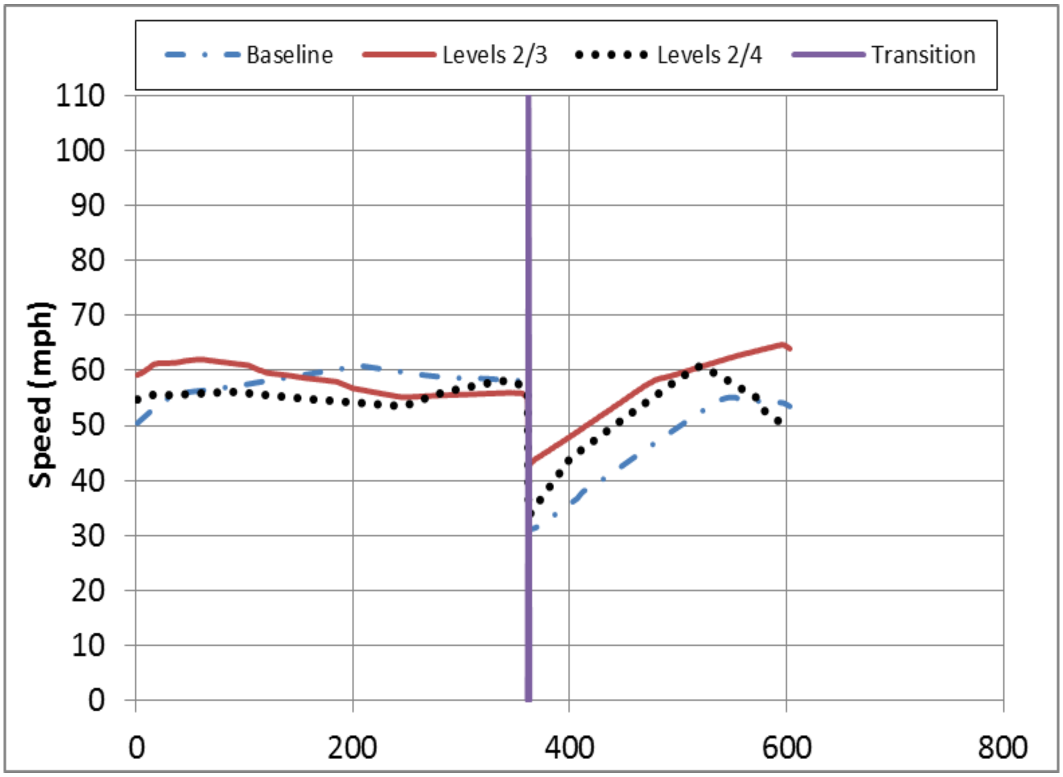

Figure D-7 Speed recorded for Participant 4 on Suburban Roadway Profile

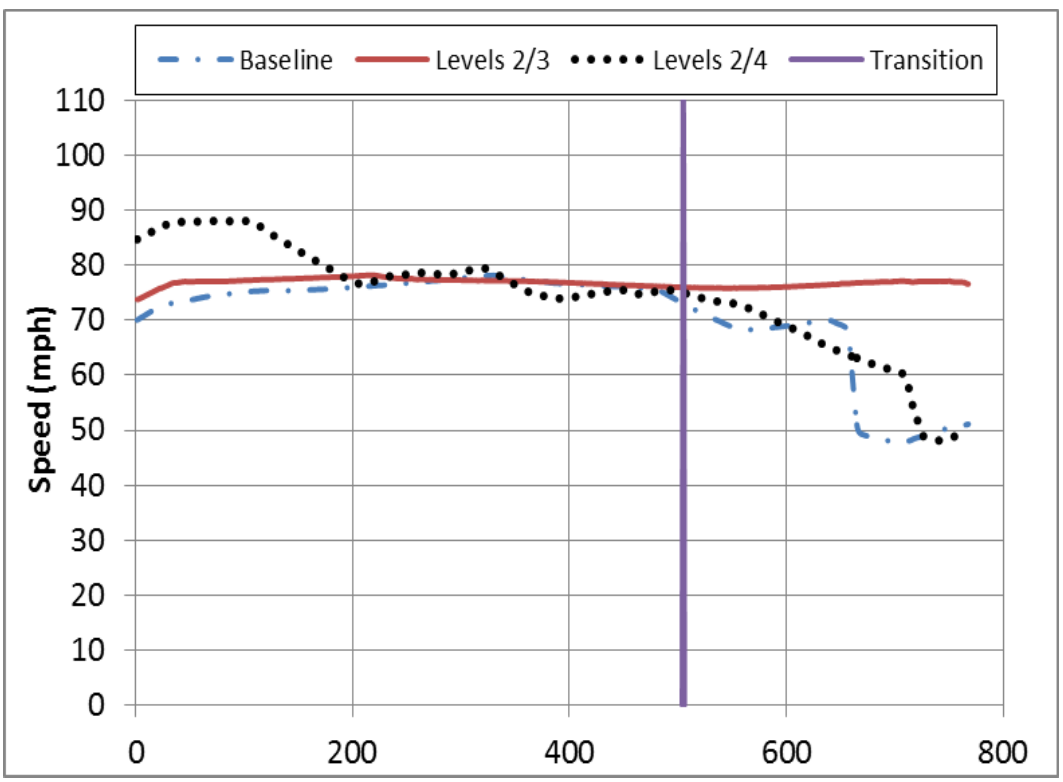

Figure D-8 Speed recorded for Participant 4 on Highway Roadway Profile

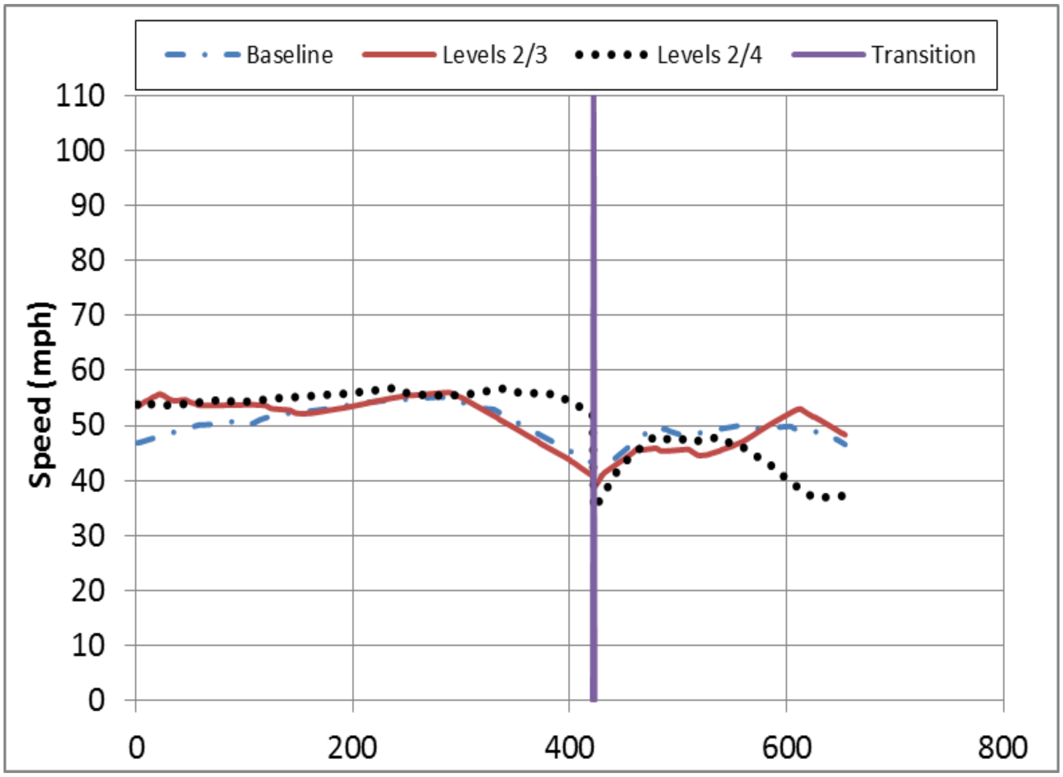

Figure D-9 Speed recorded for Participant 5 on Suburban Roadway Profile

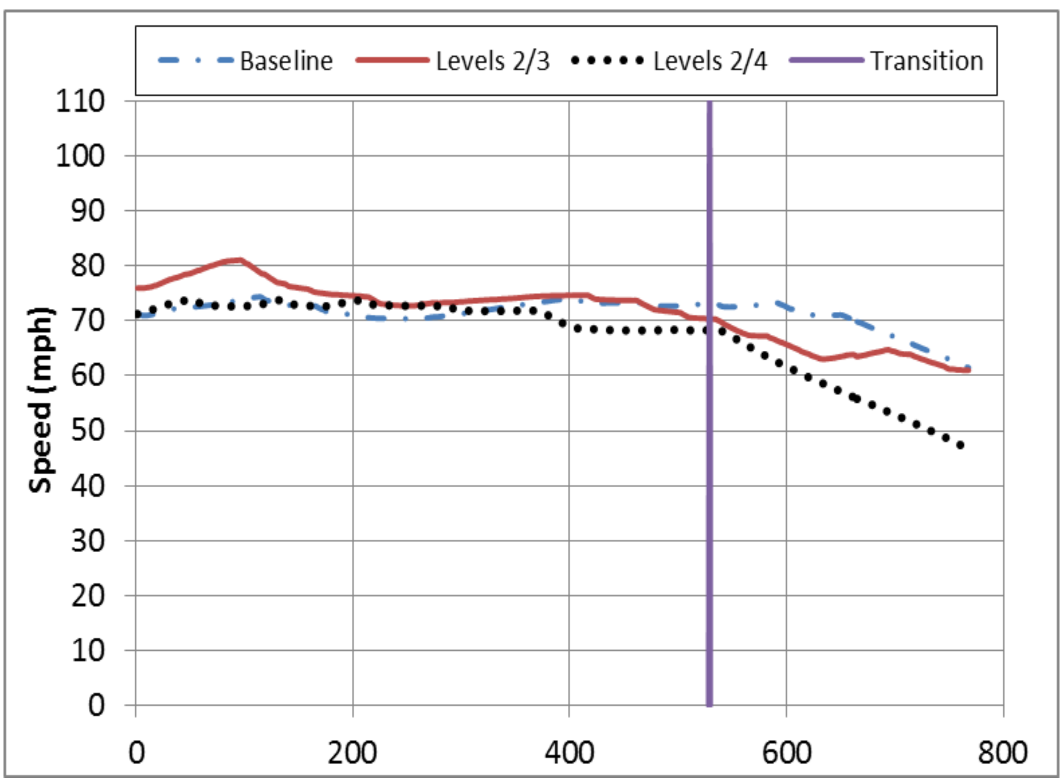

Figure D-10 Speed recorded for Participant 5 on Highway Roadway Profile

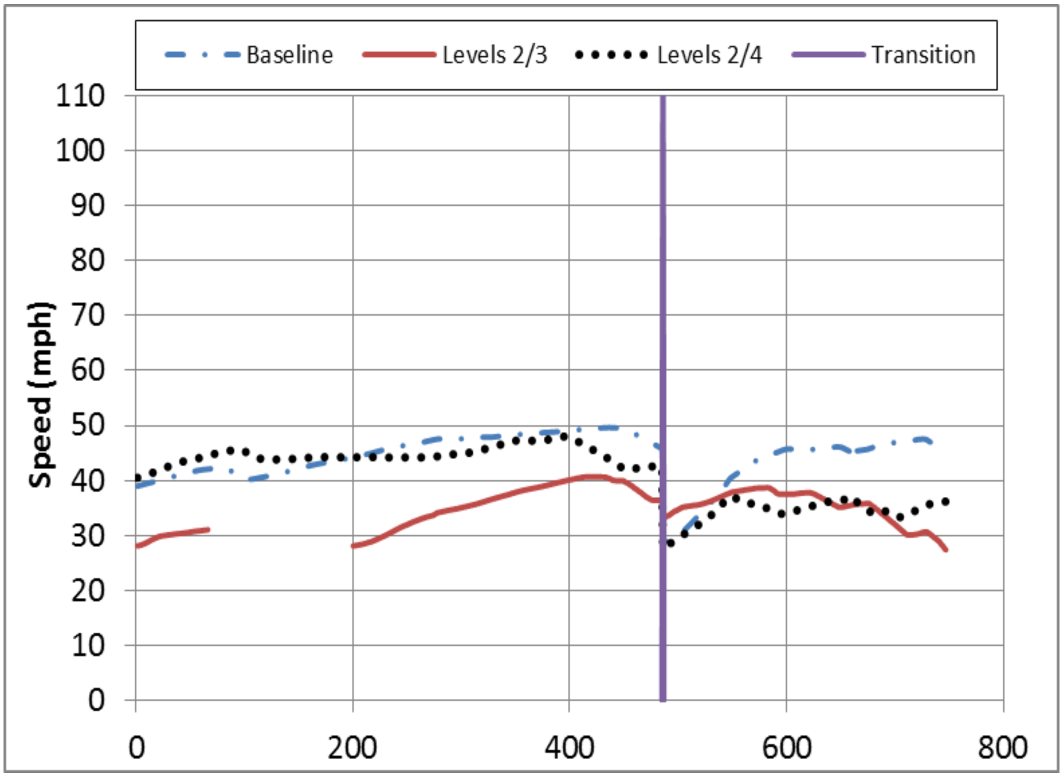

Figure D-11 Speed recorded for Participant 6 on Suburban Roadway Profile

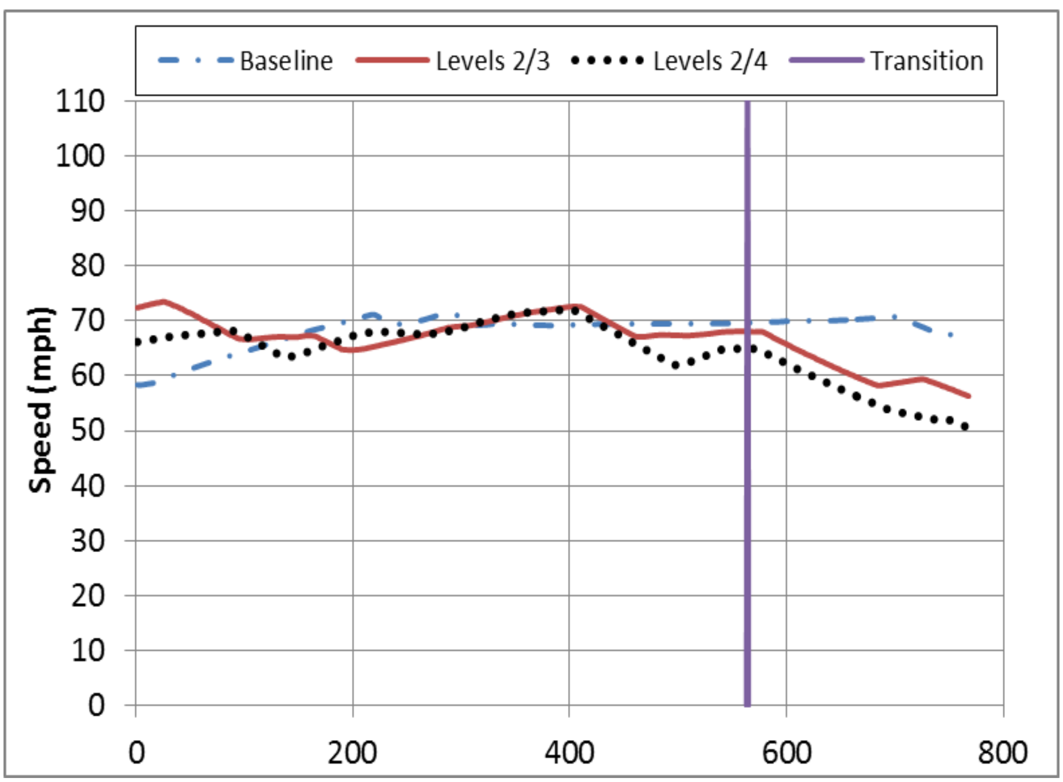

Figure D-12 Speed recorded for Participant 6 on Highway Roadway Profile

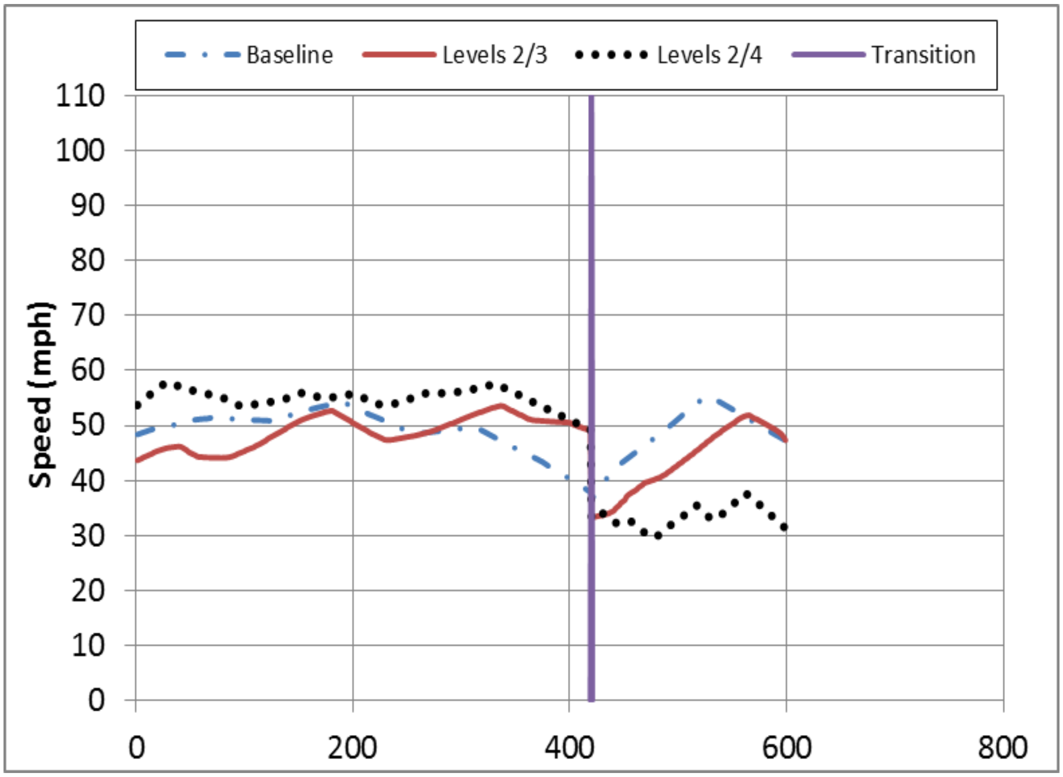

Figure D-13 Speed recorded for Participant 7 on Suburban Roadway Profile

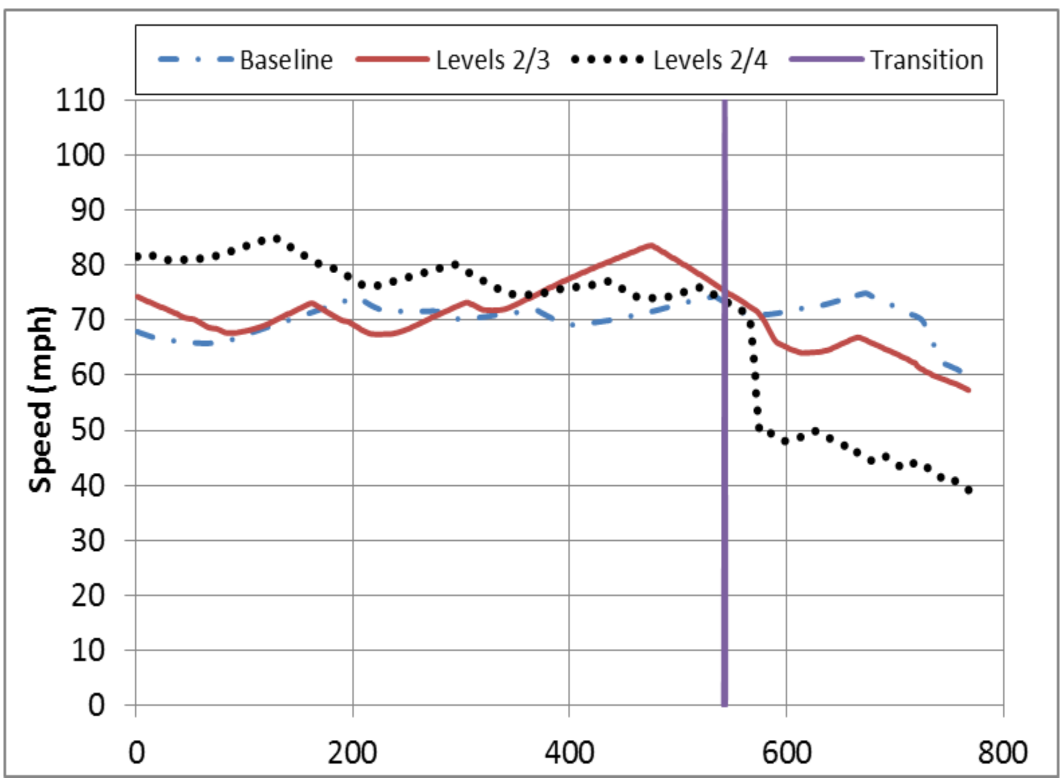

Figure D-14 Speed recorded for Participant 7 on Highway Roadway Profile

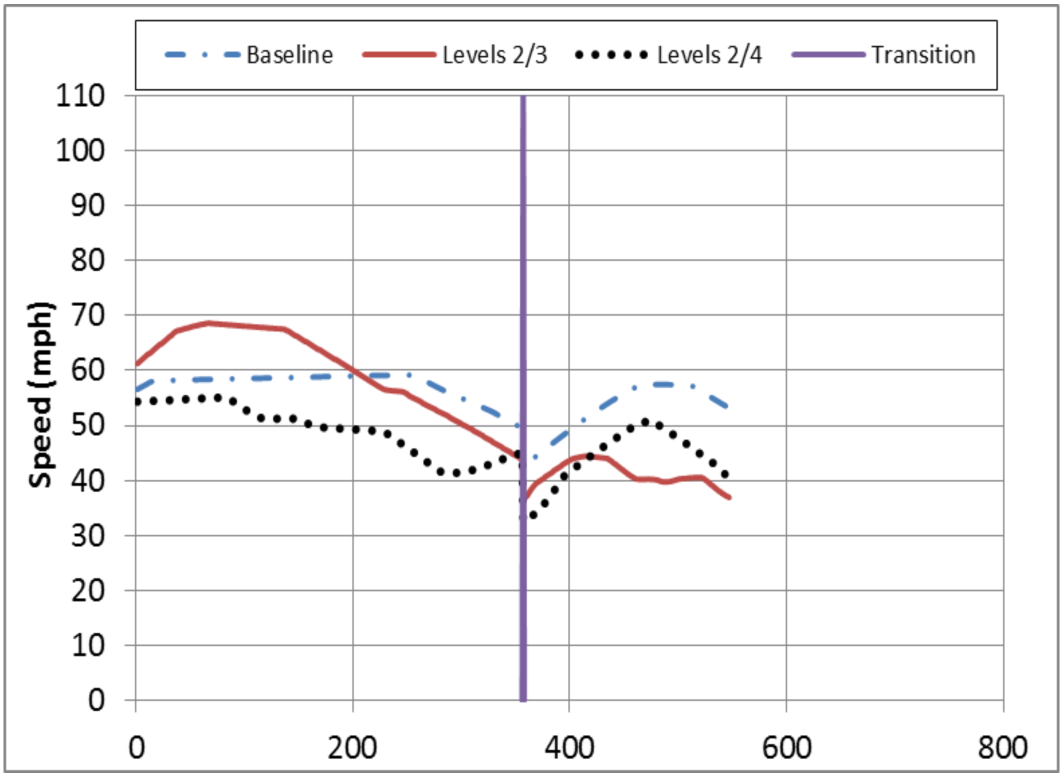

Figure D-15 Speed recorded for Participant 8 on Suburban Roadway Profile

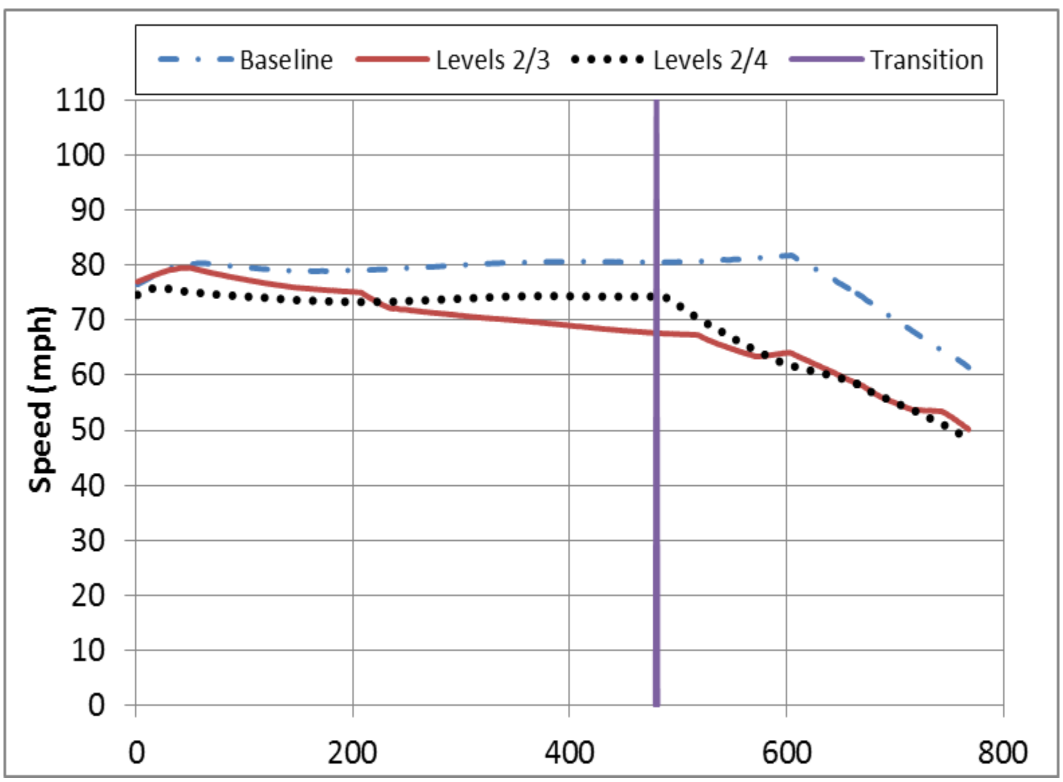

Figure D-16 Speed recorded for Participant 8 on Highway Roadway Profile

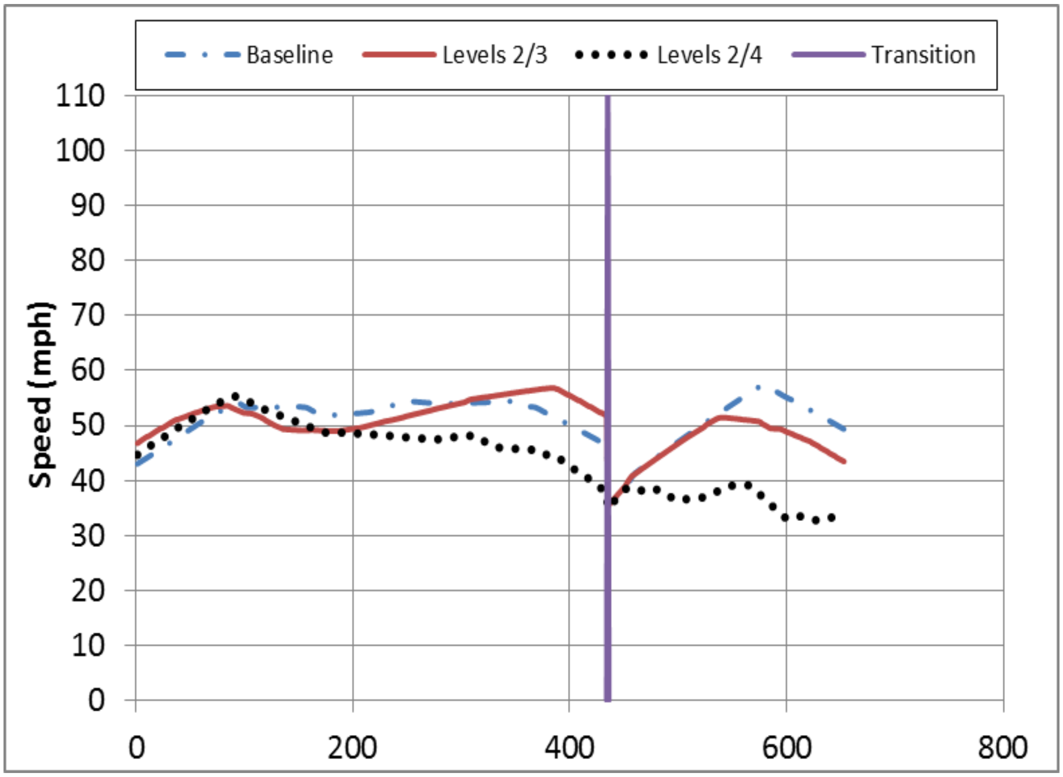

Figure D-17 Speed recorded for Participant 9 on Suburban Roadway Profile

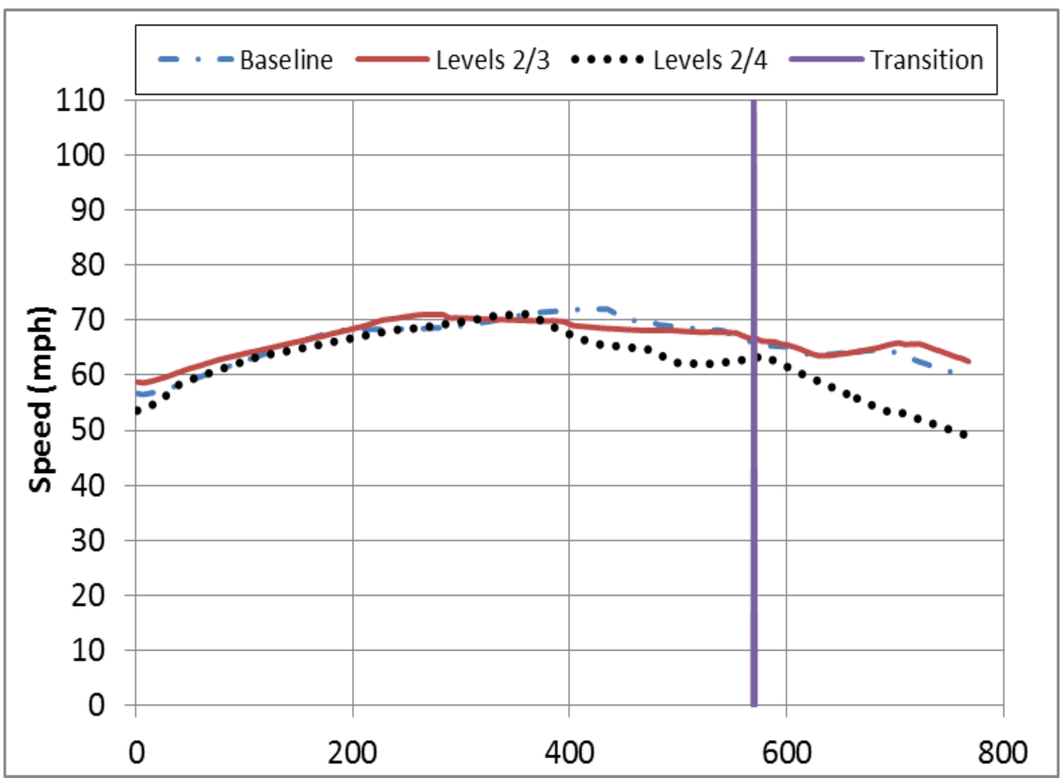

Figure D-18 Speed recorded for Participant 9 on Highway Roadway Profile

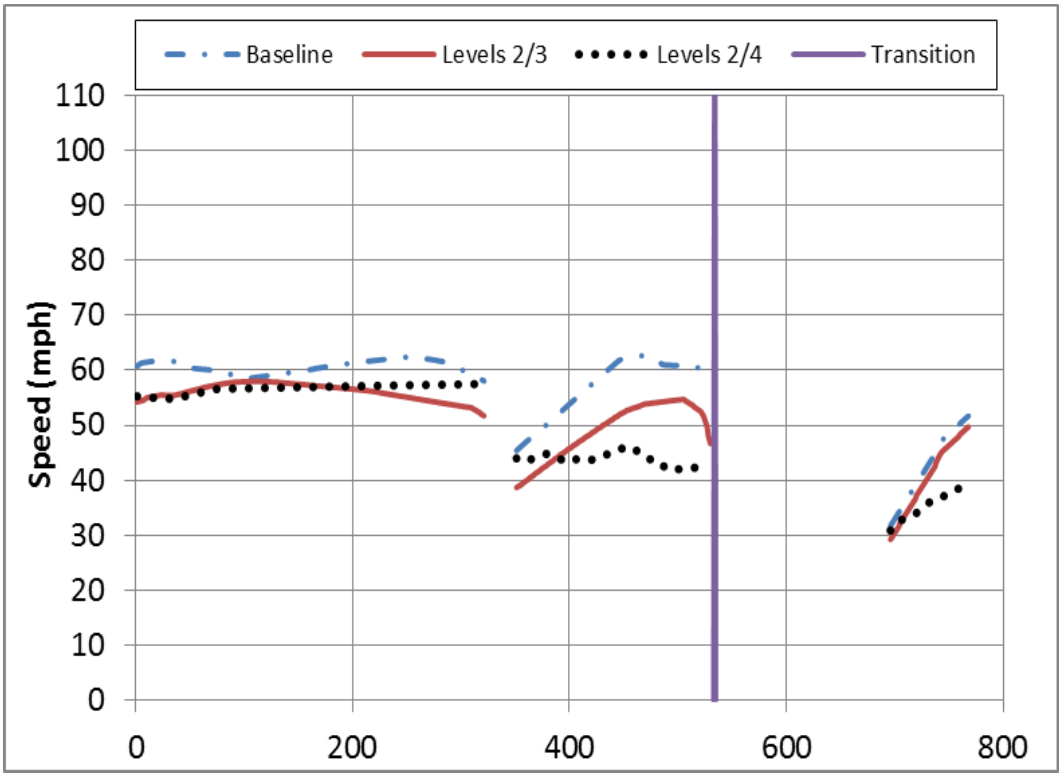

Figure D-19 Speed recorded for Participant 10 on Suburban Roadway Profile

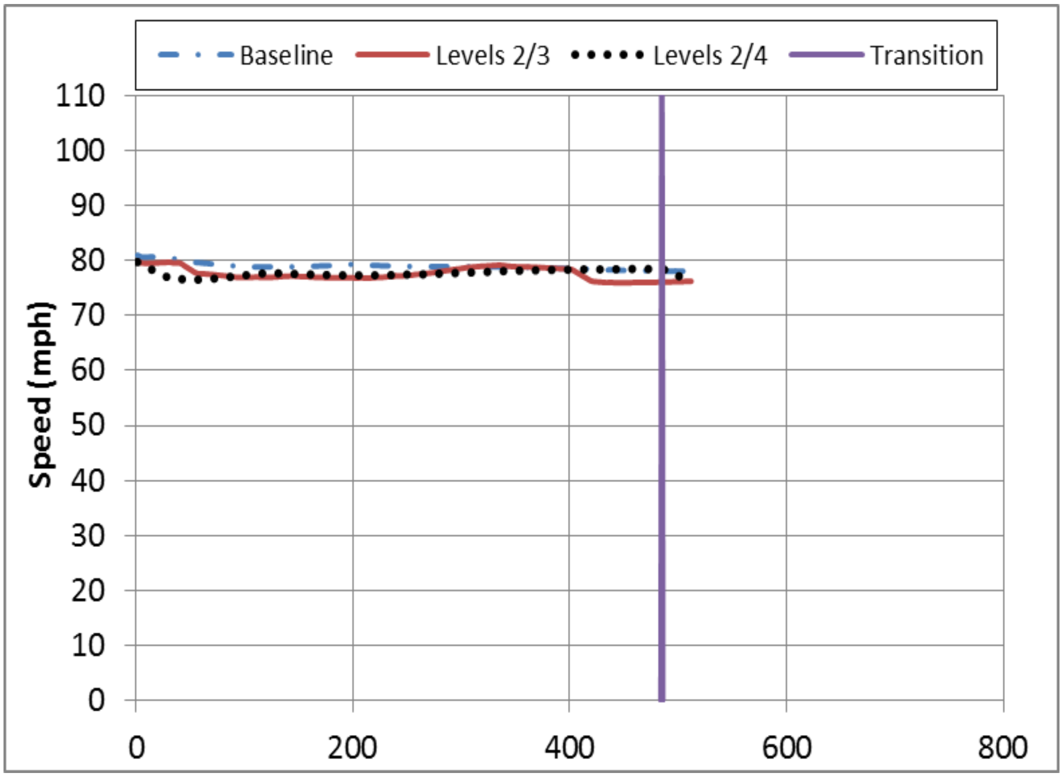

Figure D-20 Speed recorded for Participant 10 on Highway Roadway Profile

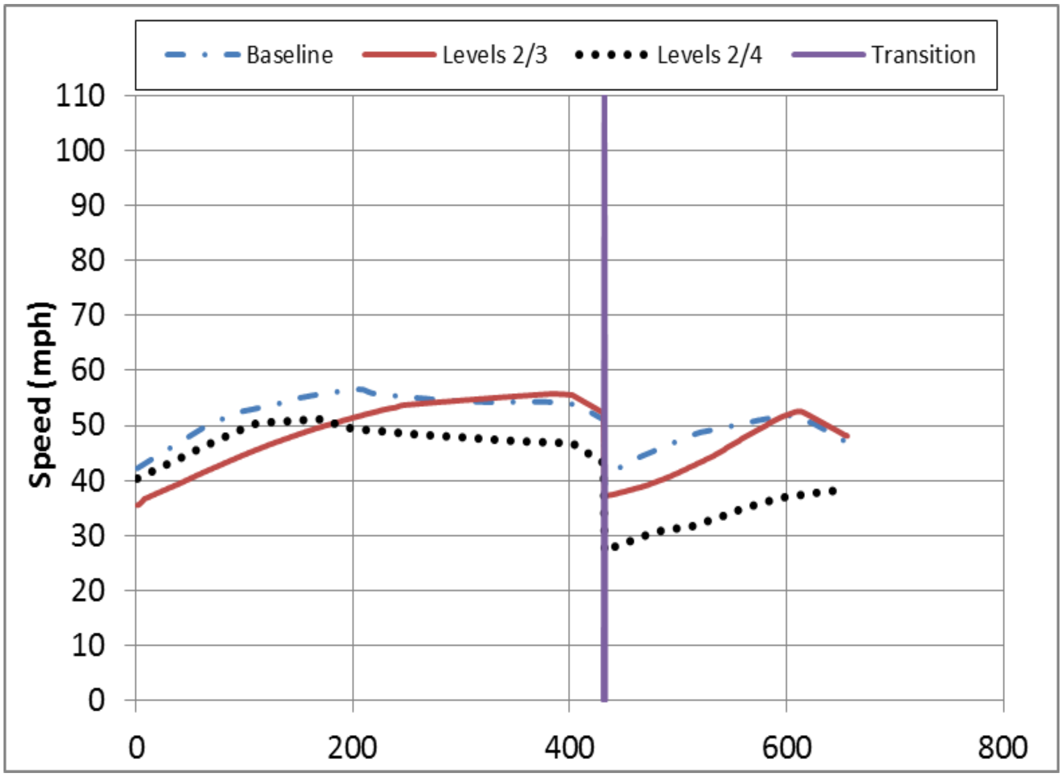

Figure D-21 Speed recorded for Participant 11 on Suburban Roadway Profile

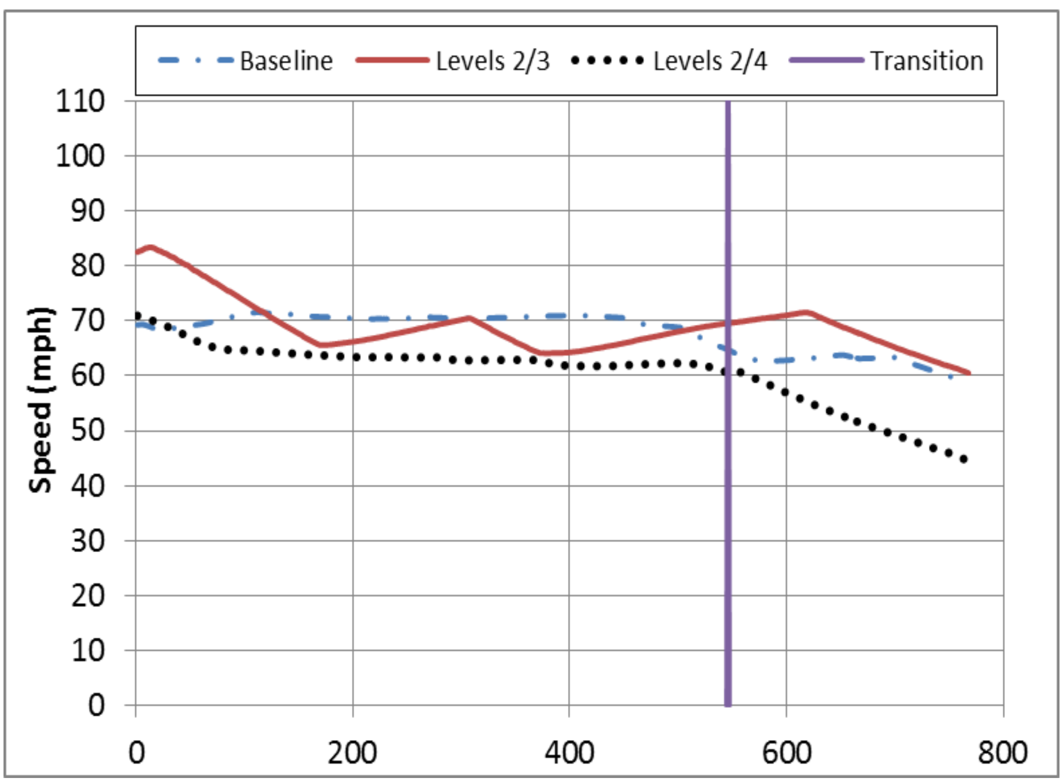

Figure D-22 Speed recorded for Participant 11 on Highway Roadway Profile

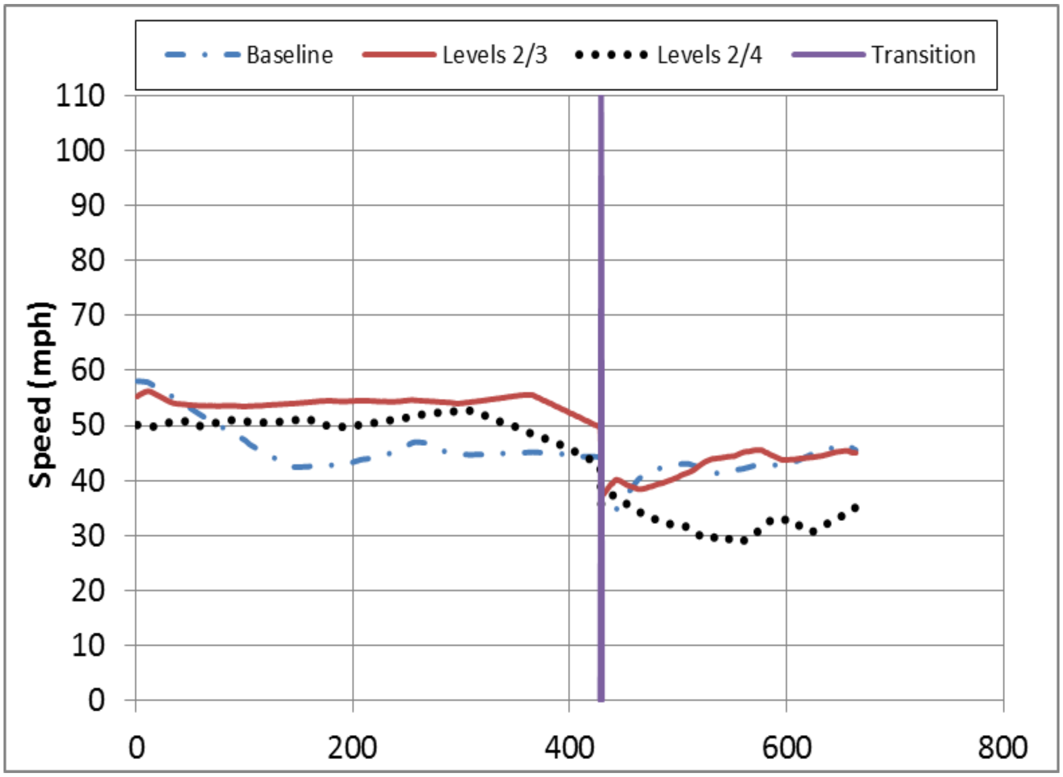

Figure D-23 Speed recorded for Participant 12 on Suburban Roadway Profile

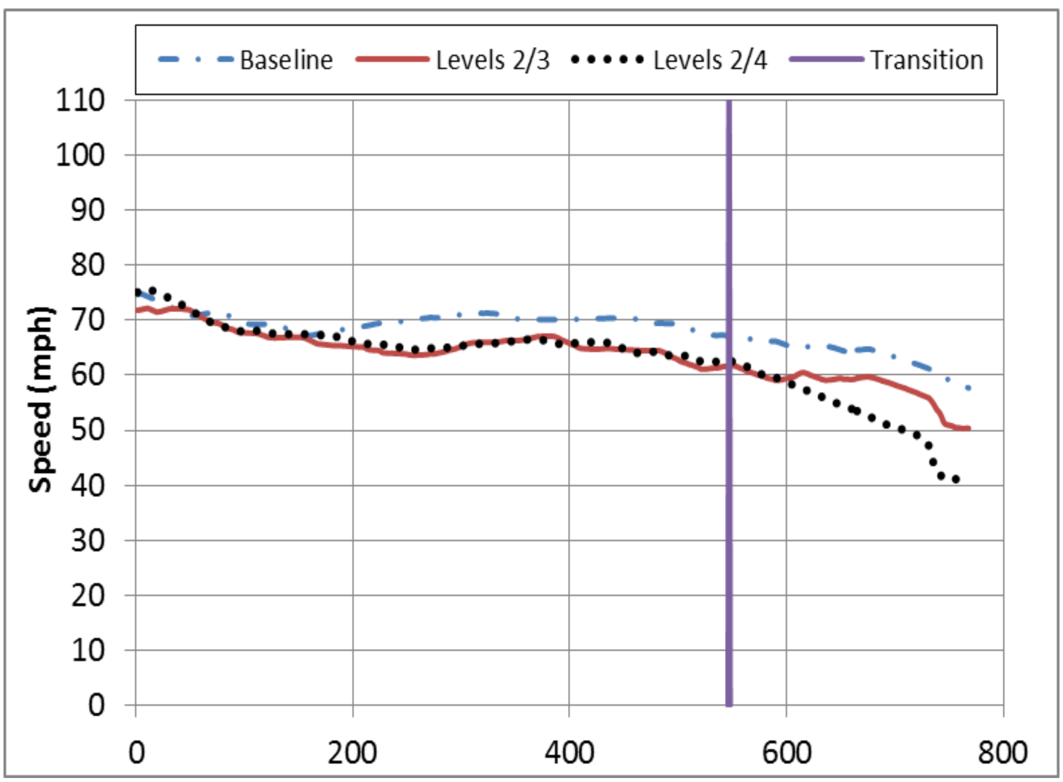

Figure D-24 Speed recorded for Participant 12 on Highway Roadway Profile

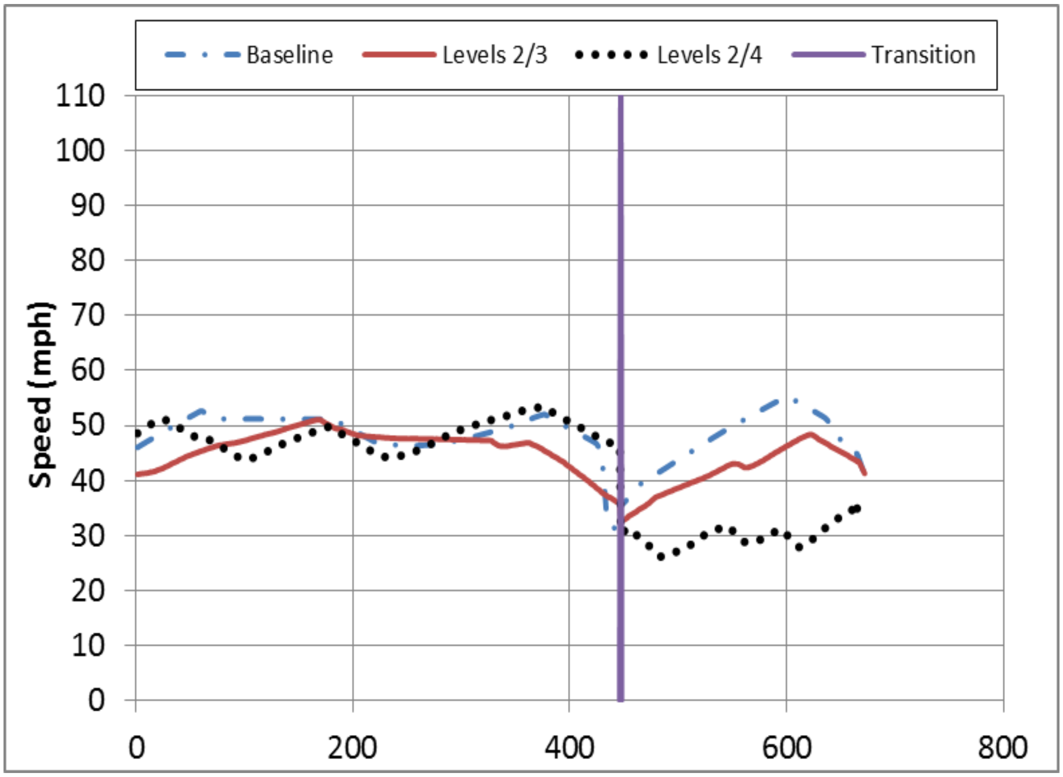

Figure D-25 Speed recorded for Participant 13 on Suburban Roadway Profile

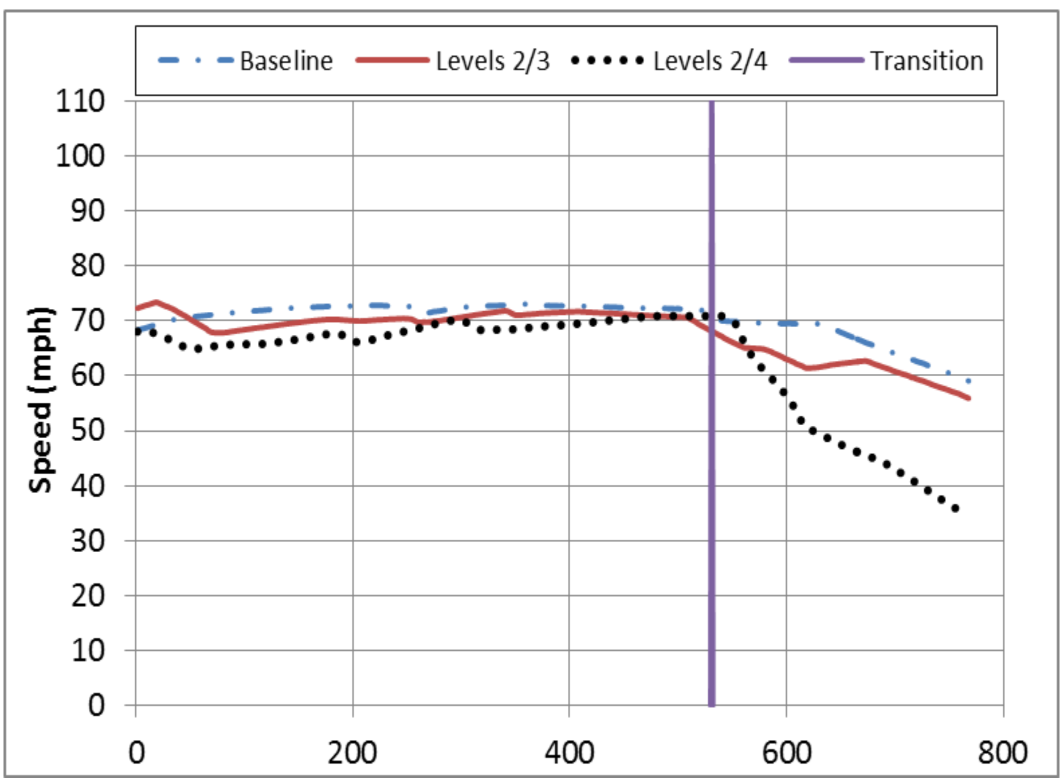

Figure D-26 Speed recorded for Participant 13 on Highway Roadway Profile

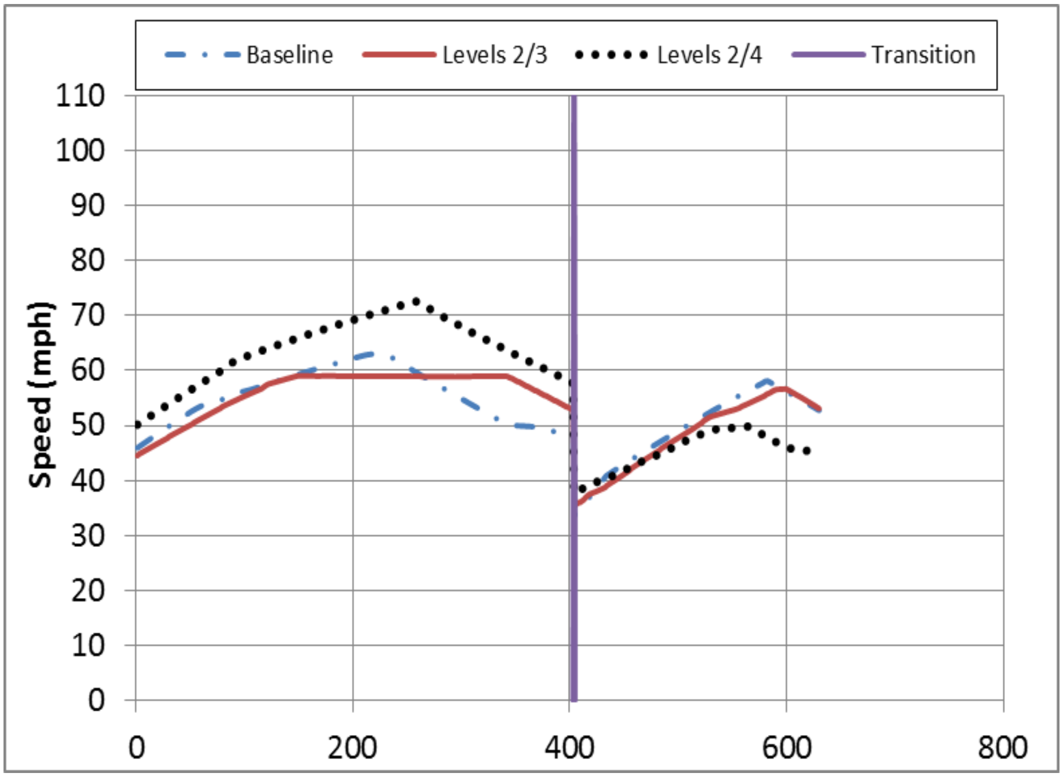

Figure D-27 Speed recorded for Participant 14 on Suburban Roadway Profile

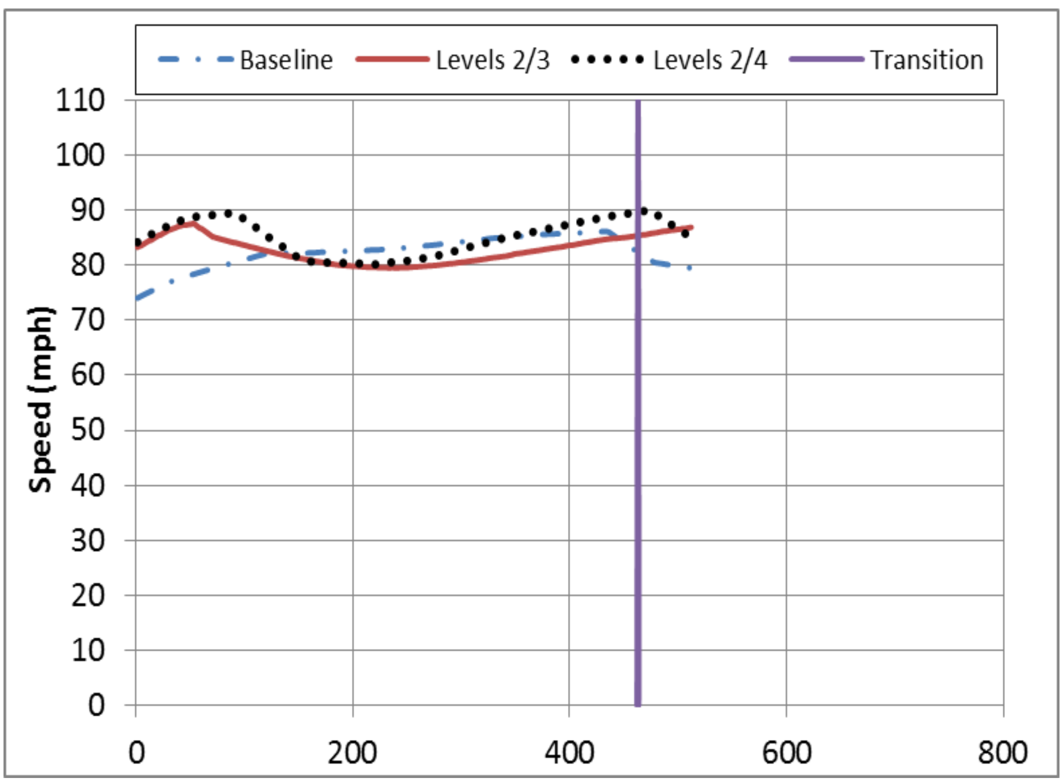

Figure D-28 Speed recorded for Participant 14 on Highway Roadway Profile

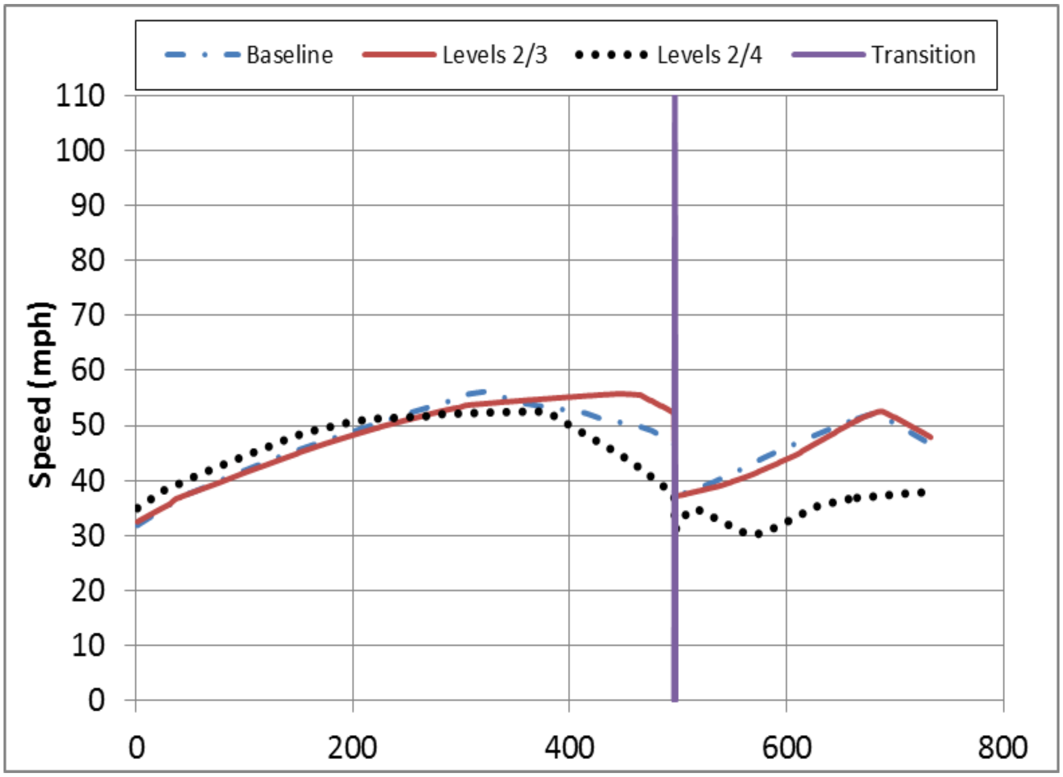

Figure D-29 Speed recorded for Participant 15 on Suburban Roadway Profile

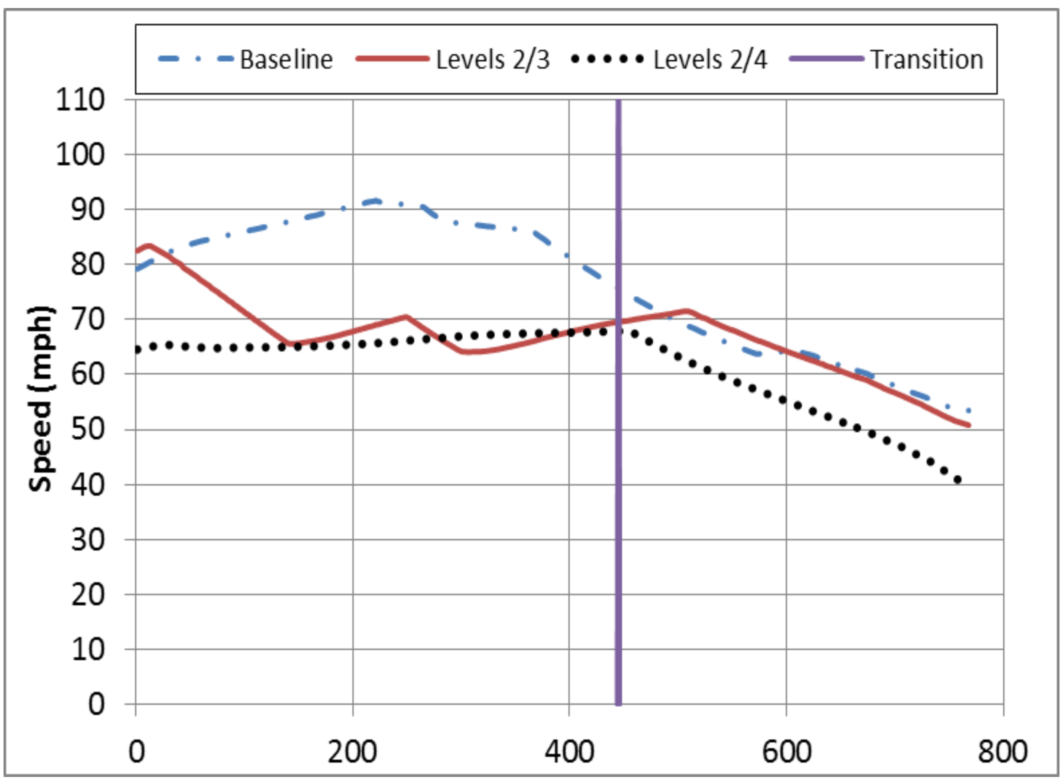

Figure D-30 Speed recorded for Participant 15 on Highway Roadway Profile

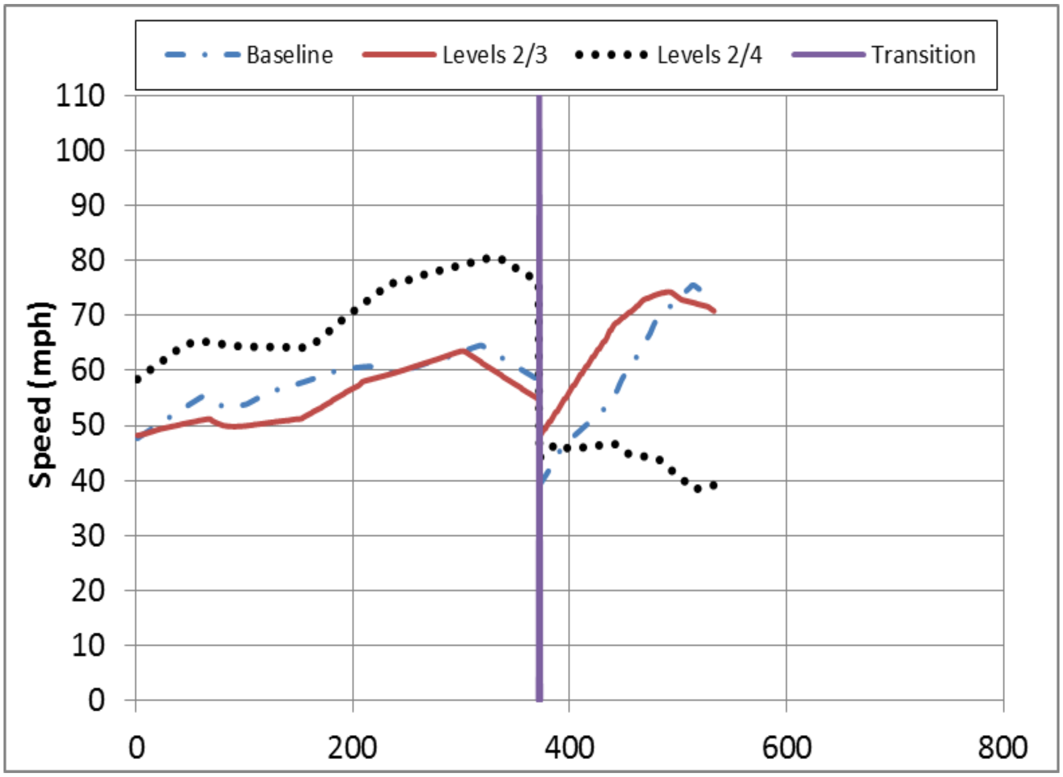

Figure D-31 Speed recorded for Participant 16 on Suburban Roadway Profile

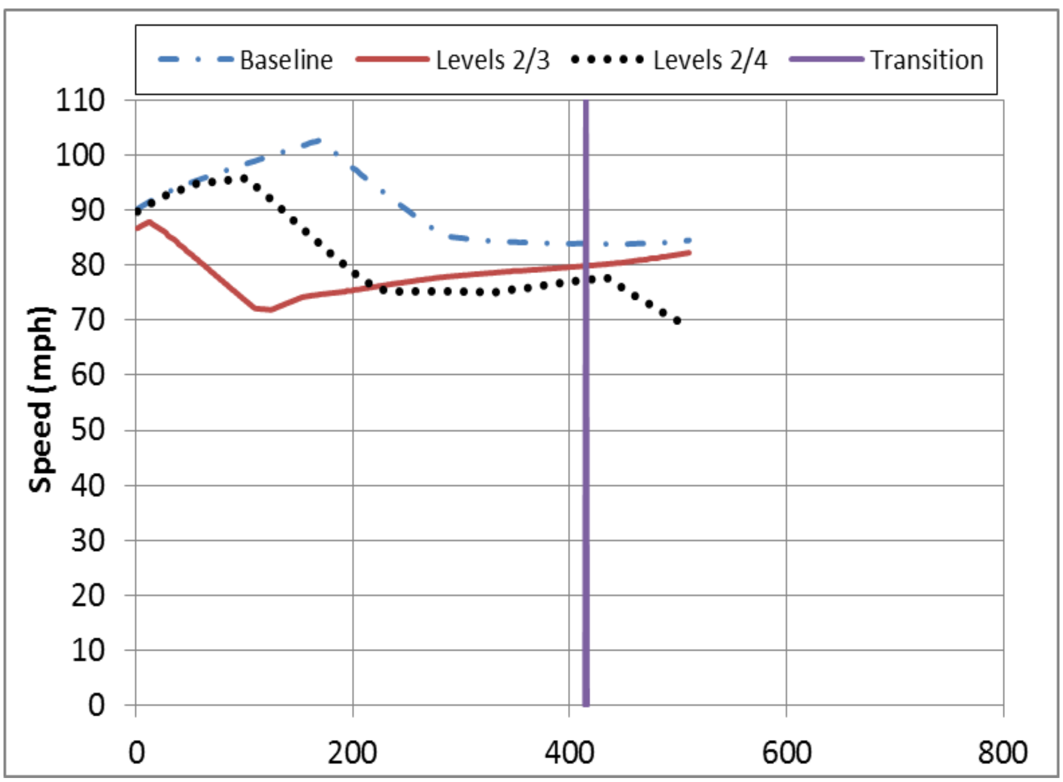

Figure D-32 Speed recorded for Participant 16 on Highway Roadway Profile

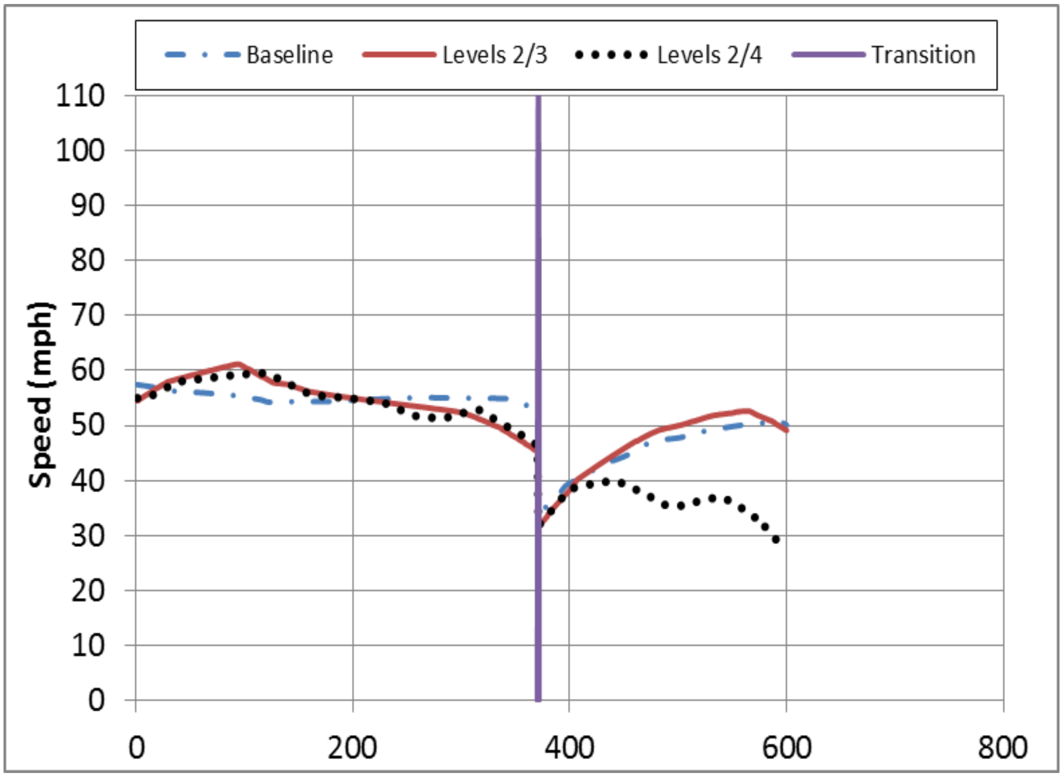

Figure D-33 Speed recorded for Participant 17 on Suburban Roadway Profile

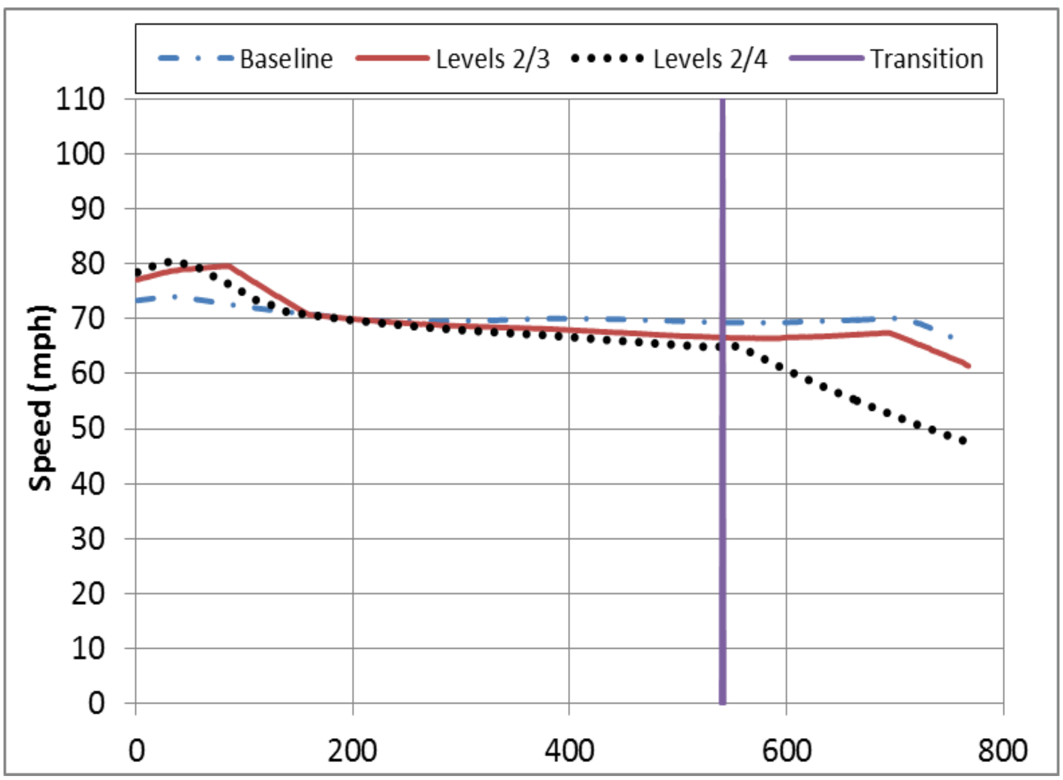

Figure D-34 Speed recorded for Participant 17 on Highway Roadway Profile

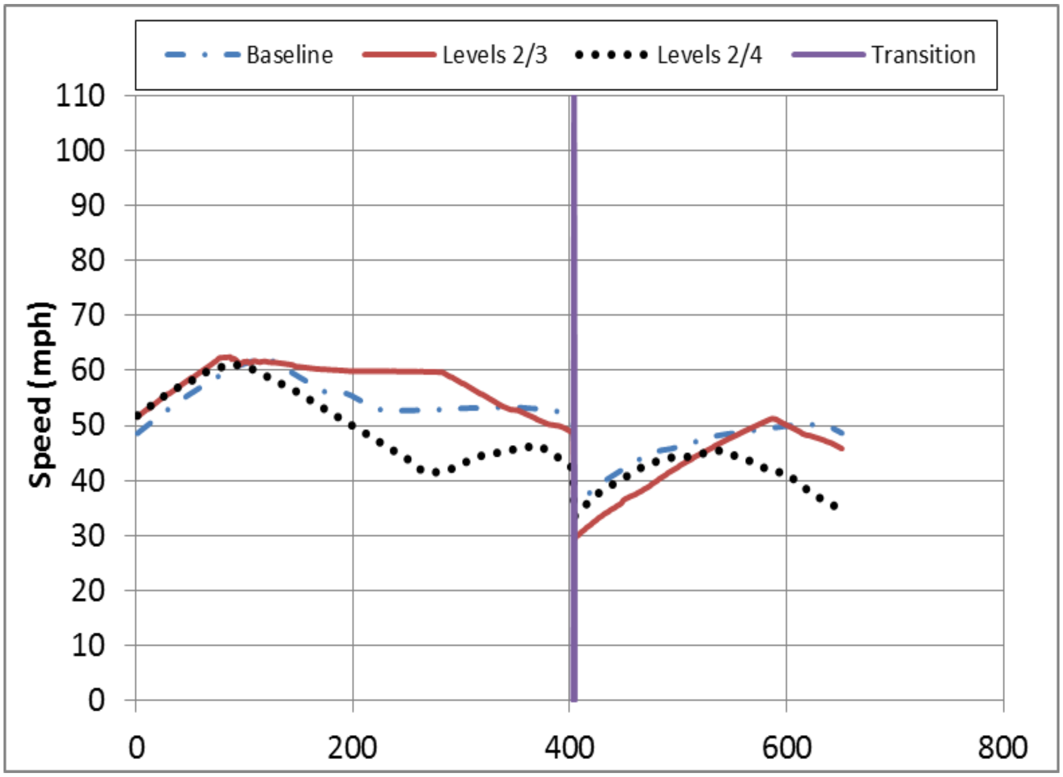

Figure D-35 Speed recorded for Participant 18 on Suburban Roadway Profile

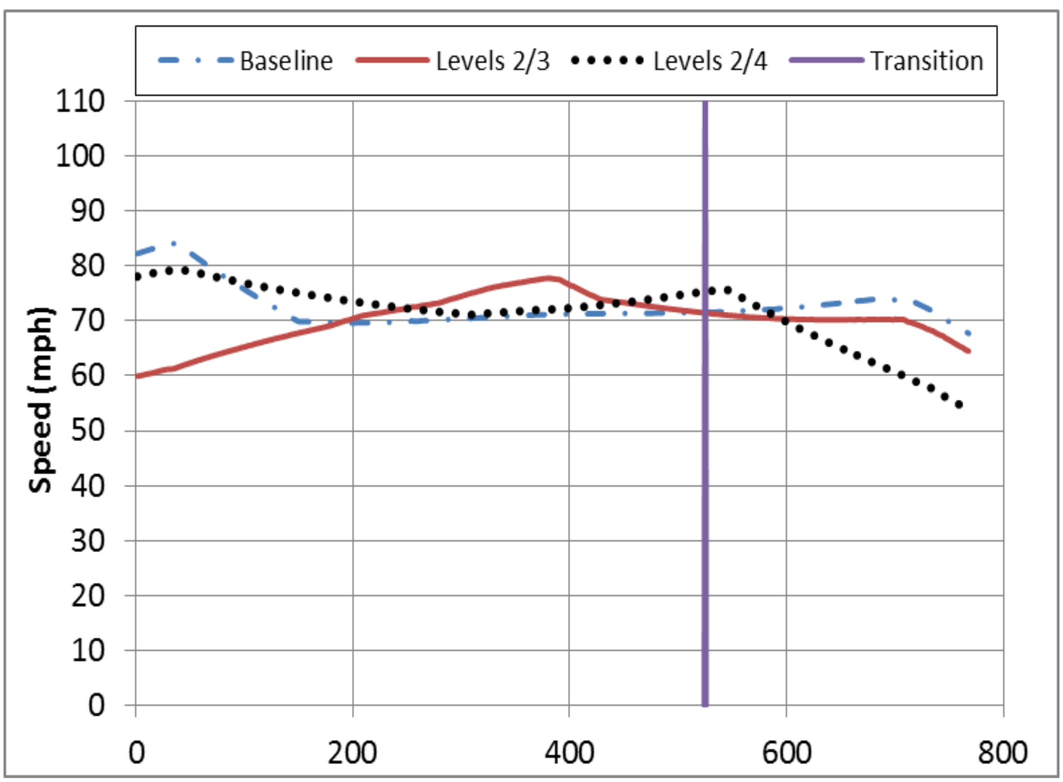

Figure D-36 Speed recorded for Participant 18 on Highway Roadway Profile

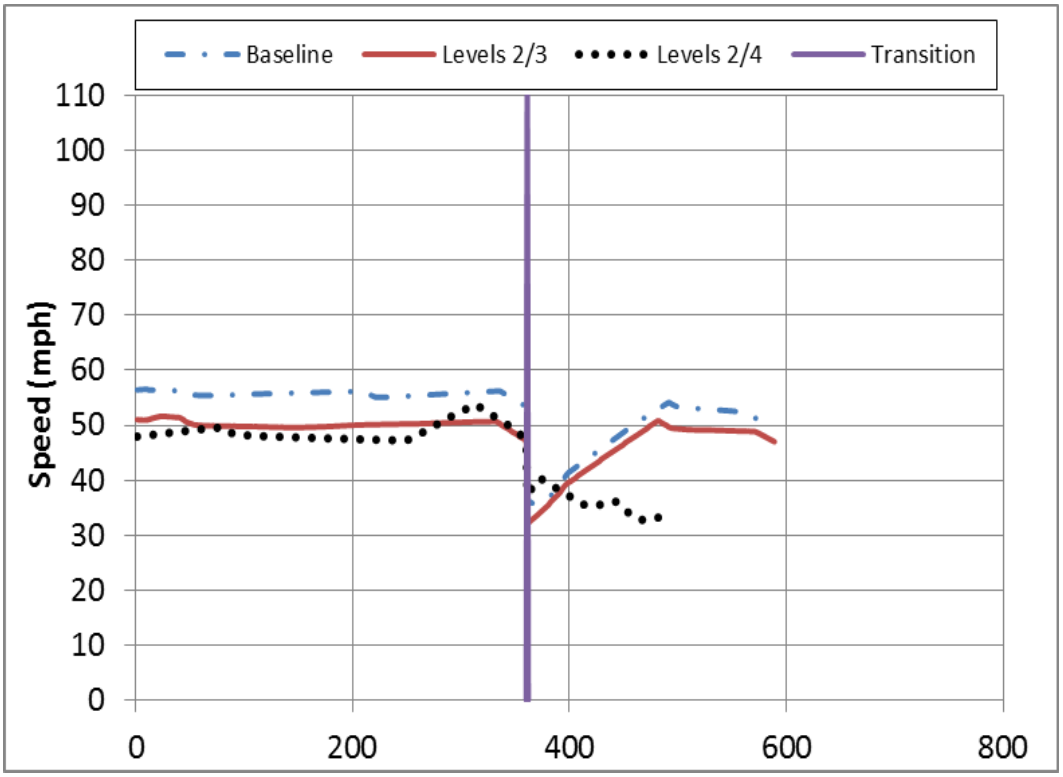

Figure D-37 Speed recorded for Participant 19 on Suburban Roadway Profile

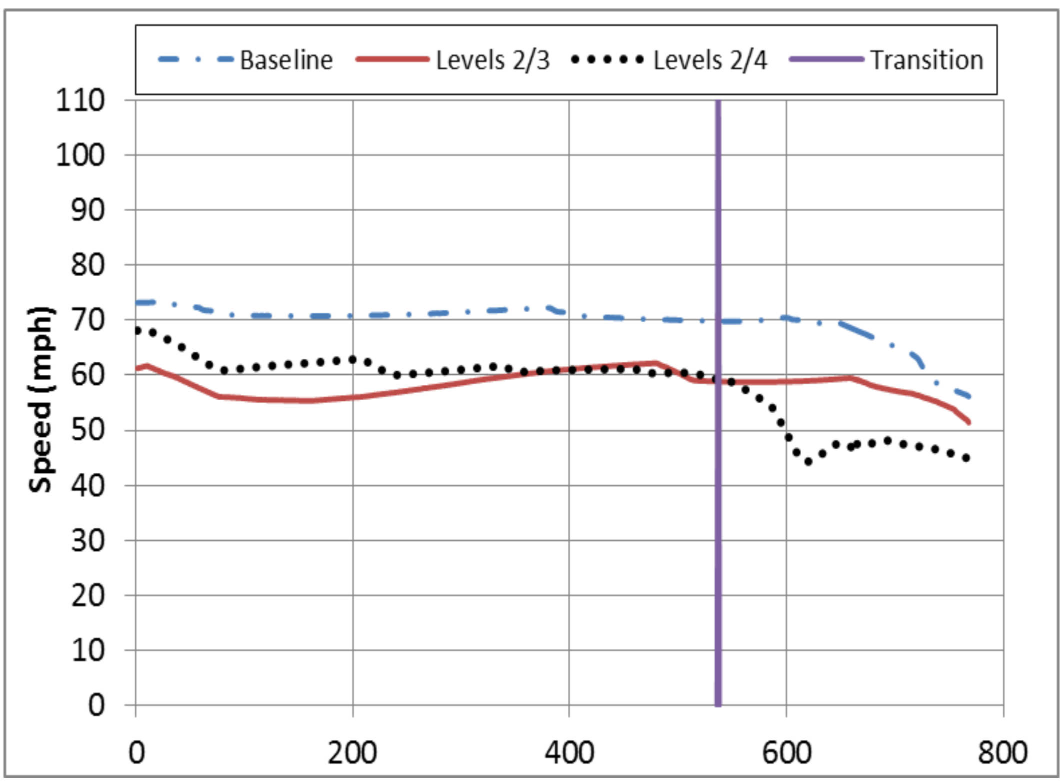

Figure D-38 Speed recorded for Participant 19 on Highway Roadway Profile

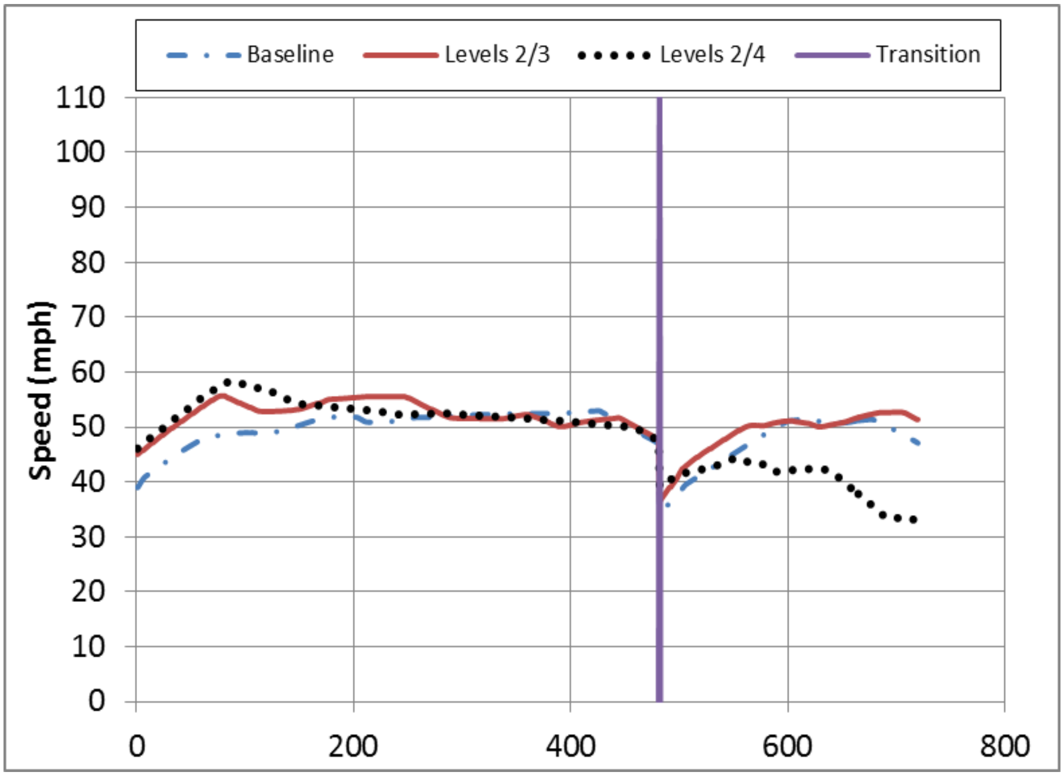

Figure D-39 Speed recorded for Participant 20 on Suburban Roadway Profile

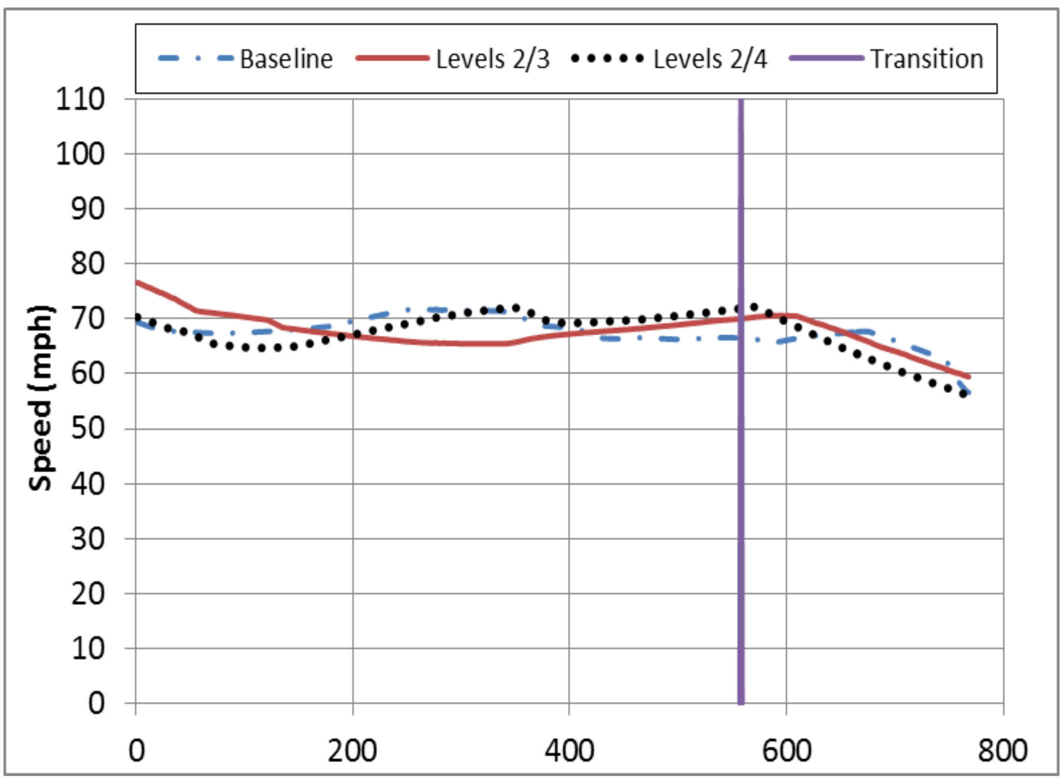

Figure D-40 Speed recorded for Participant 20 on Highway Roadway Profile

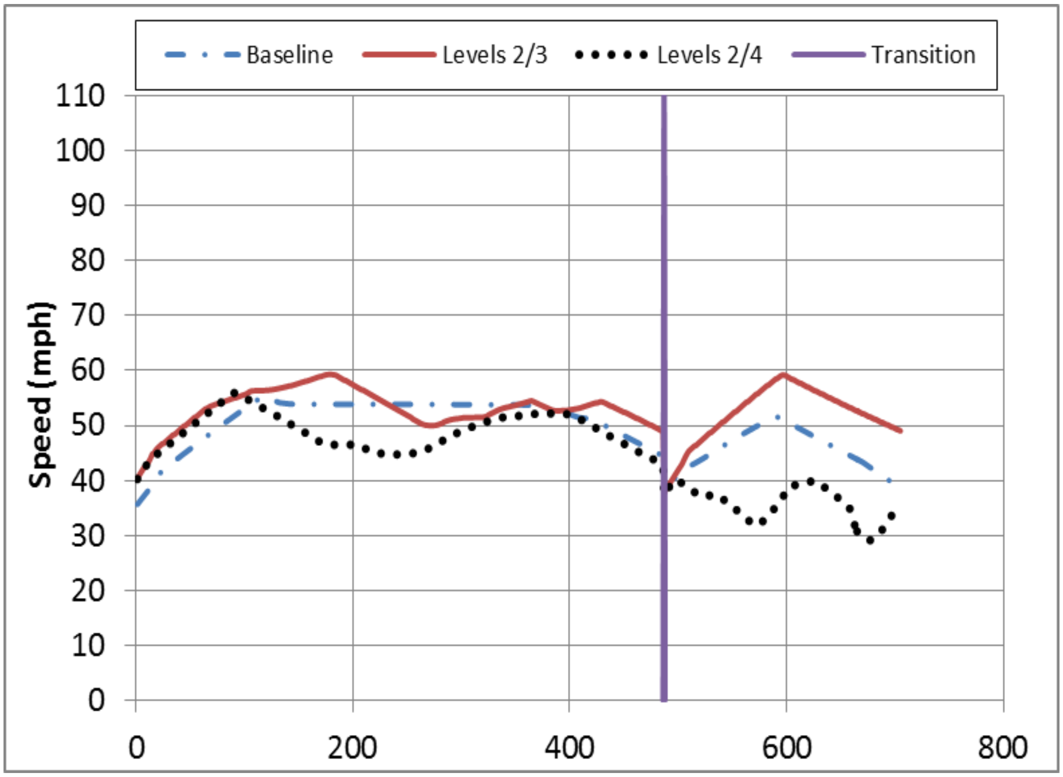

Figure D-41 Speed recorded for Participant 21 on Suburban Roadway Profile

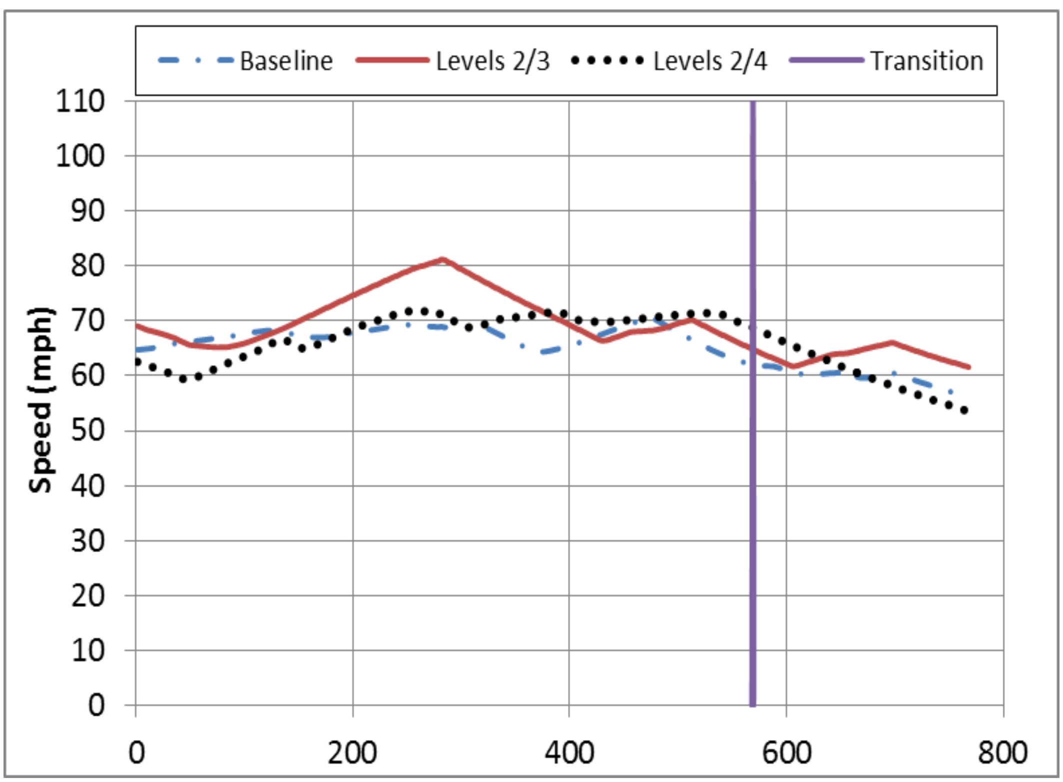

Figure D-42 Speed recorded for Participant 21 on Highway Roadway Profile

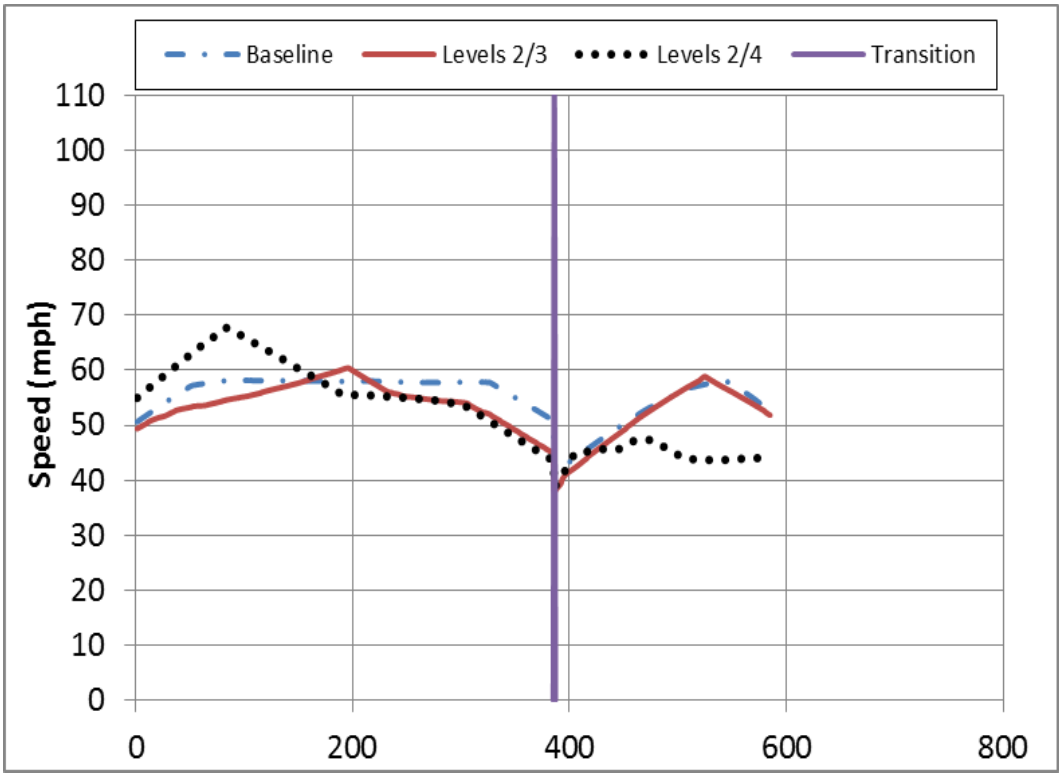

Figure D-43 Speed recorded for Participant 22 on Suburban Roadway Profile

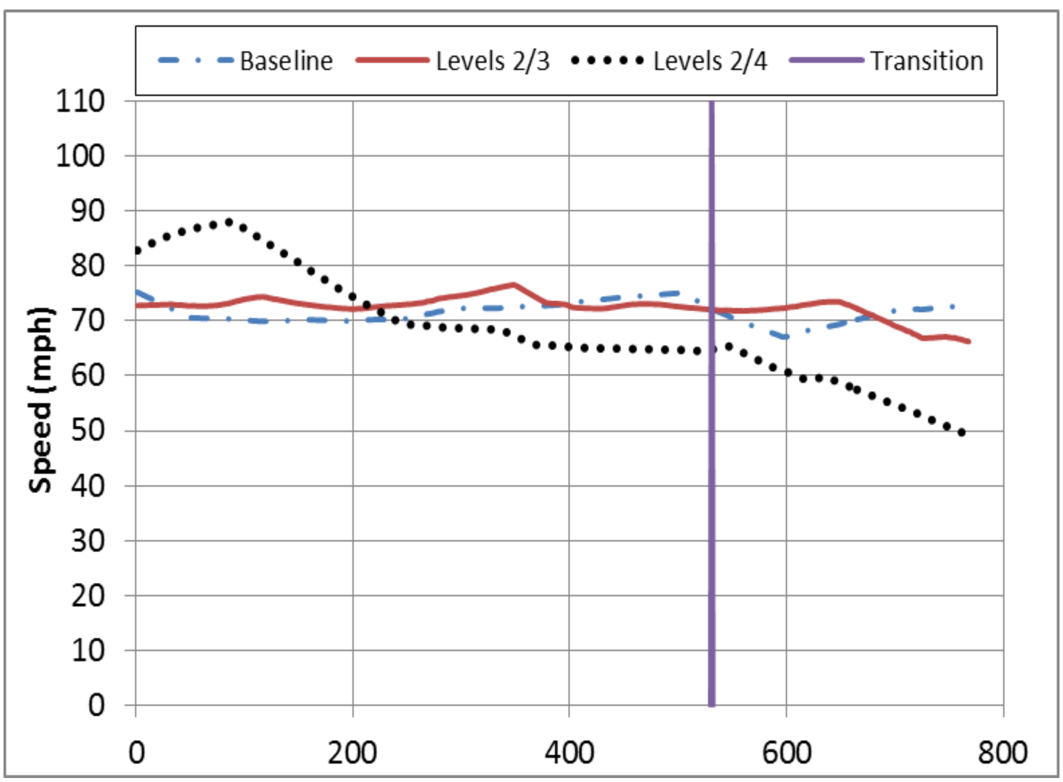

Figure D-44 Speed recorded for Participant 22 on Highway Roadway Profile

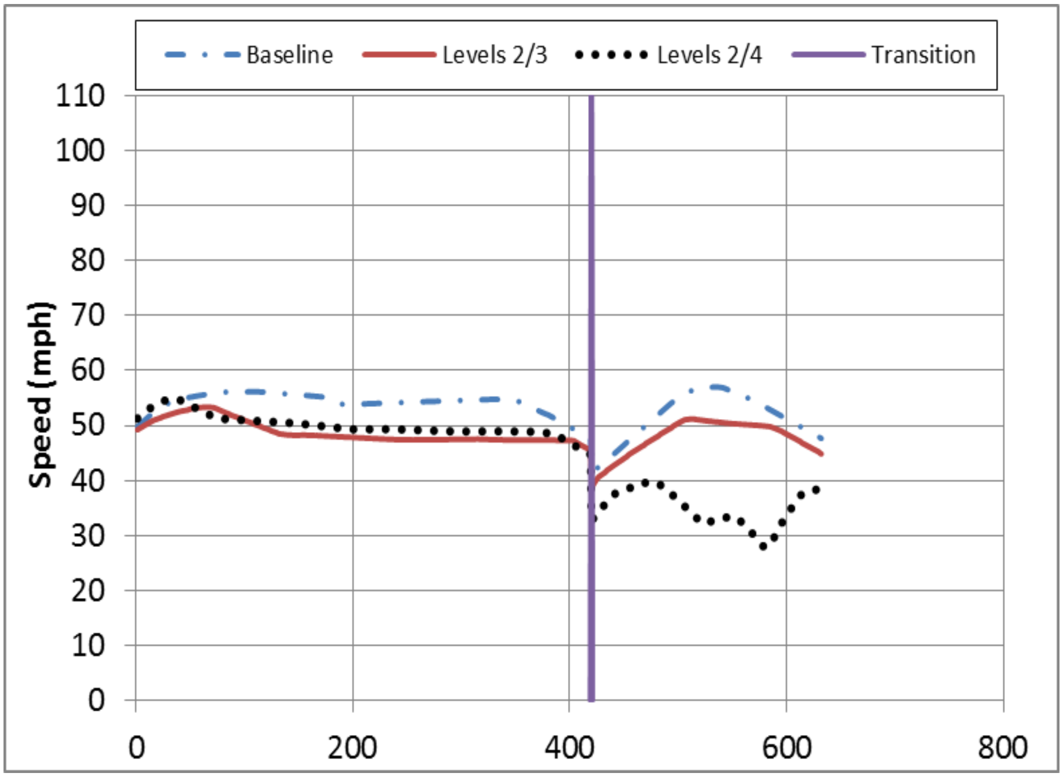

Figure D-45 Speed recorded for Participant 23 on Suburban Roadway Profile

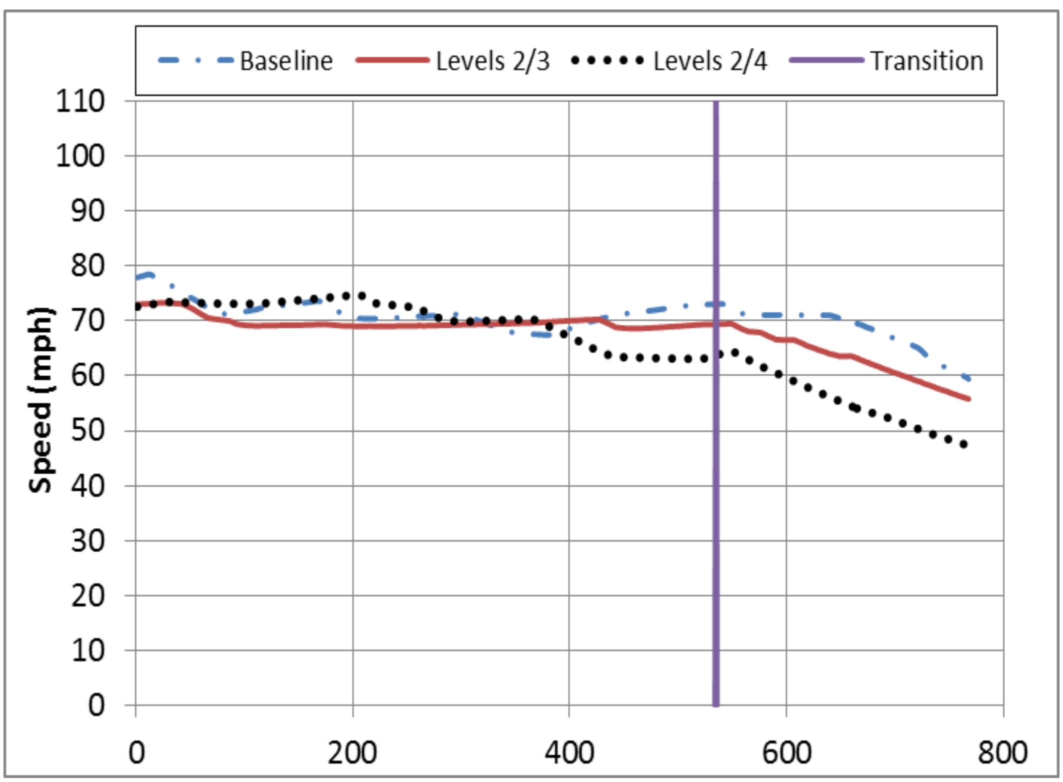

Figure D-46 Speed recorded for Participant 23 on Highway Roadway Profile

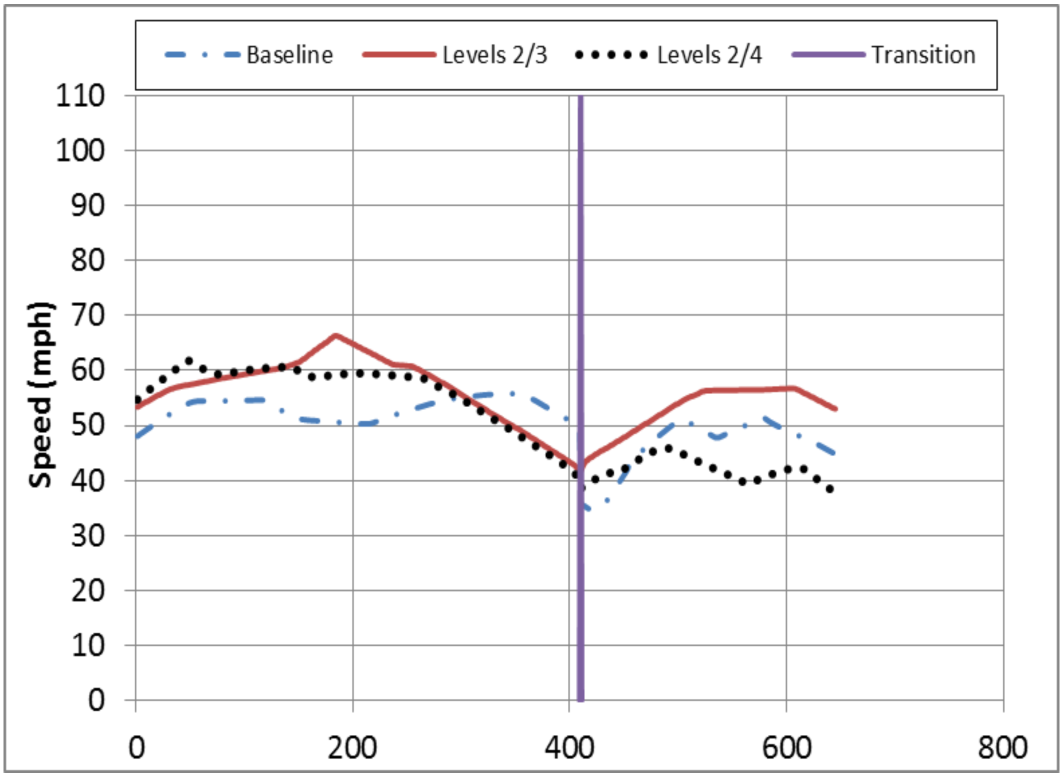

Figure D-47 Speed recorded for Participant 24 on Suburban Roadway Profile

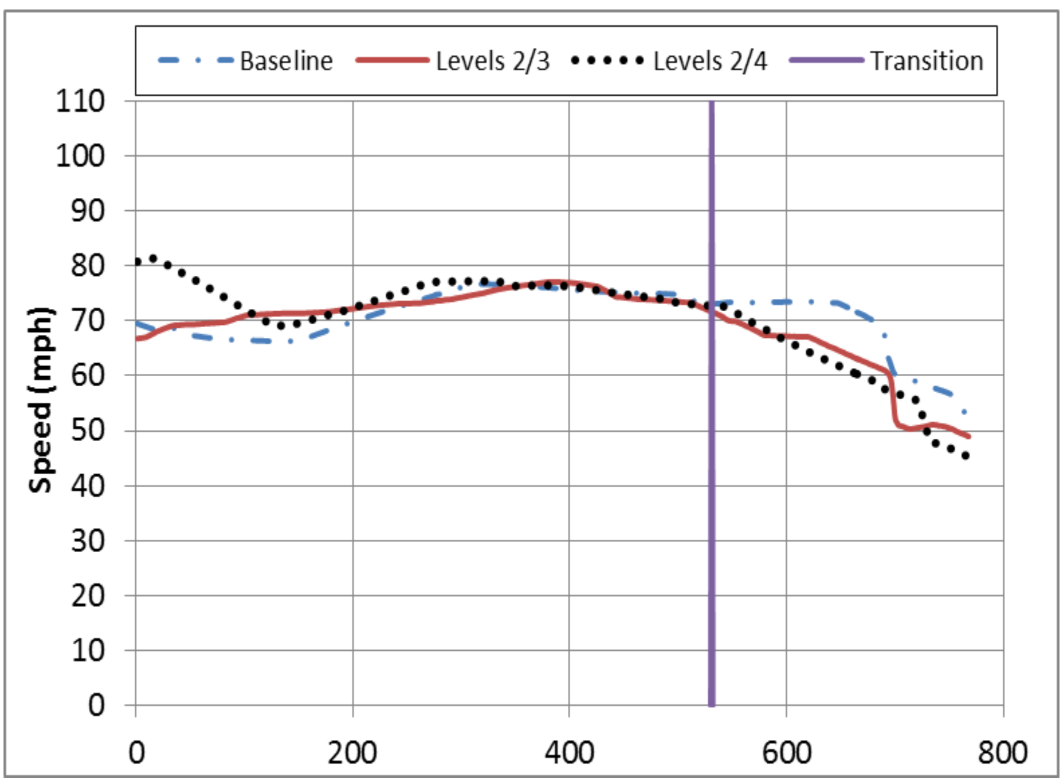

Figure D-48 Speed recorded for Participant 24 on Highway Roadway Profile

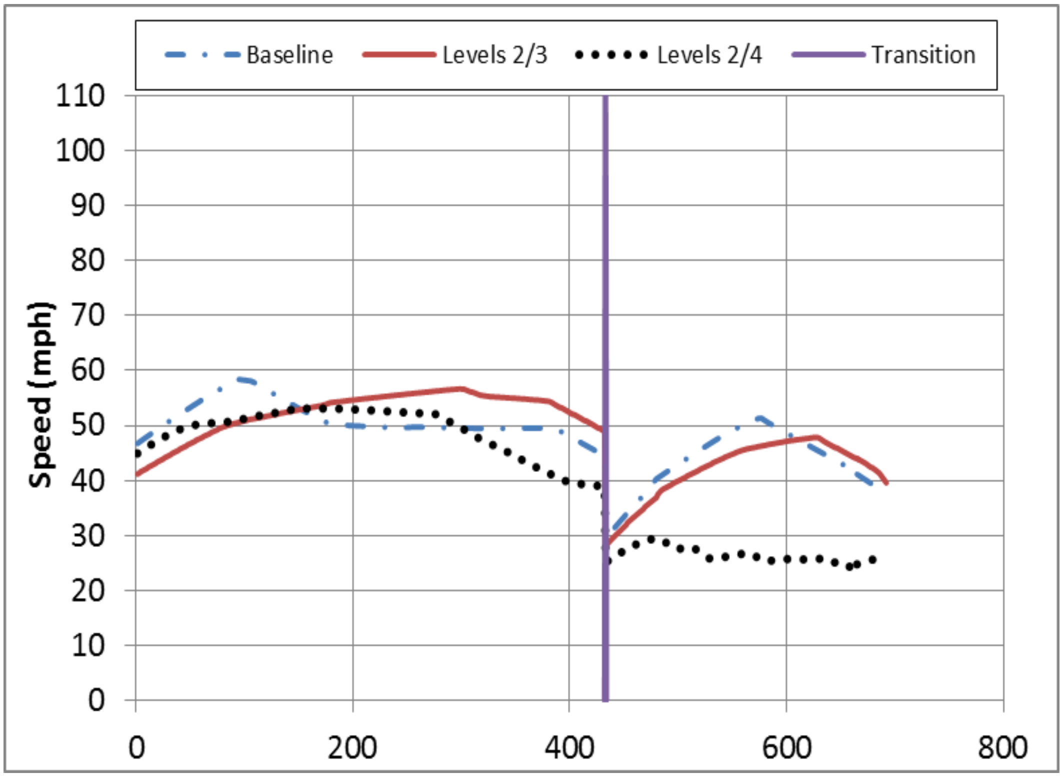

Figure D-49 Speed recorded for Participant 25 on Suburban Roadway Profile

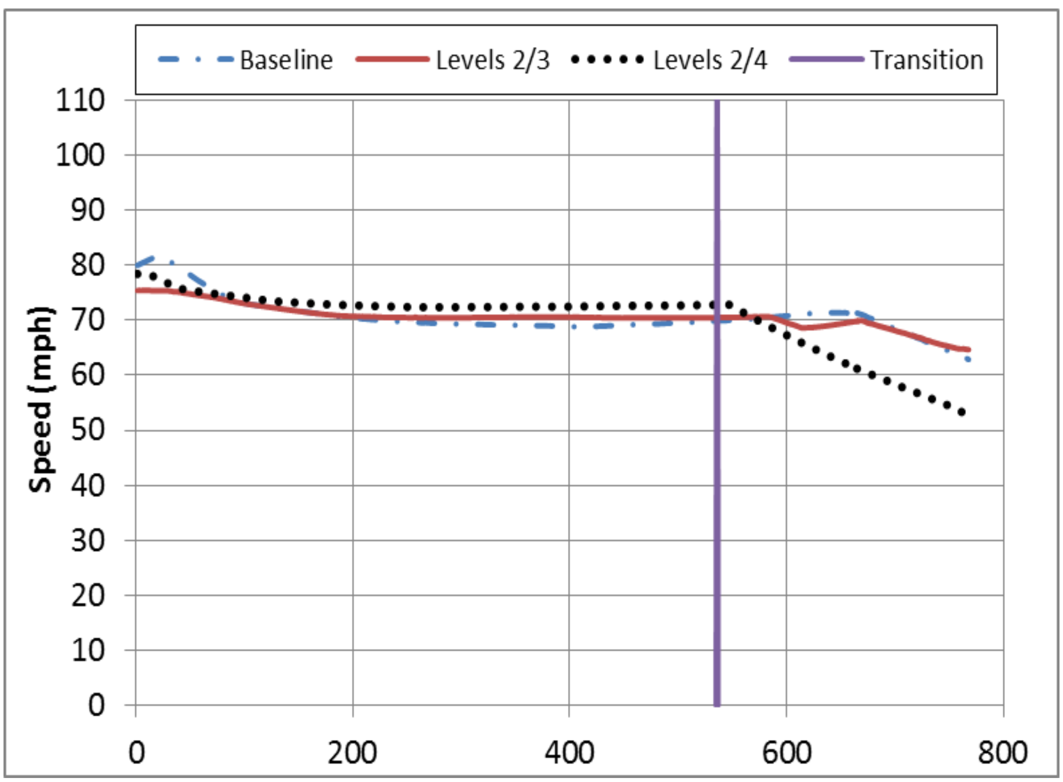

Figure D-50 Speed recorded for Participant 25 on Highway Roadway Profile

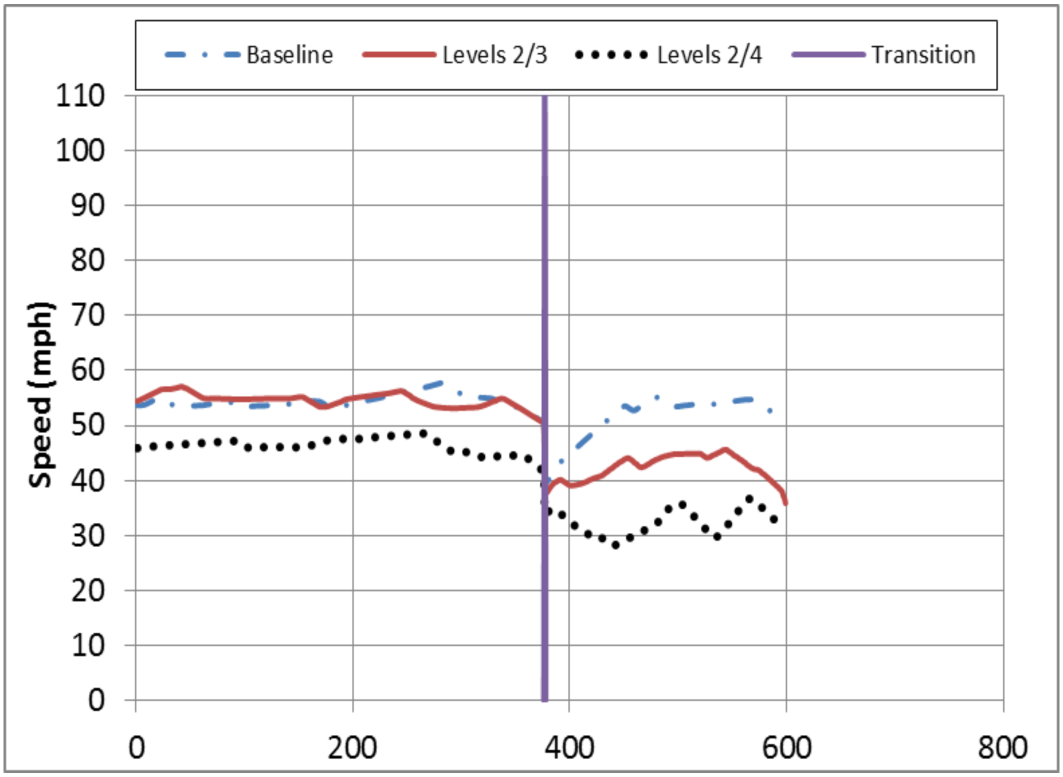

Figure D-51 Speed recorded for Participant 26 on Suburban Roadway Profile

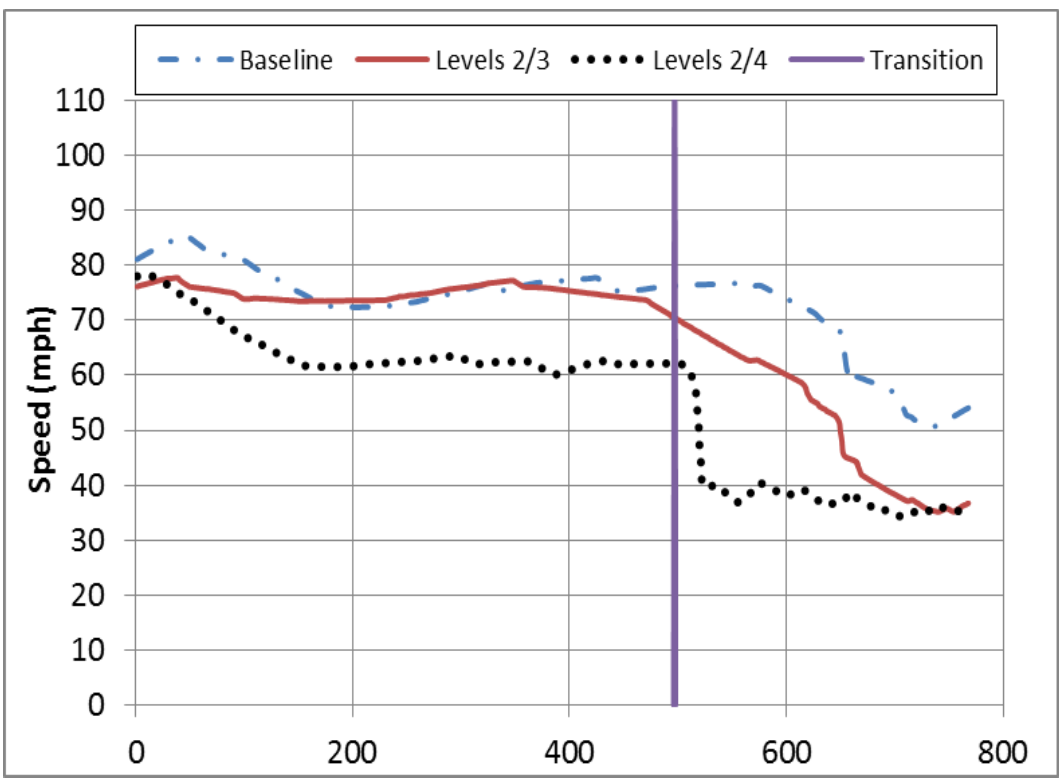

Figure D-52 Speed recorded for Participant 26 on Highway Roadway Profile

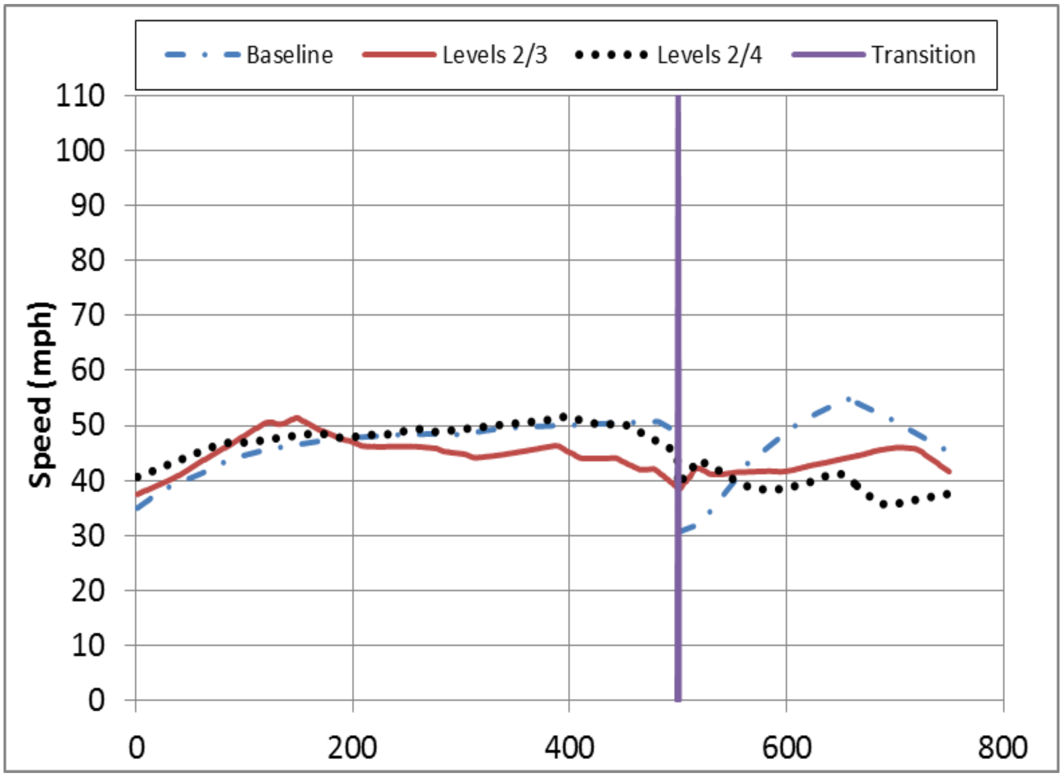

Figure D-53 Speed recorded for Participant 27 on Suburban Roadway Profile

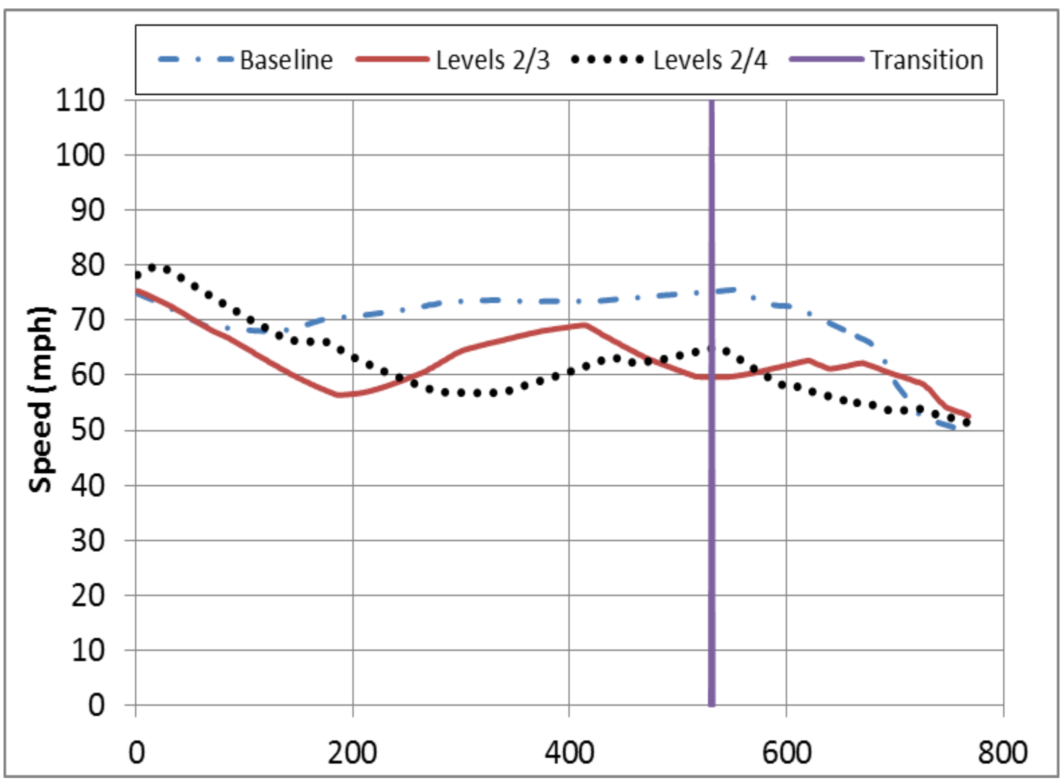

Figure D-54 Speed recorded for Participant 27 on Highway Roadway Profile

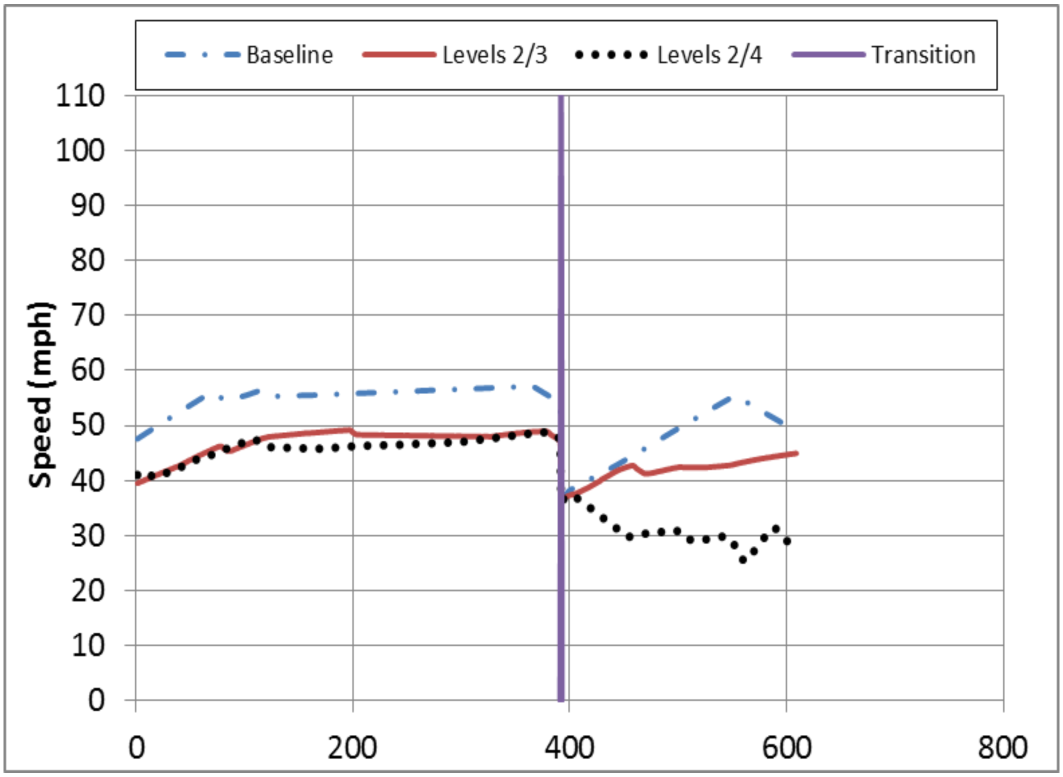

Figure D-55 Speed recorded for Participant 28 on Suburban Roadway Profile

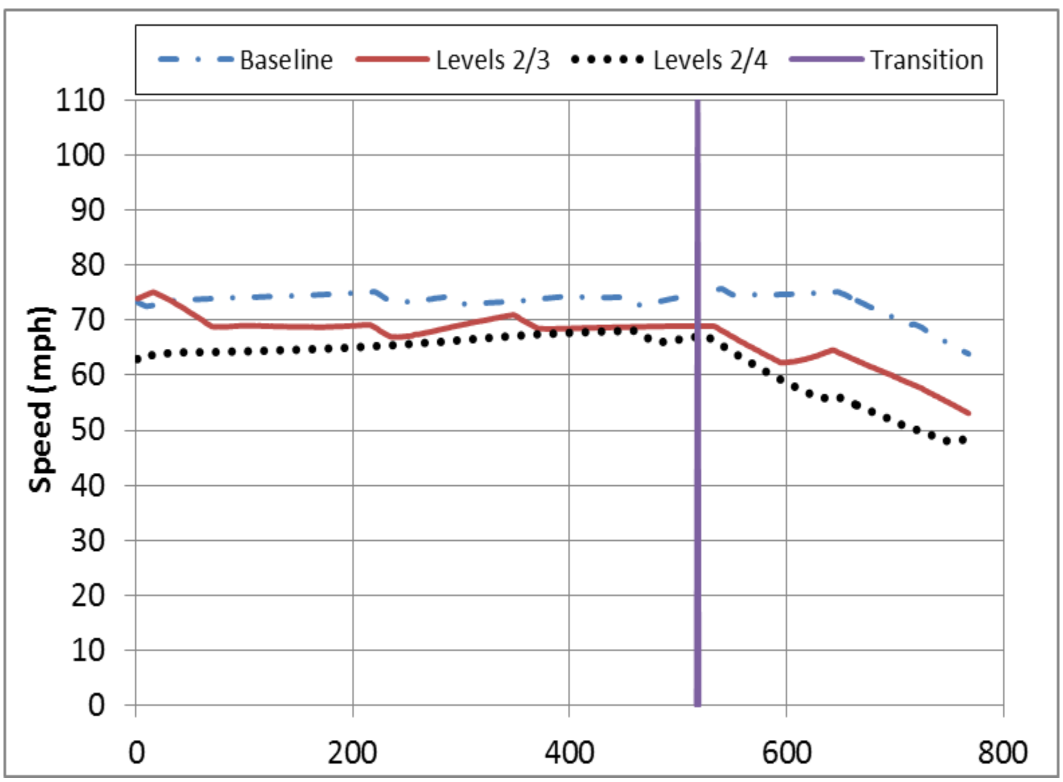

Figure D-56 Speed recorded for Participant 28 on Highway Roadway Profile

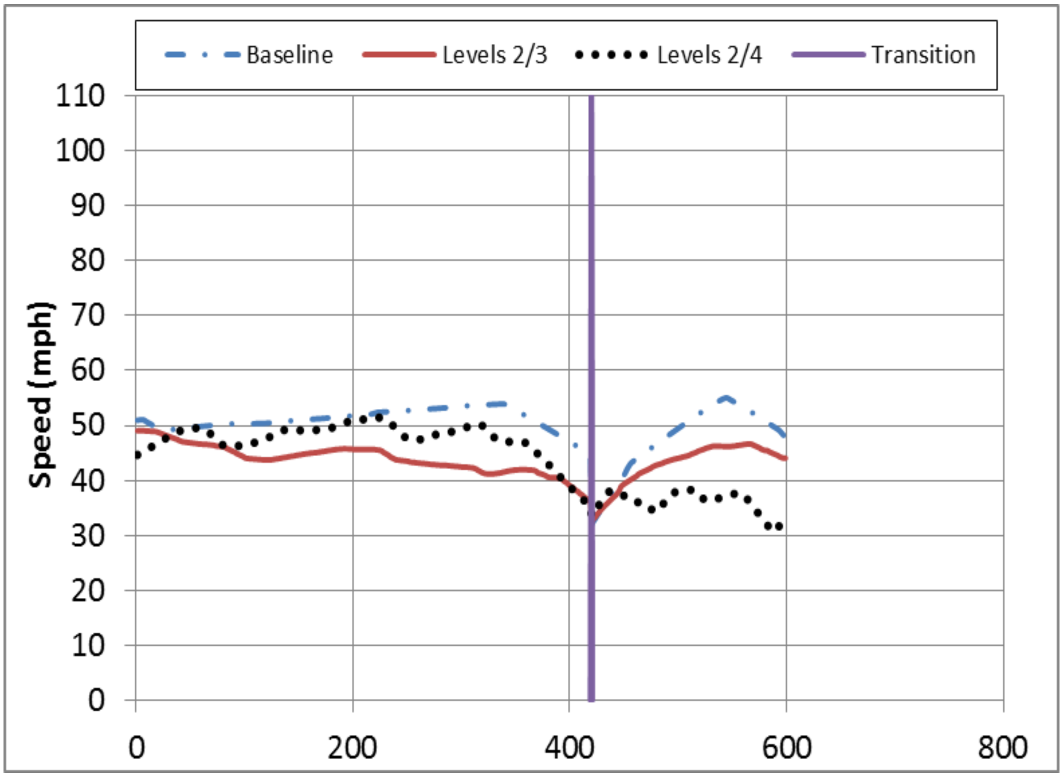

Figure D-57 Speed recorded for Participant 30 on Suburban Roadway Profile

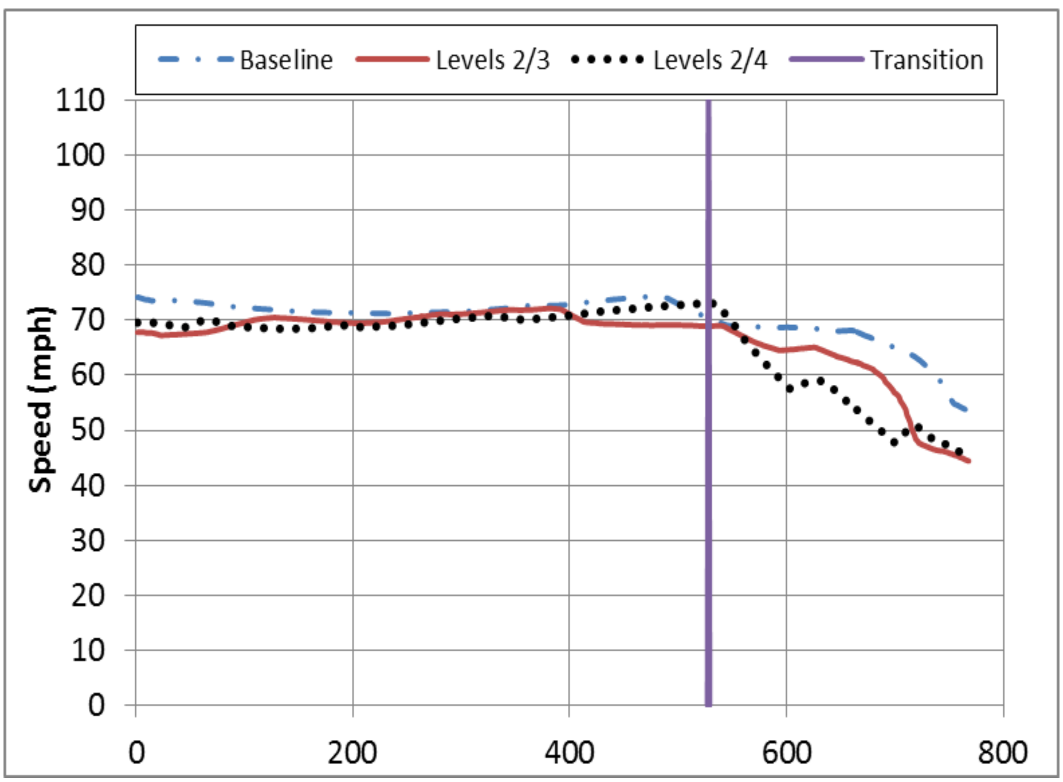

Figure D-58 Speed recorded for Participant 30 on Highway Roadway Profile

APPENDIX E
AVERAGE SPEED DURING RAINFALL CONDITION WITH 95% CONFIDENCE INTERVAL ERROR BARS

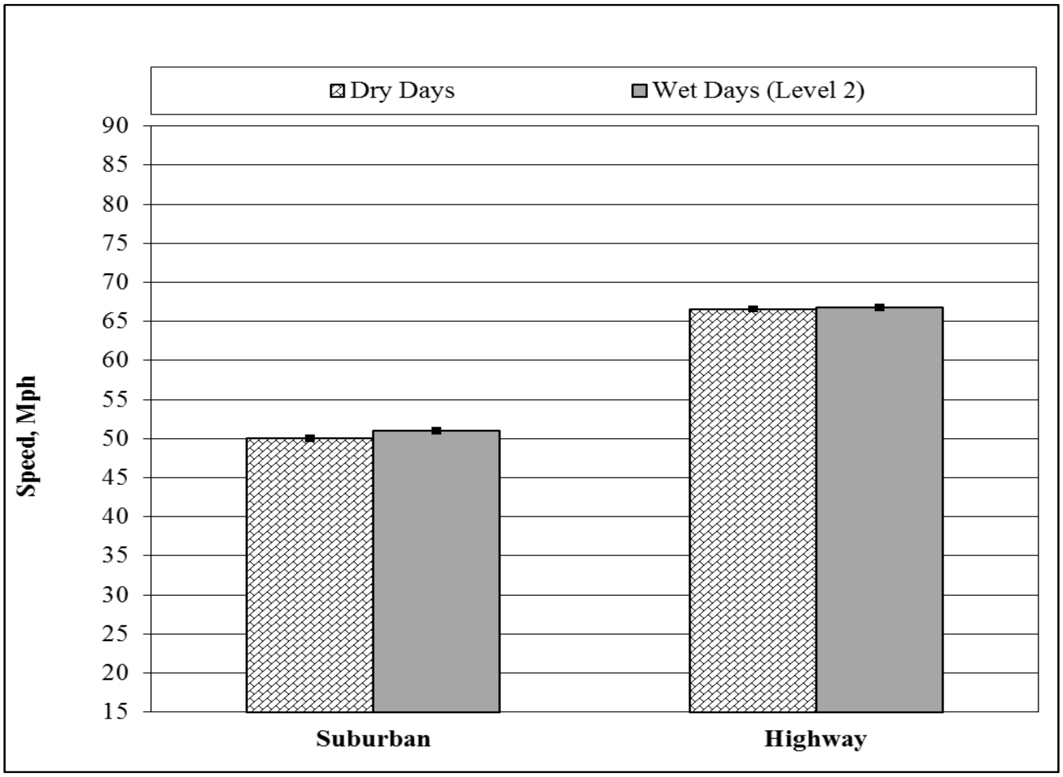

Figure E-1 Average speed during light rain condition with 95% confidence interval error bars for Participant 1

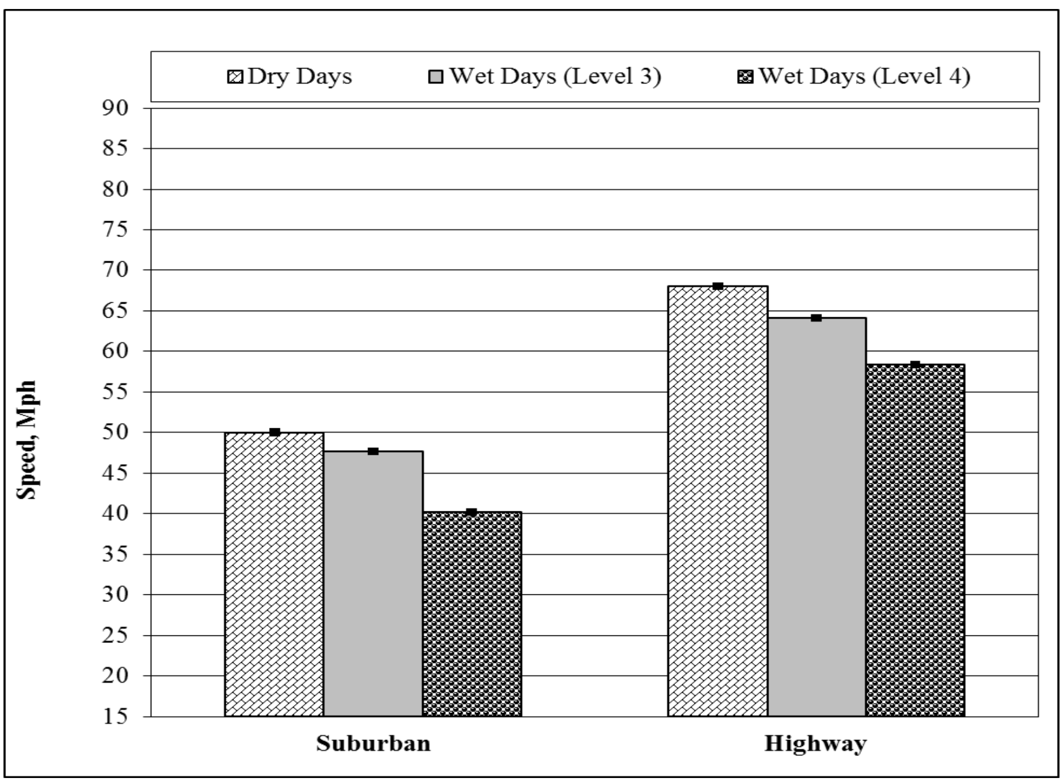

Figure E-2 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 1

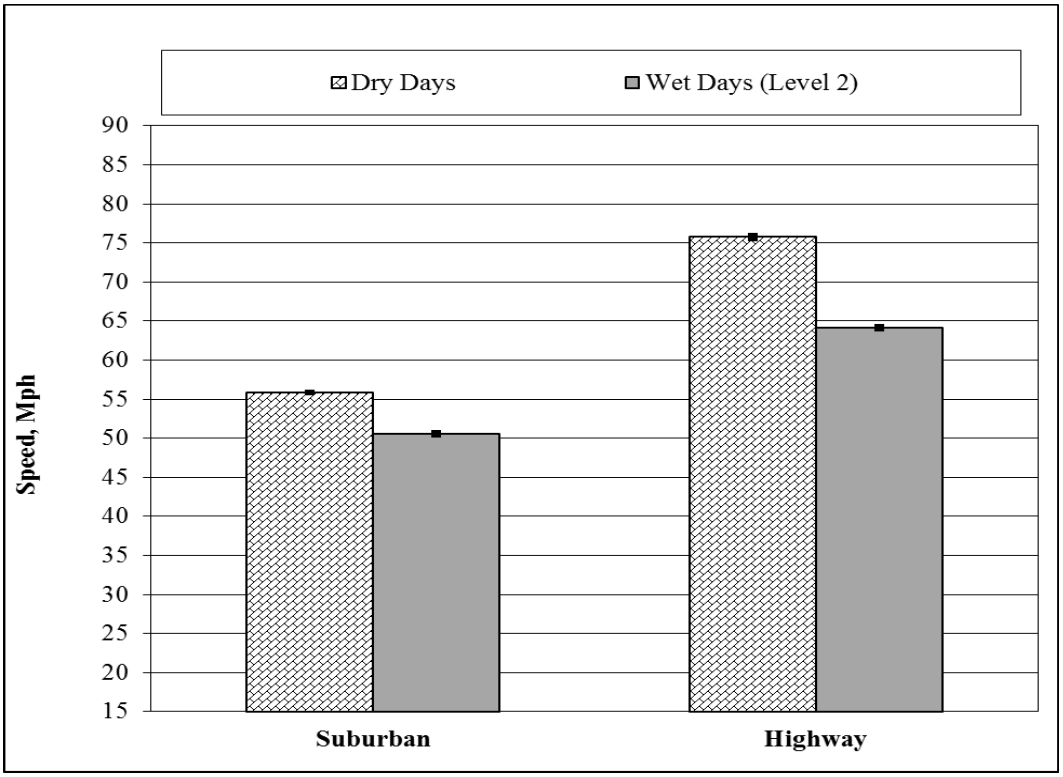

Figure E-3 Average speed during light rain condition with 95% confidence interval error bars for Participant 2

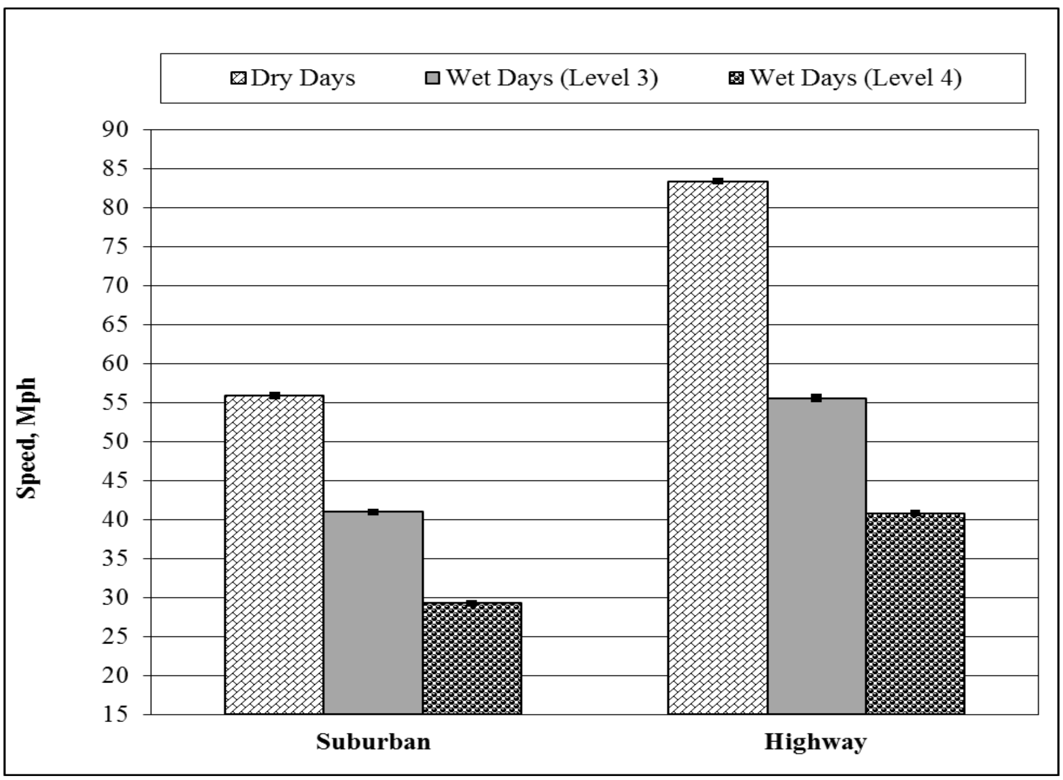

Figure E-4 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 2

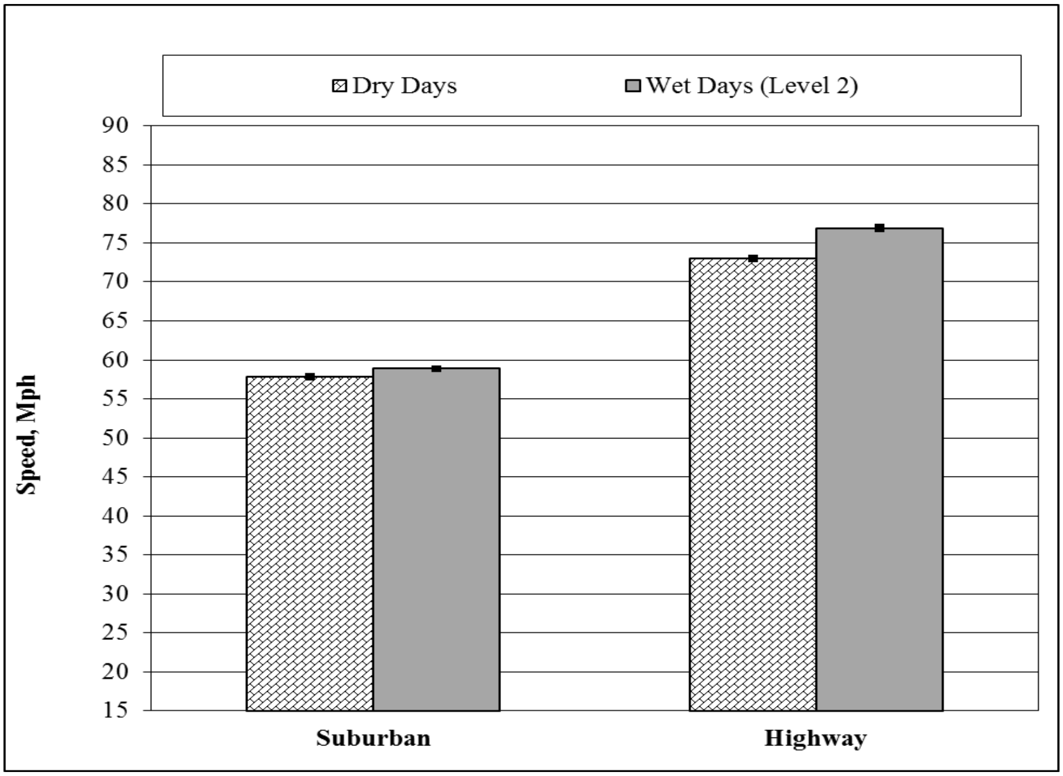

Figure E-5 Average speed during light rain condition with 95% confidence interval error bars for Participant 3

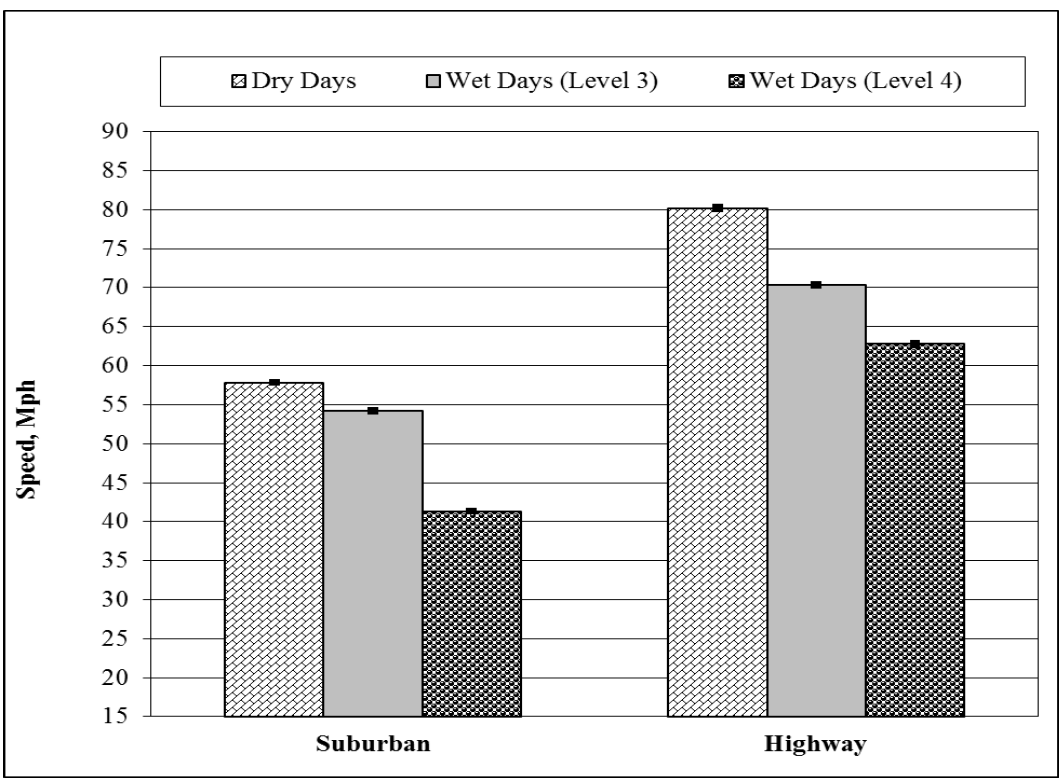

Figure E-6 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 3

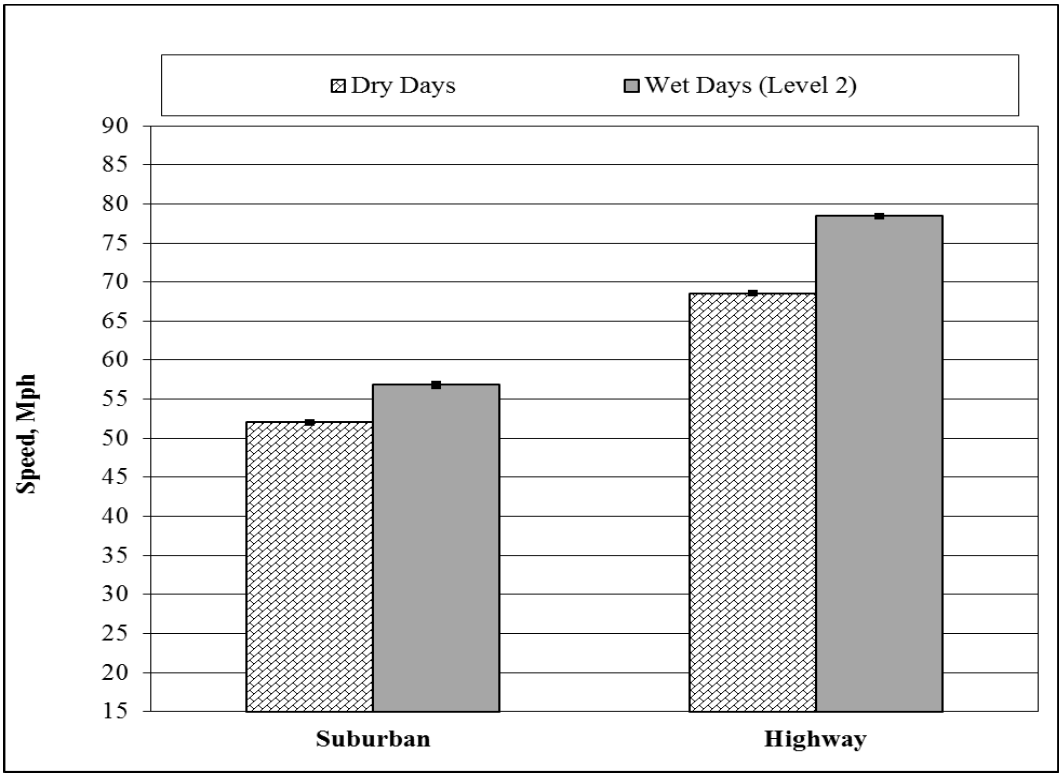

Figure E-7 Average speed during light rain condition with 95% confidence interval error bars for Participant 4

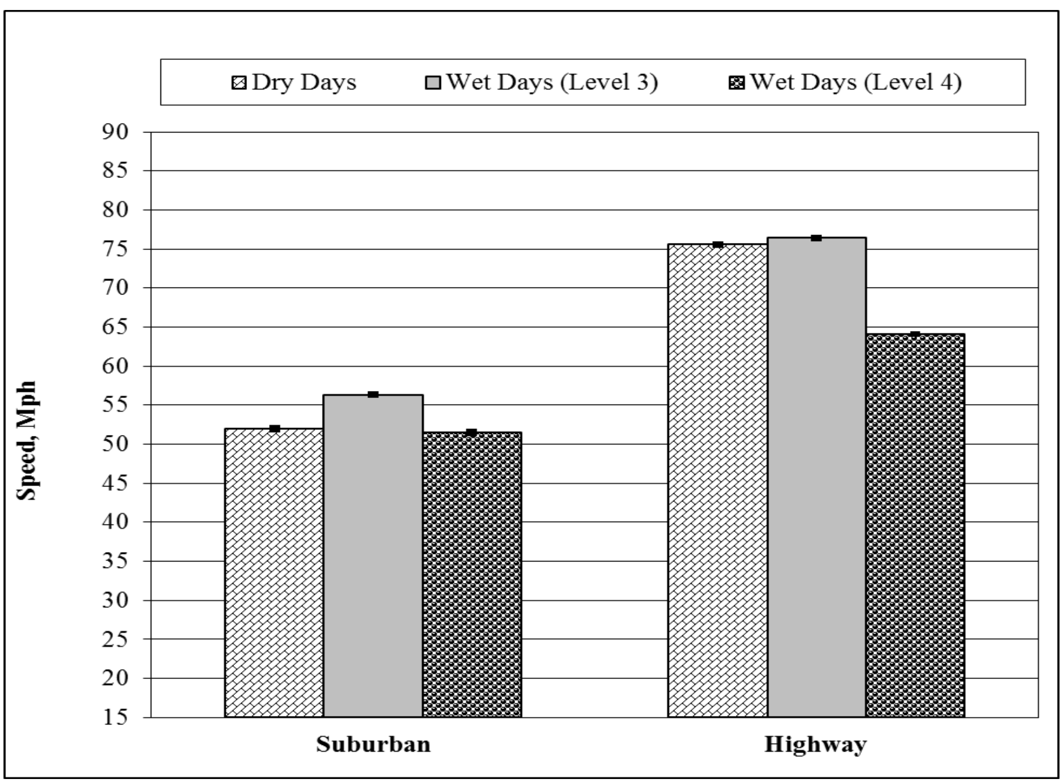

Figure E-8 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 4

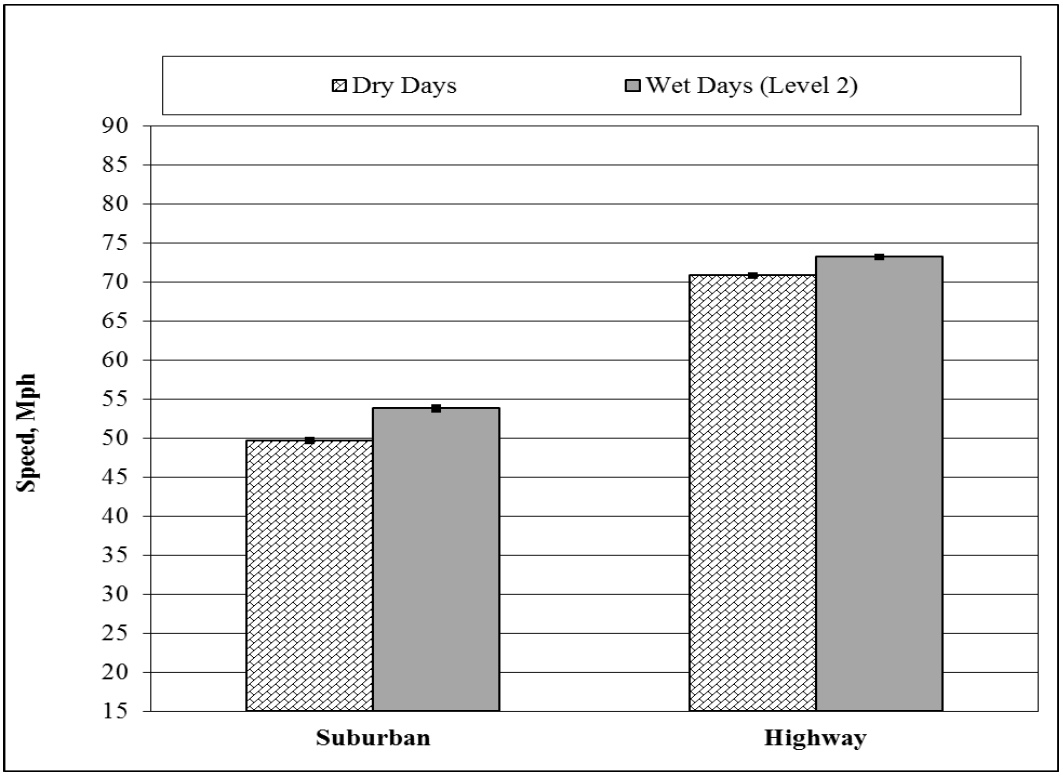

Figure E-9 Average speed during light rain condition with 95% confidence interval error bars for Participant 5

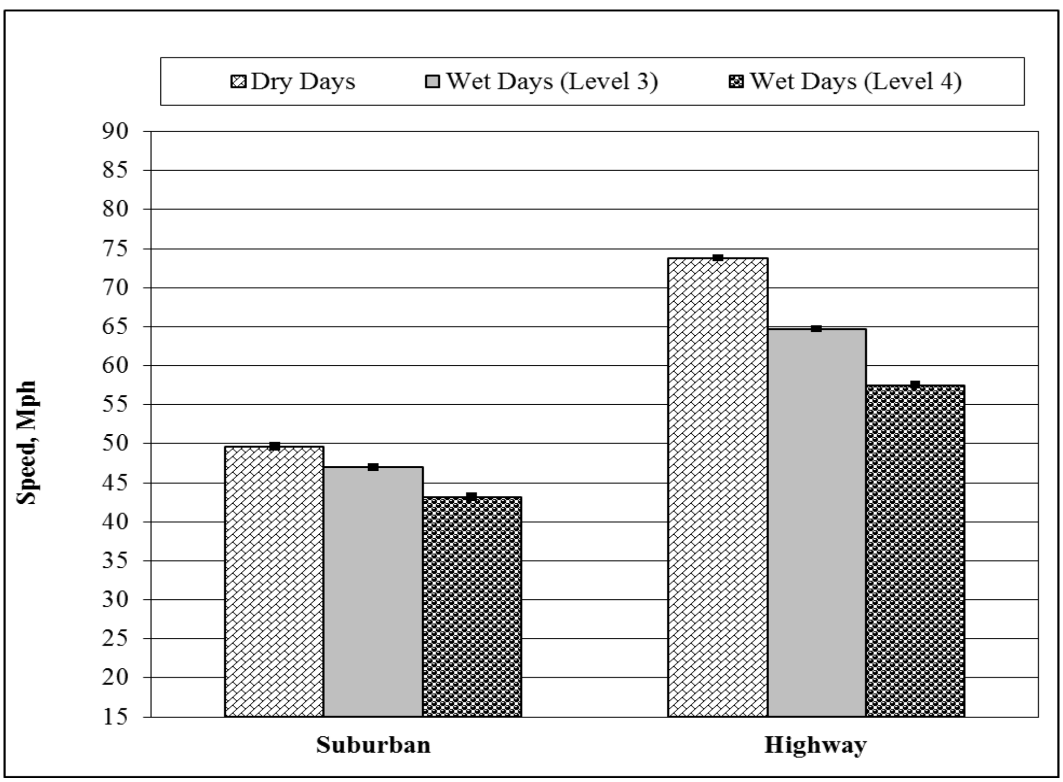

Figure E-10 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 5

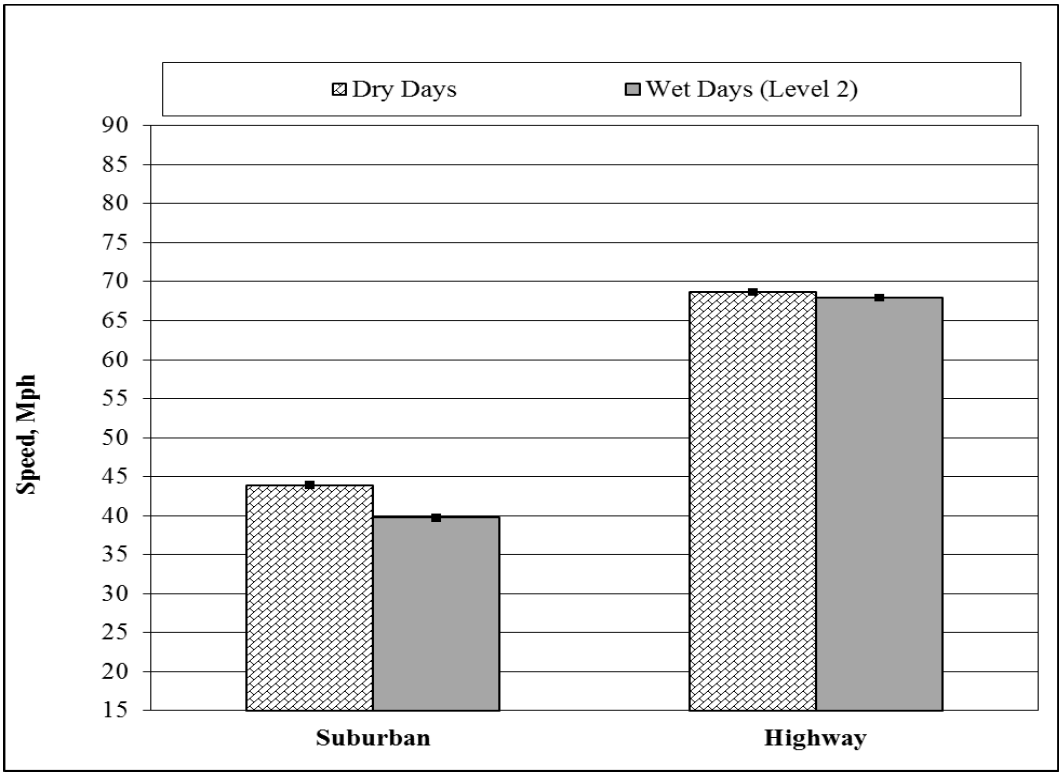

Figure E-11 Average speed during light rain condition with 95% confidence interval error bars for Participant 6

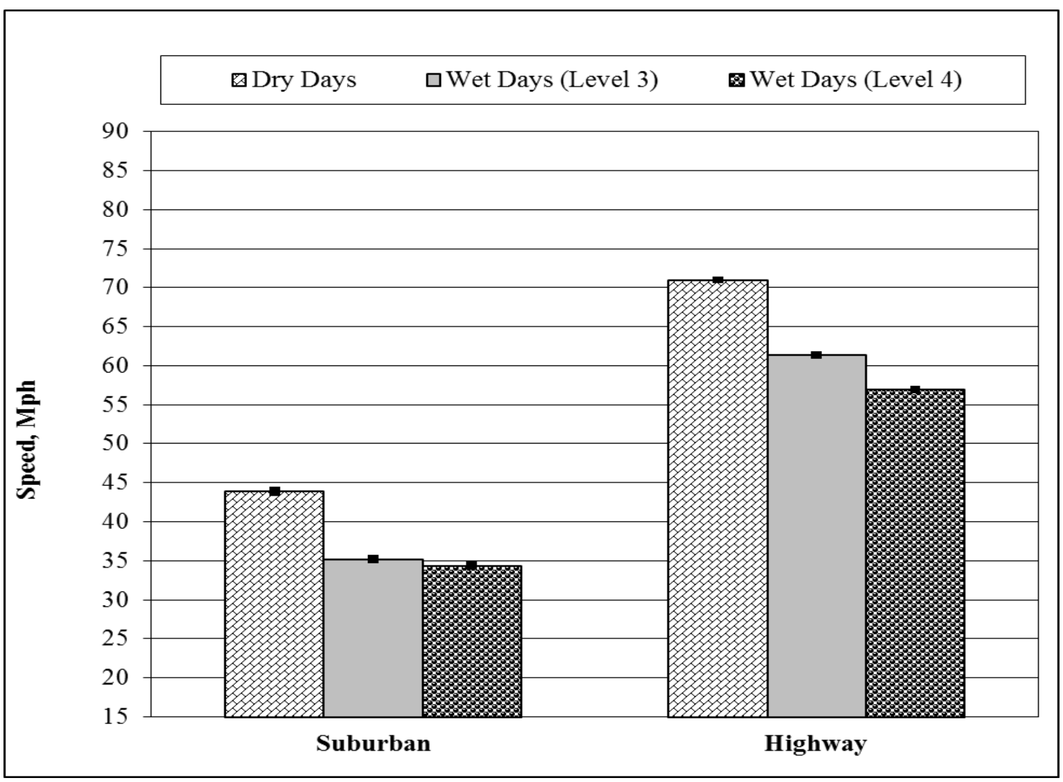

Figure E-12 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 6

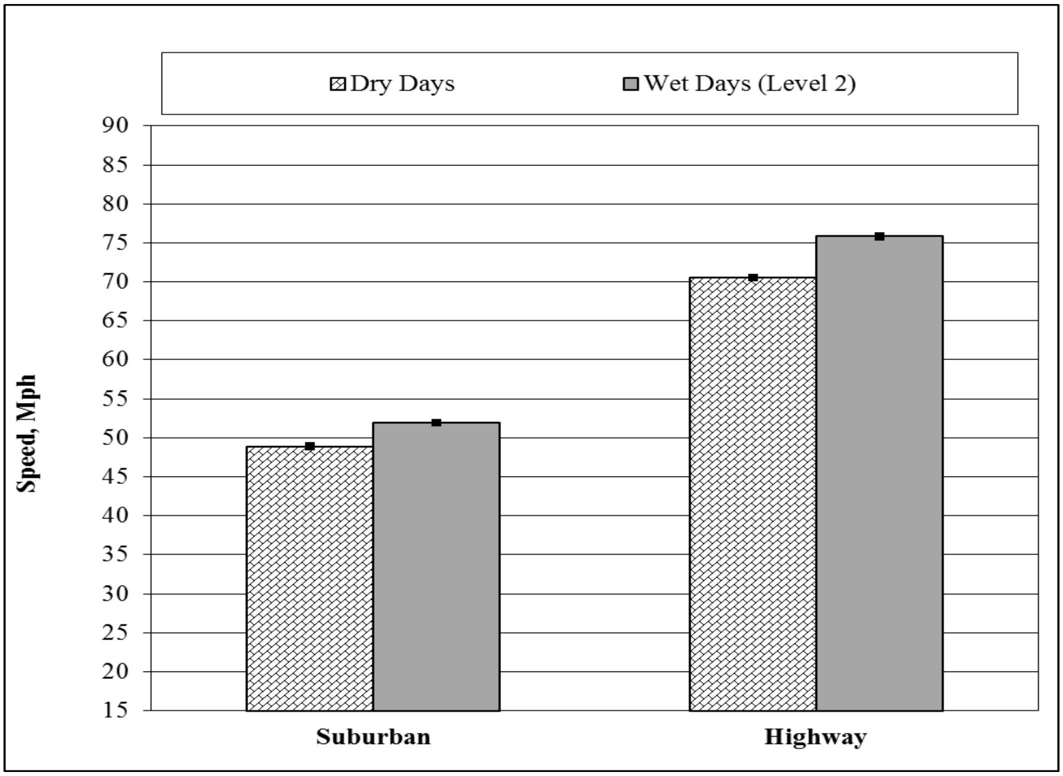

Figure E-13 Average speed during light rain condition with 95% confidence interval error bars for Participant 7

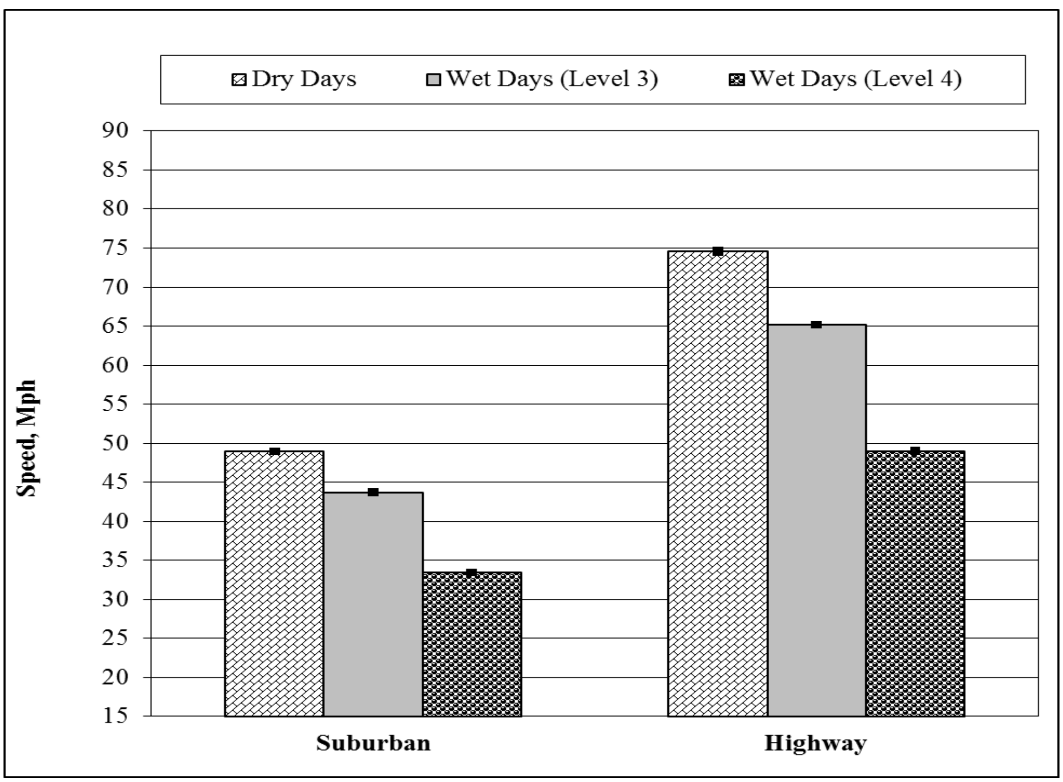

Figure E-14 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 7

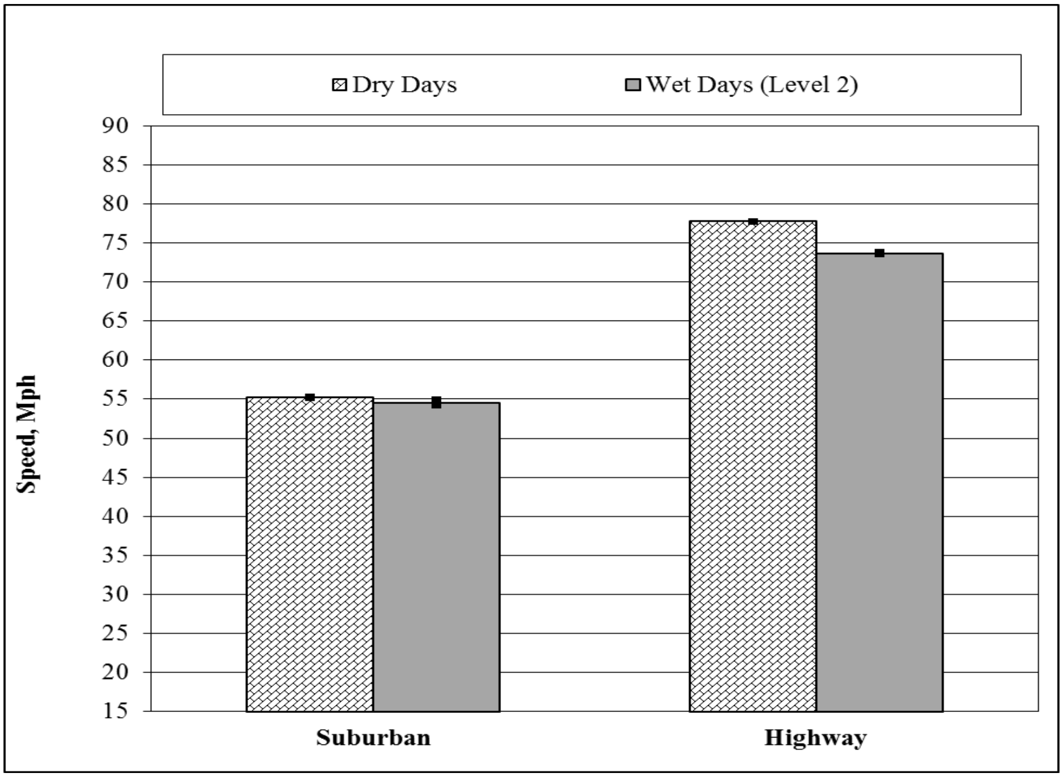

Figure E-15 Average speed during light rain condition with 95% confidence interval error bars for Participant 8

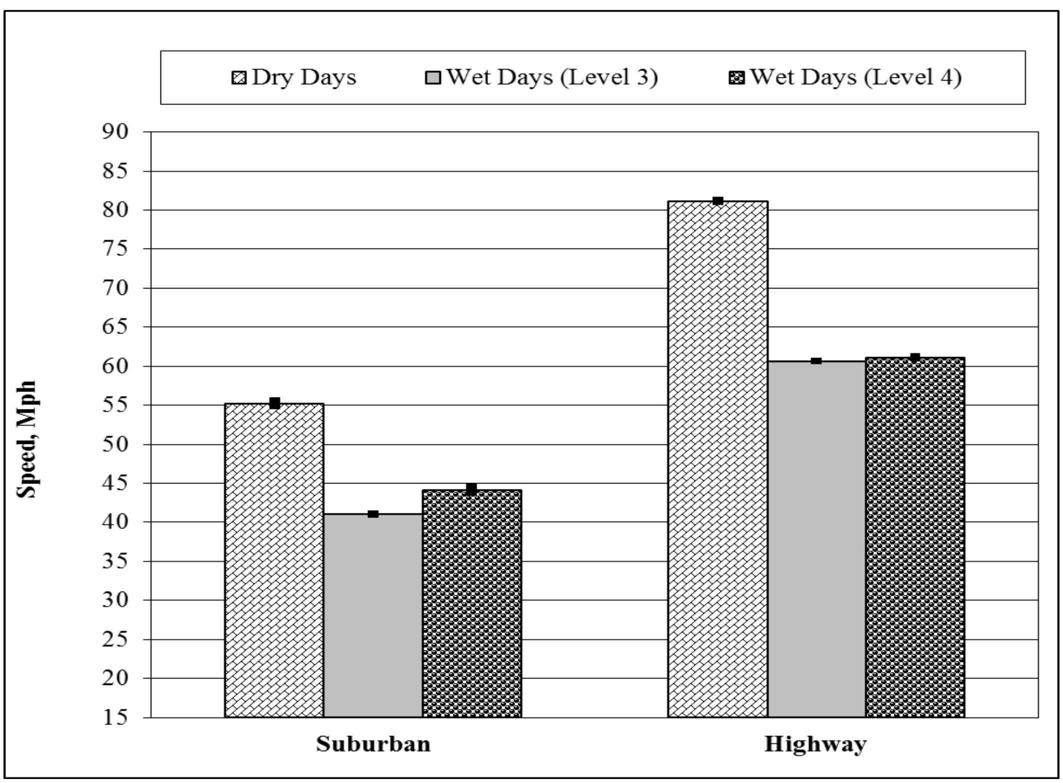

Figure E-16 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 8

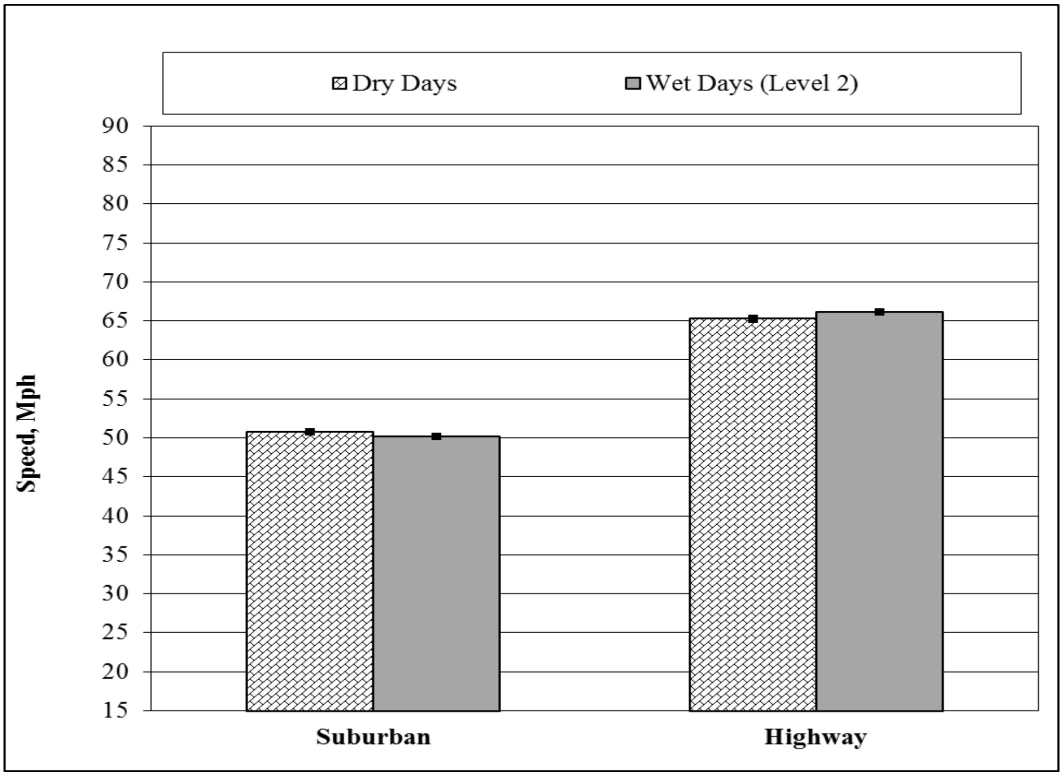

Figure E-17 Average speed during light rain condition with 95% confidence interval error bars for Participant 9

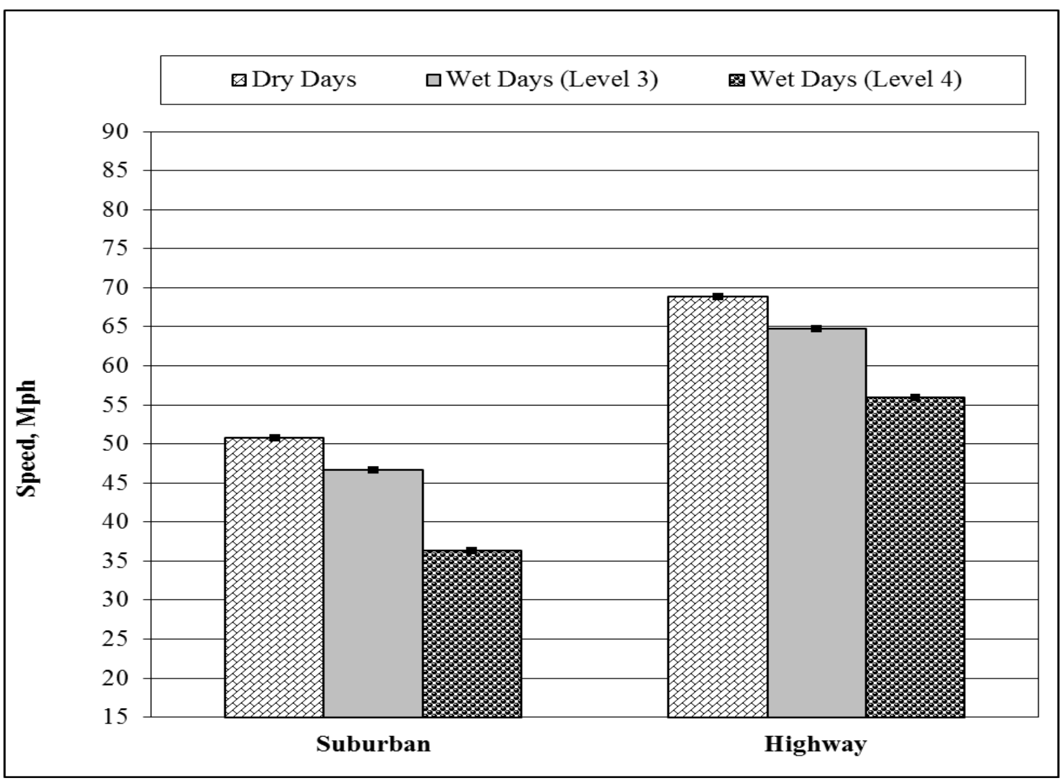

Figure E-18 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 9

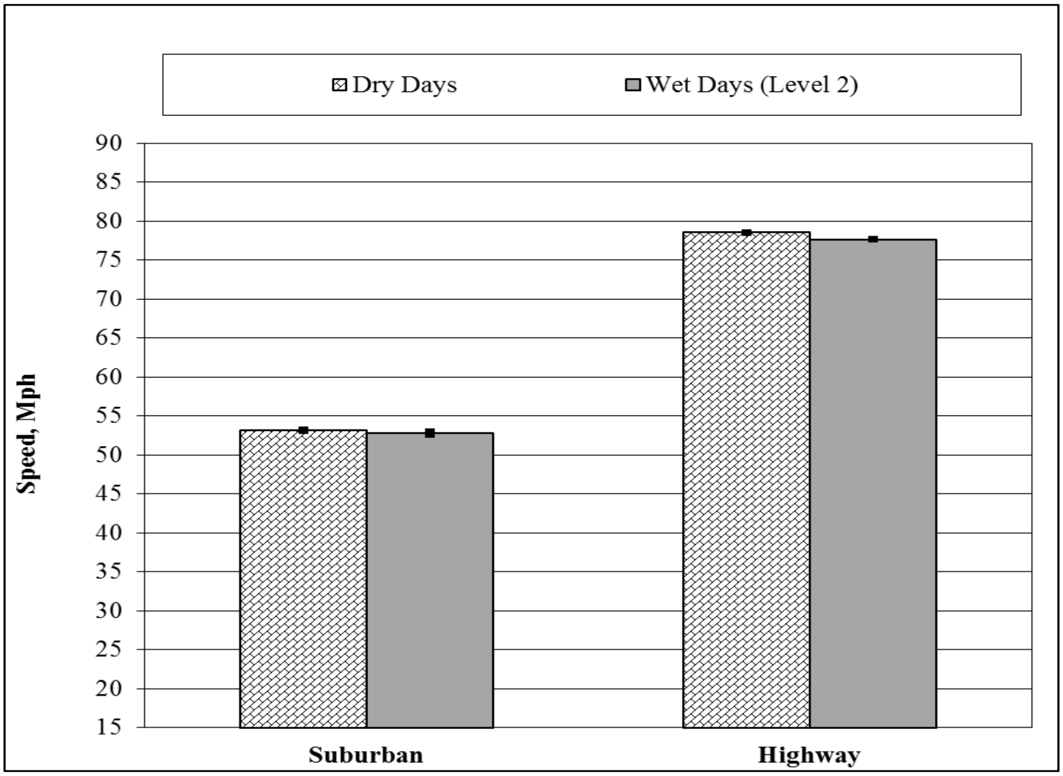

Figure E-19 Average speed during light rain condition with 95% confidence interval error bars for Participant 10

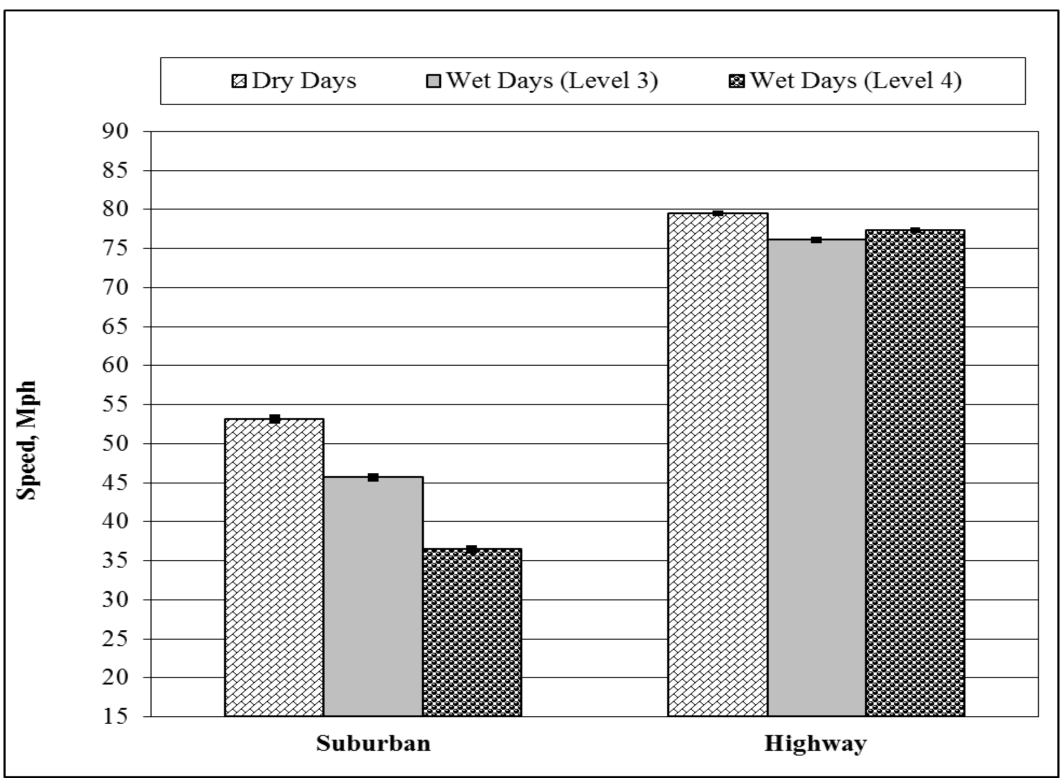

Figure E-20 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 10

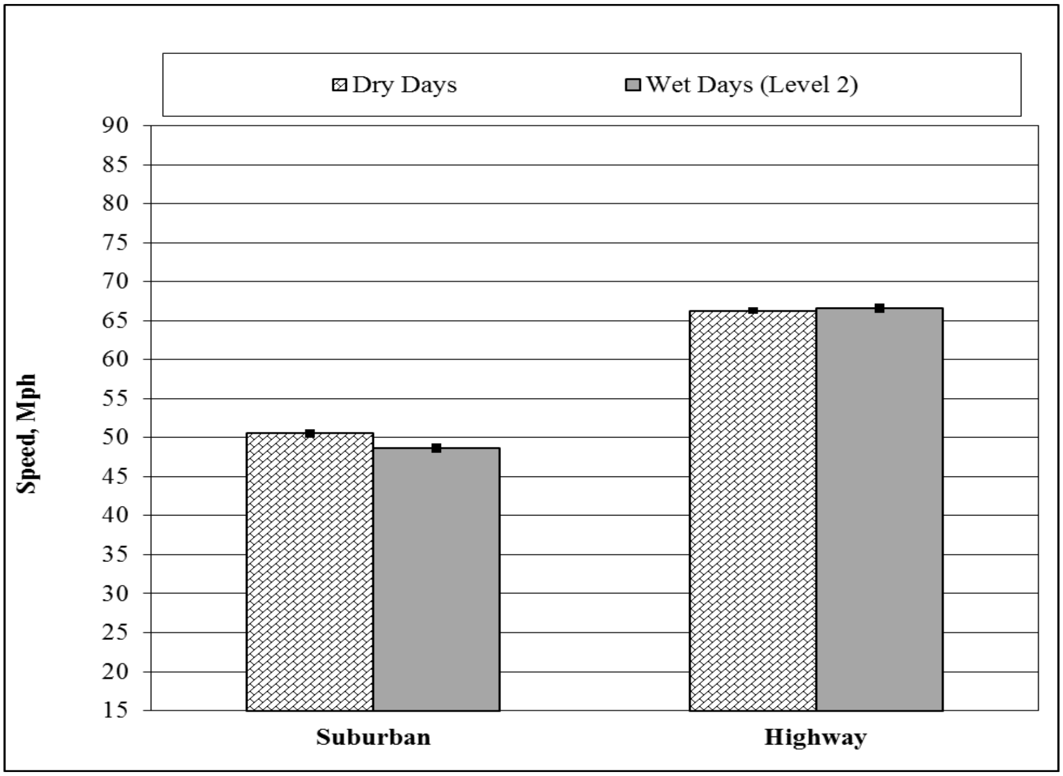

Figure E-21 Average speed during light rain condition with 95% confidence interval error bars for Participant 11

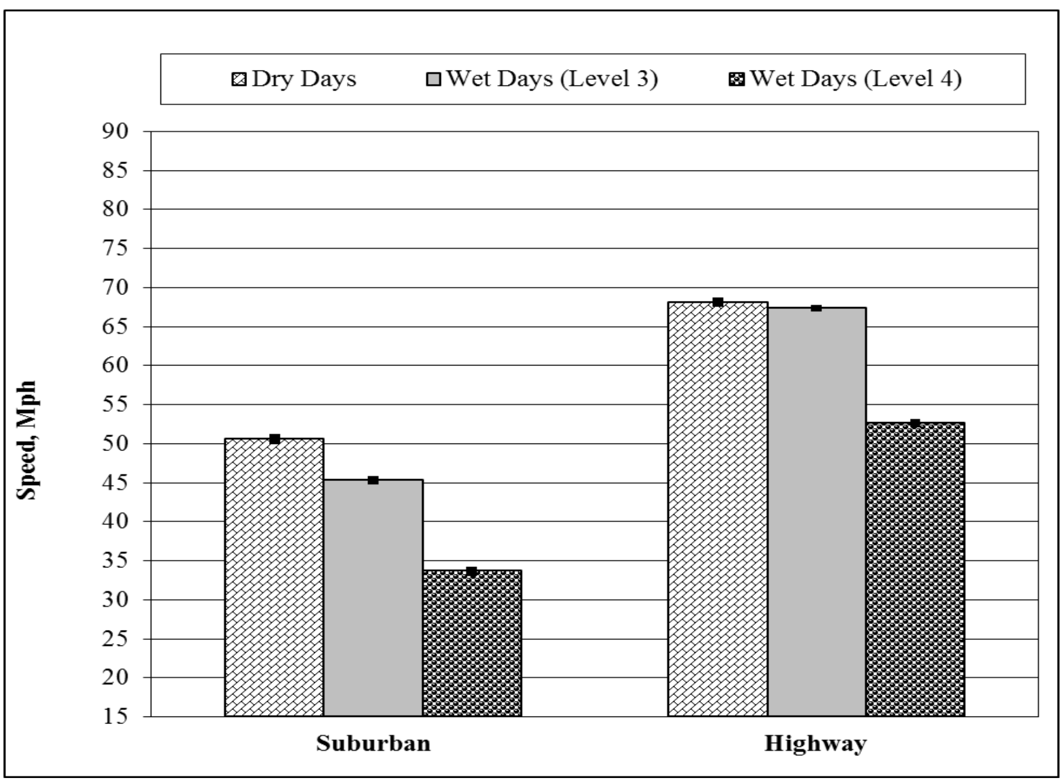

Figure E-22 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 11

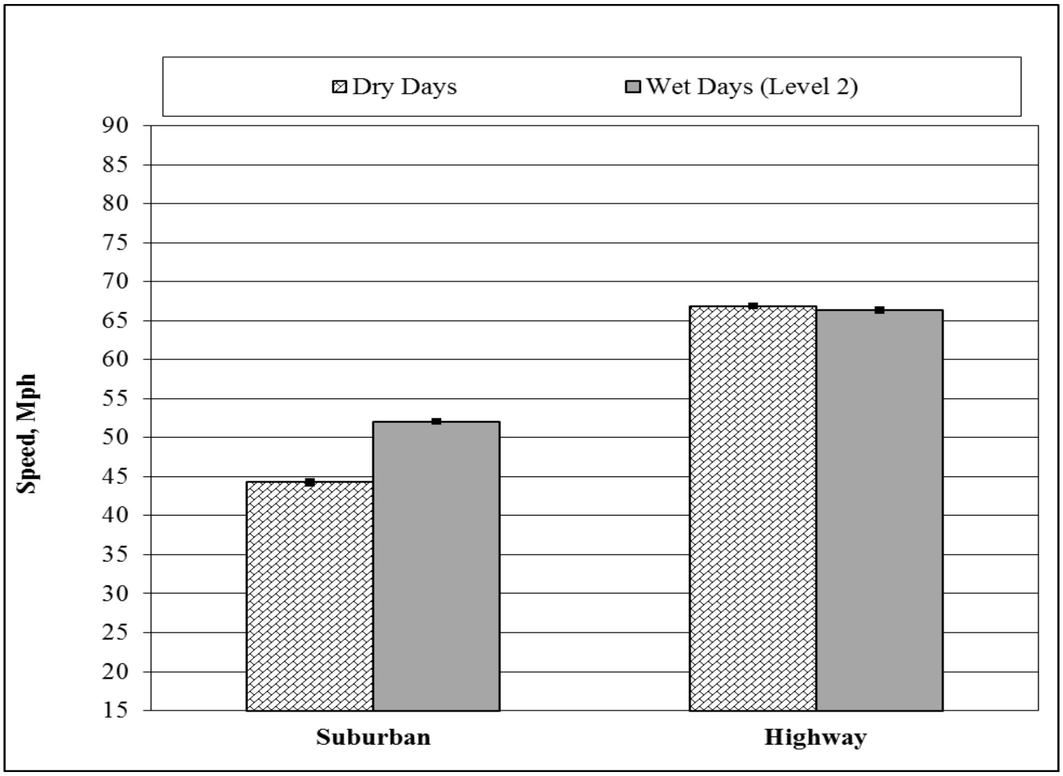

Figure E-23 Average speed during light rain condition with 95% confidence interval error bars for Participant 12

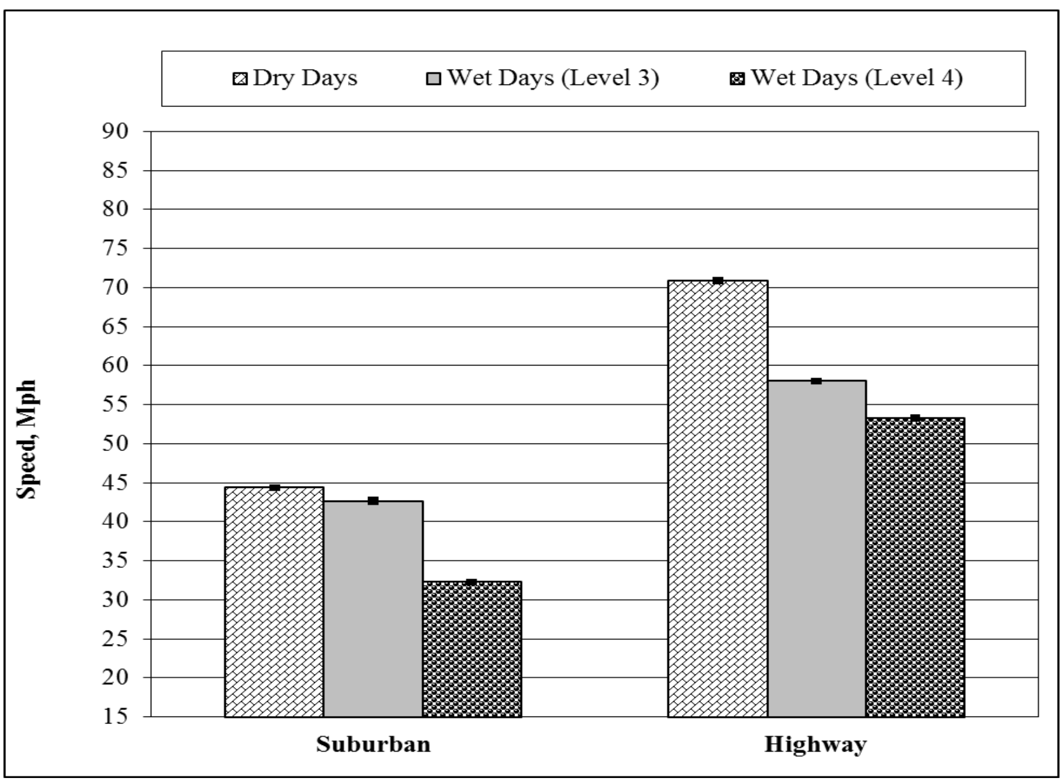

Figure E-24 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 12

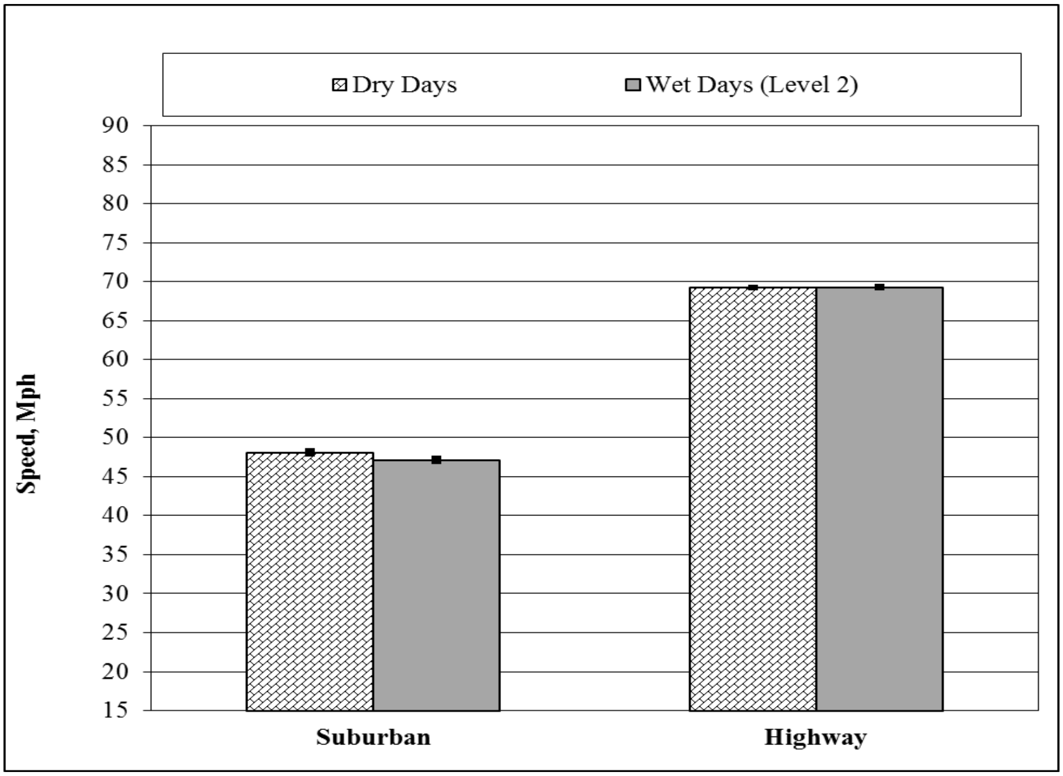

Figure E-25 Average speed during light rain condition with 95% confidence interval error bars for Participant 13

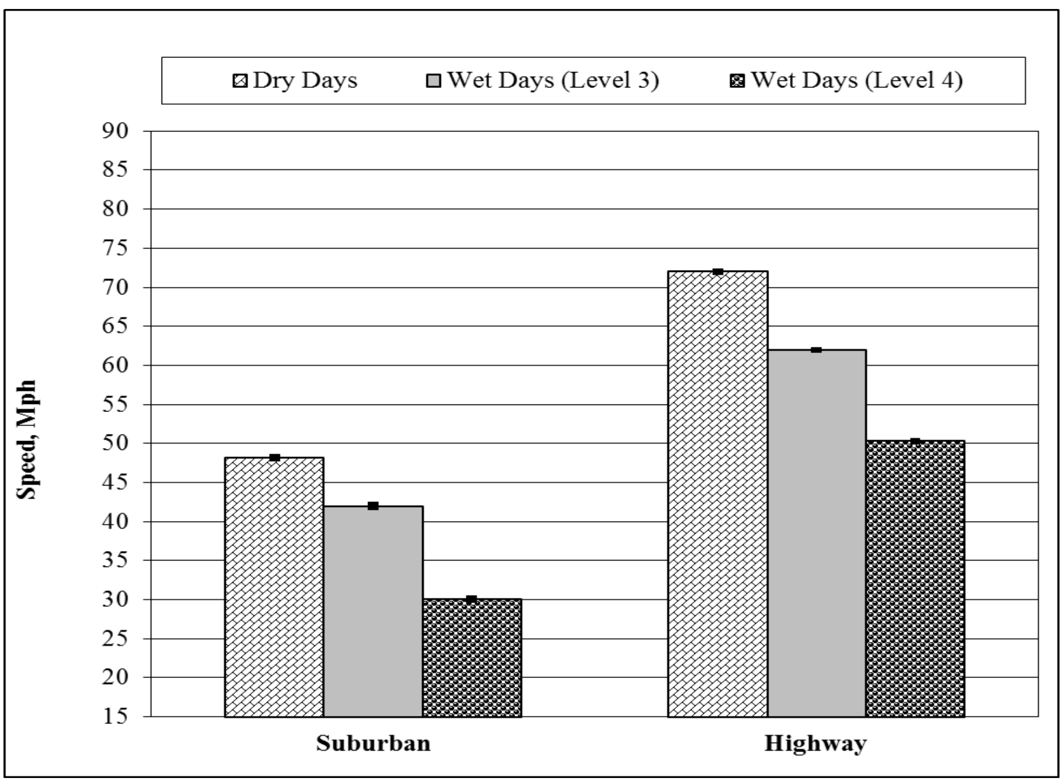

Figure E-26 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 13

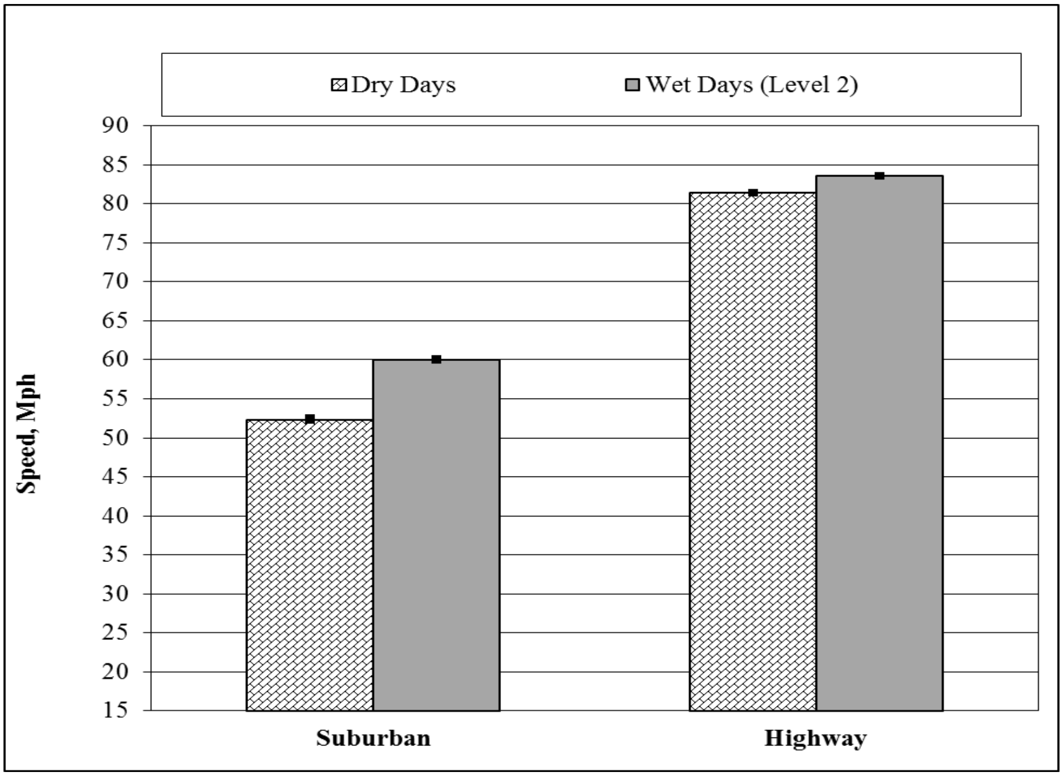

Figure E-27 Average speed during light rain condition with 95% confidence interval error bars for Participant 14

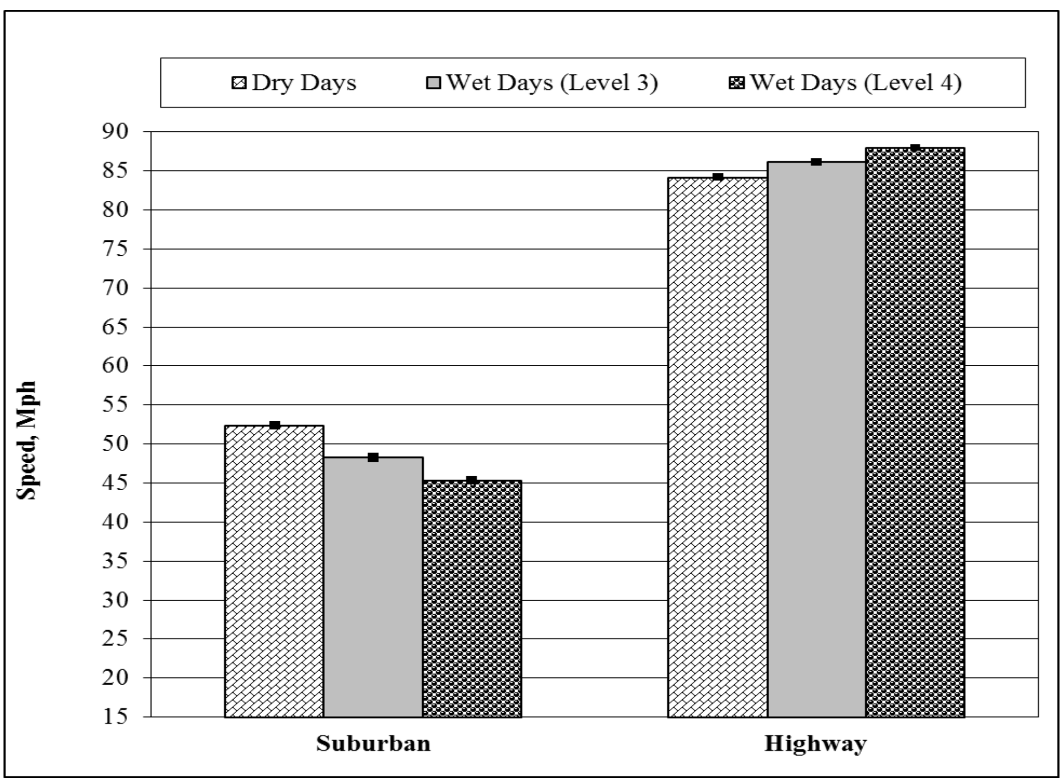

Figure E-28 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 14

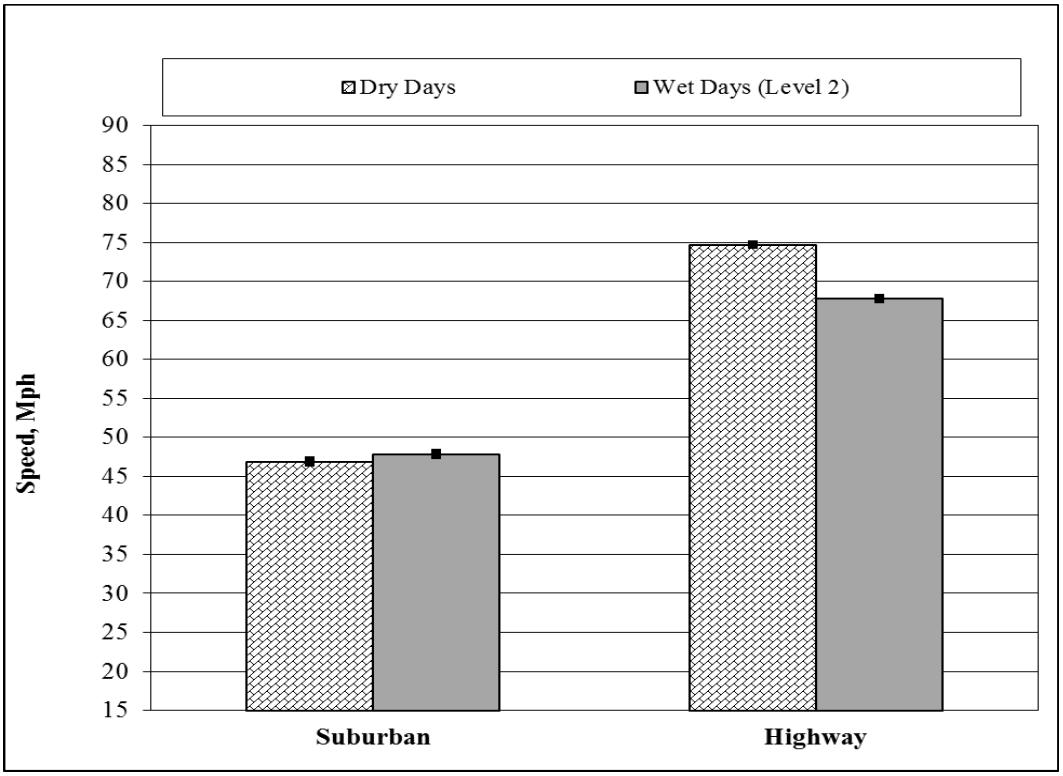

Figure E-29 Average speed during light rain condition with 95% confidence interval error bars for Participant 15

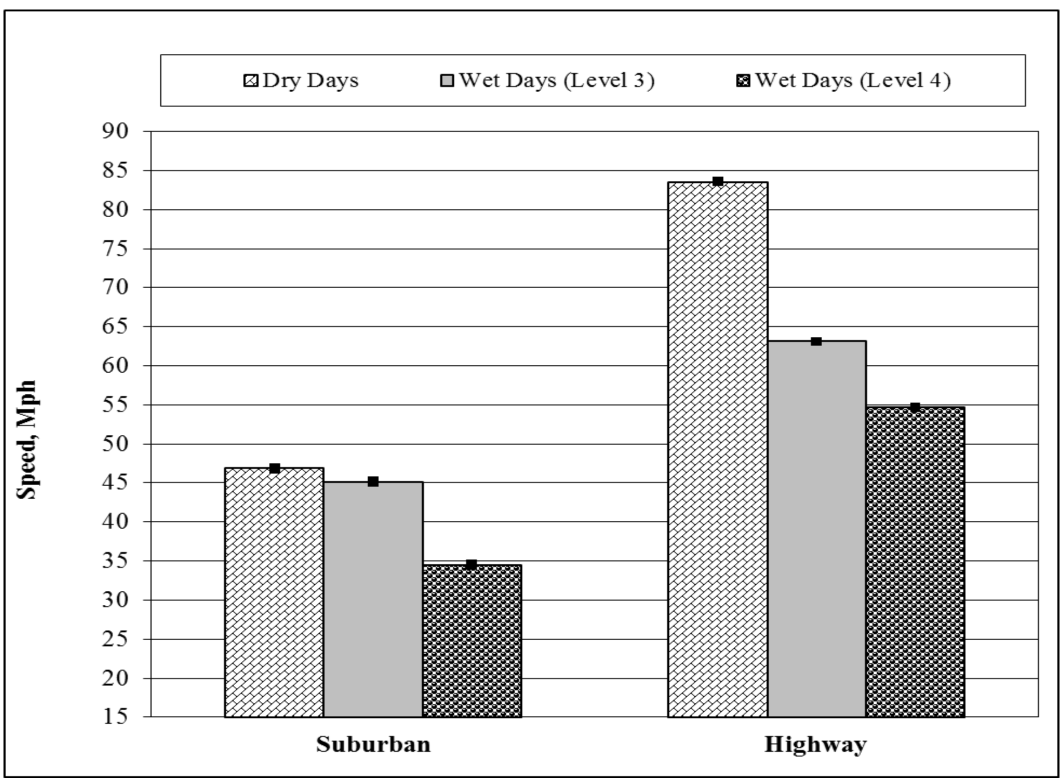

Figure E-30 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 15

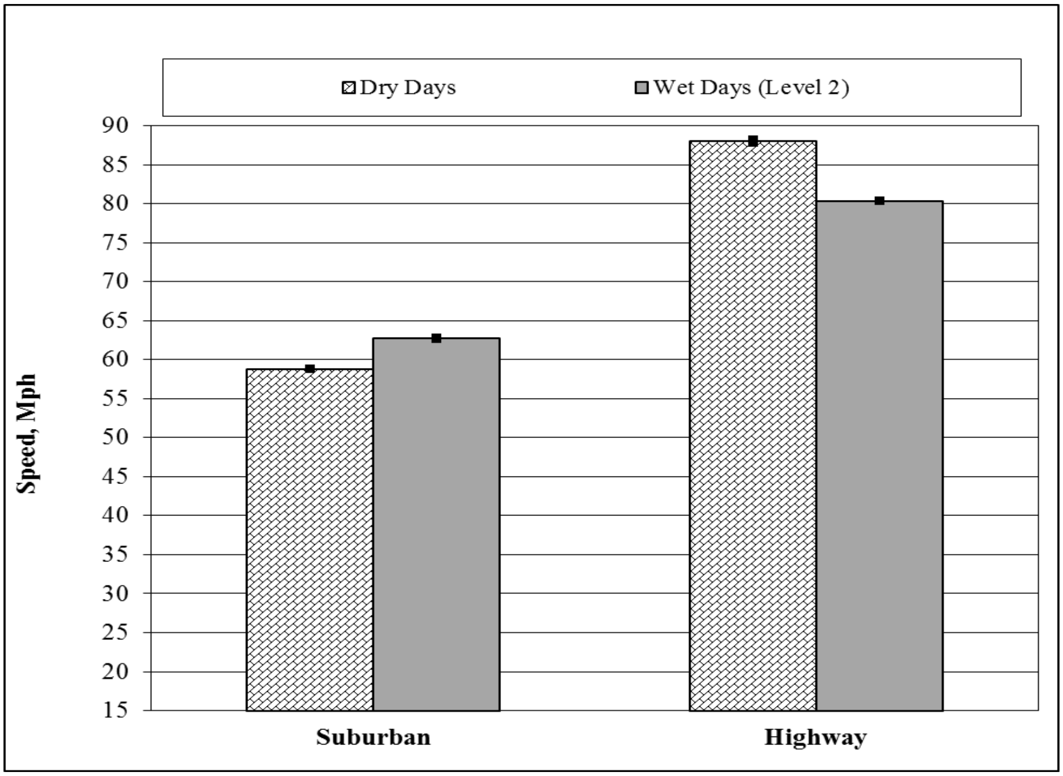

Figure E-31 Average speed during light rain condition with 95% confidence interval error bars for Participant 16

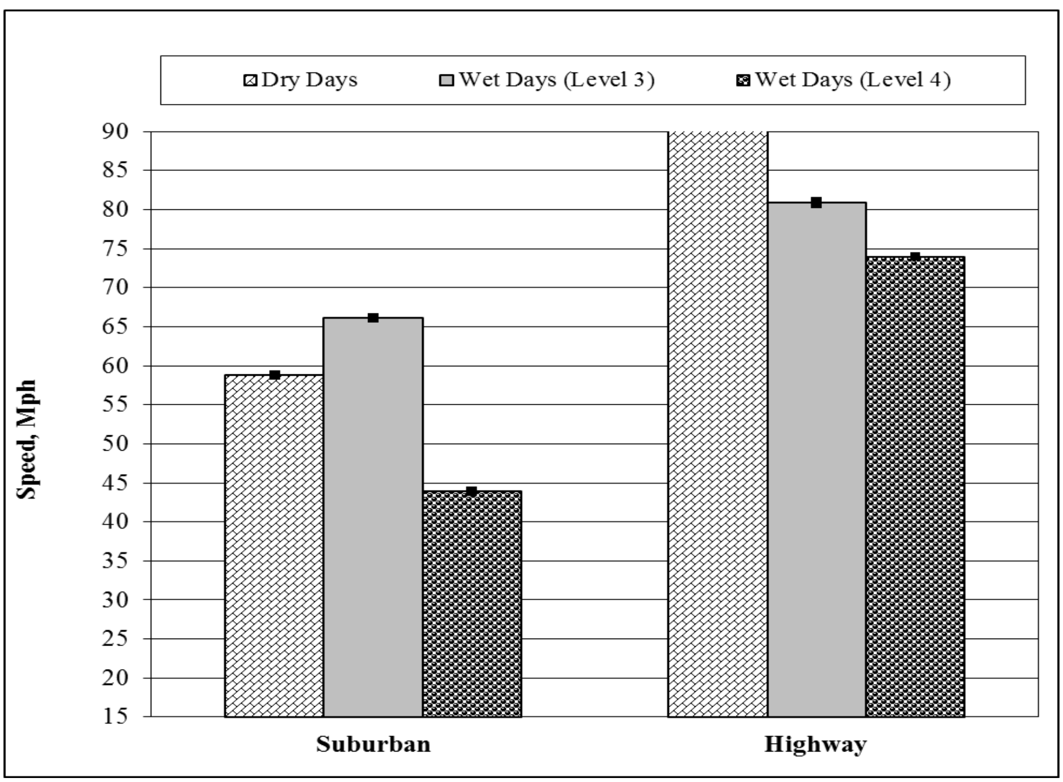

Figure E-32 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 16

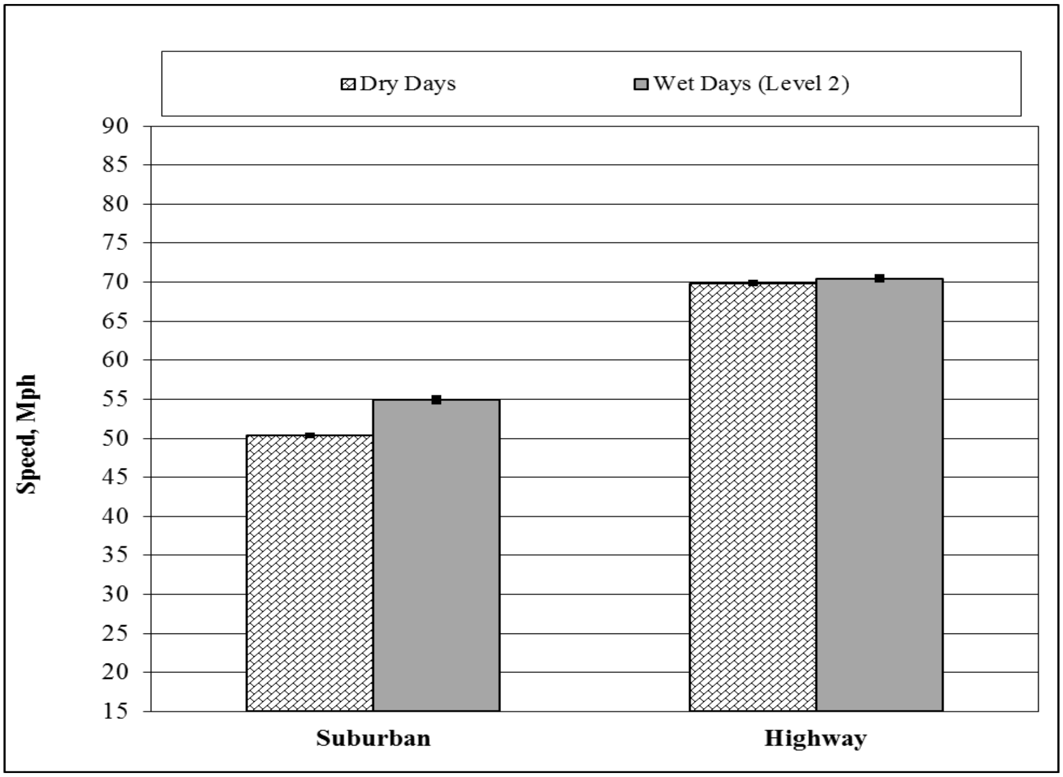

Figure E-33 Average speed during light rain condition with 95% confidence interval error bars for Participant 17

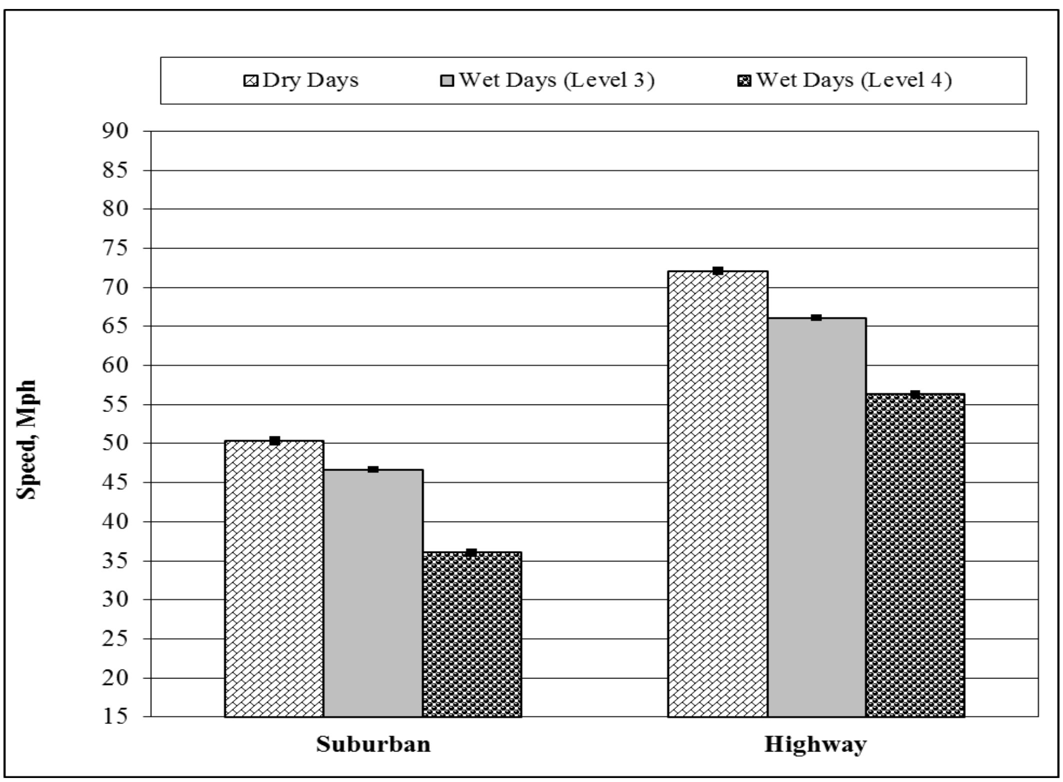

Figure E-34 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 17

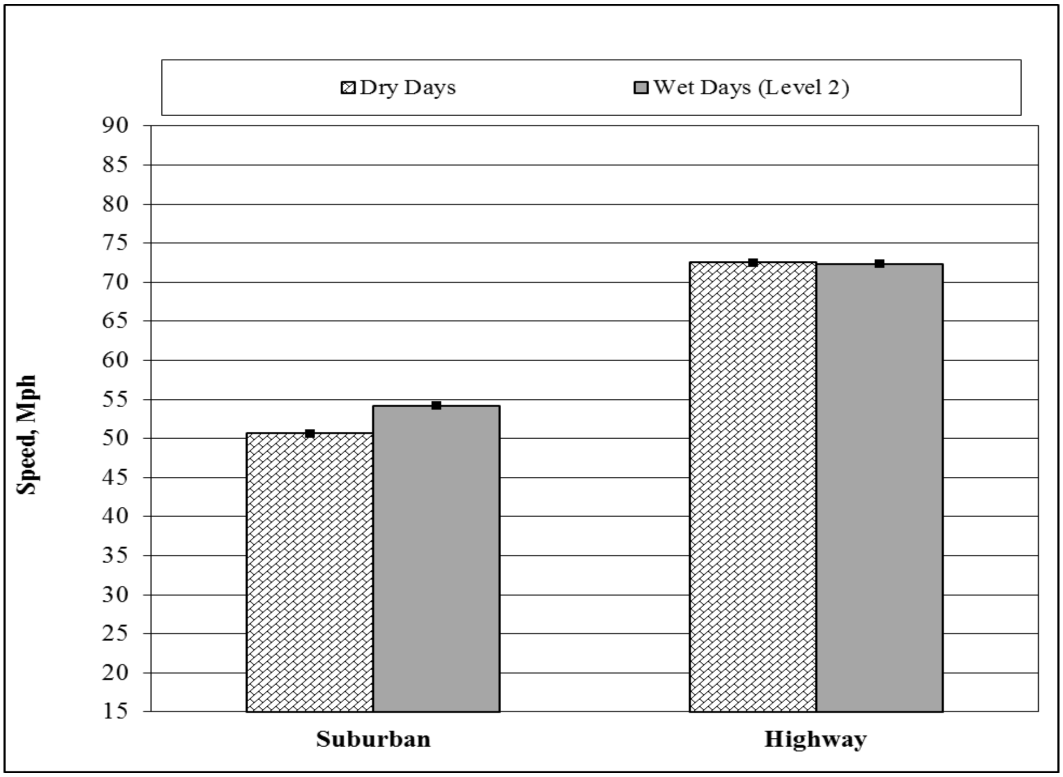

Figure E-35 Average speed during light rain condition with 95% confidence interval error bars for Participant 18

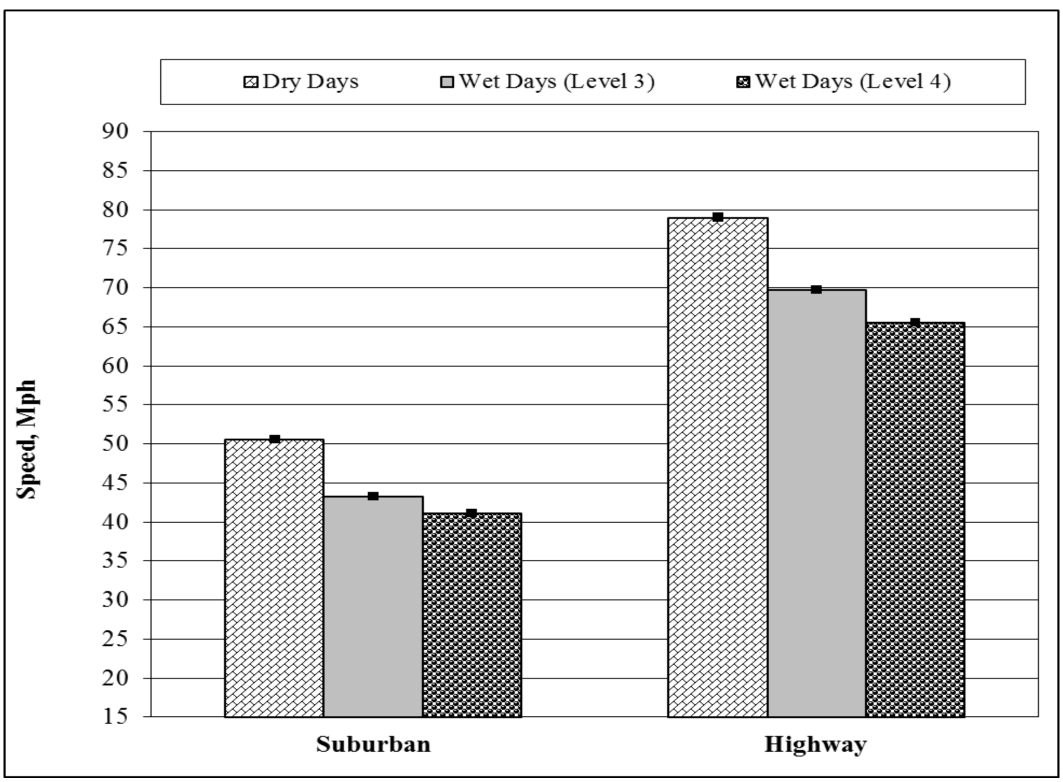

Figure E-36 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 18

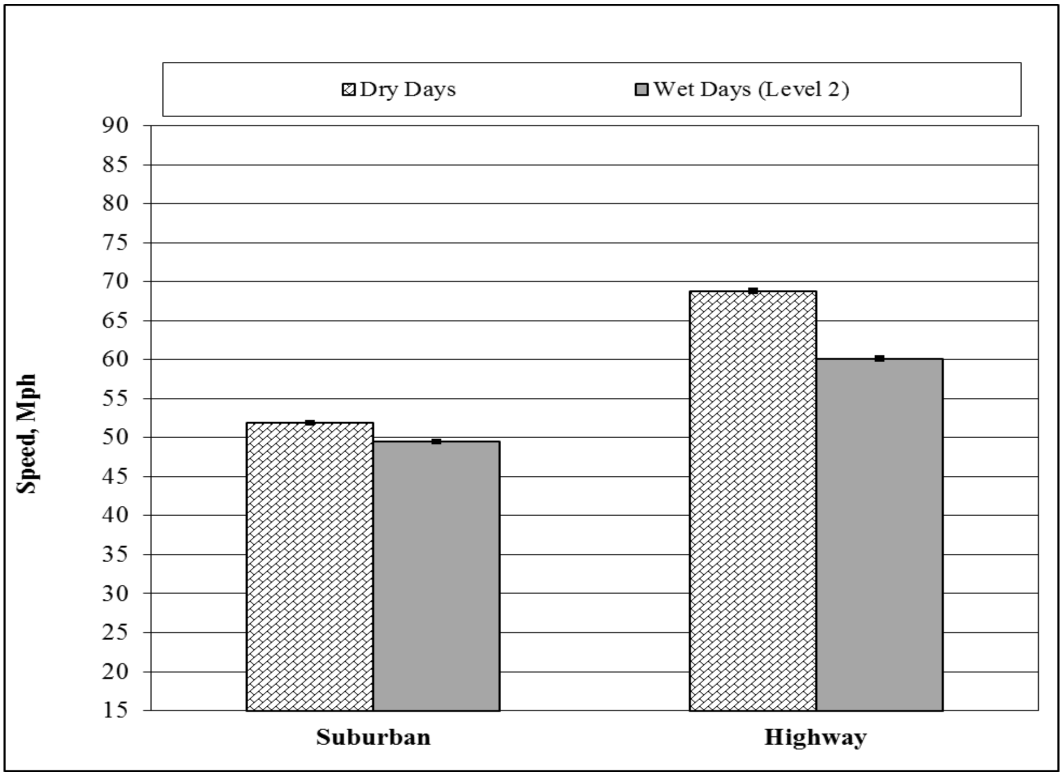

Figure E-37 Average speed during light rain condition with 95% confidence interval error bars for Participant 19

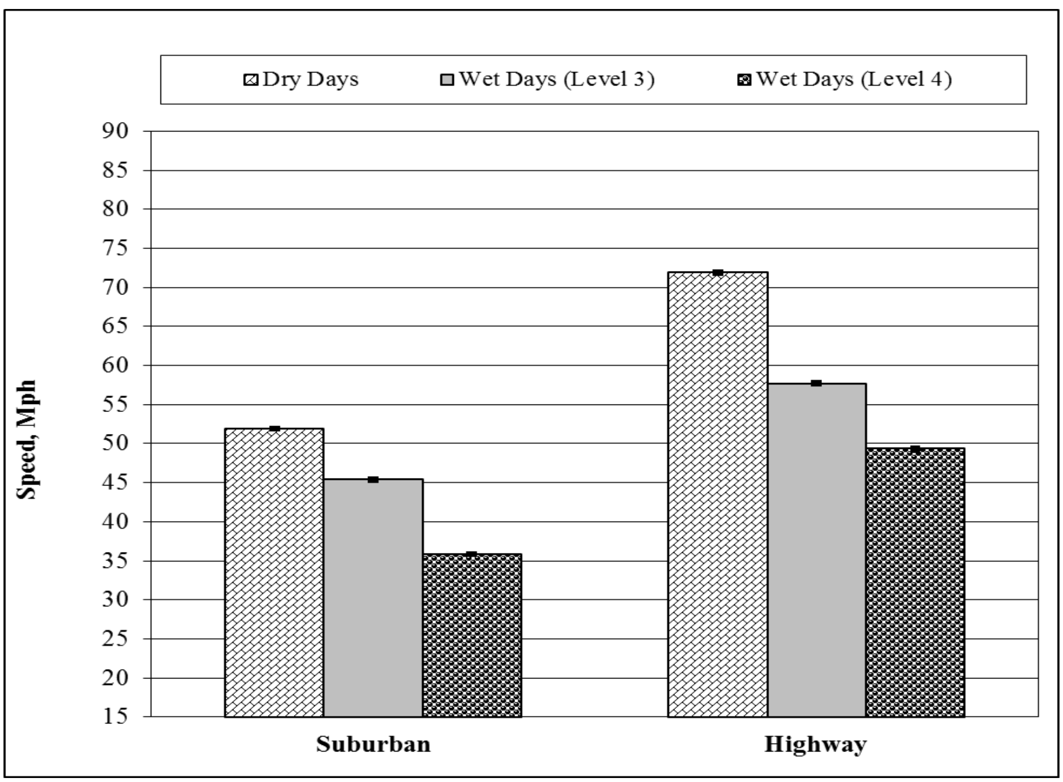

Figure E-38 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 19

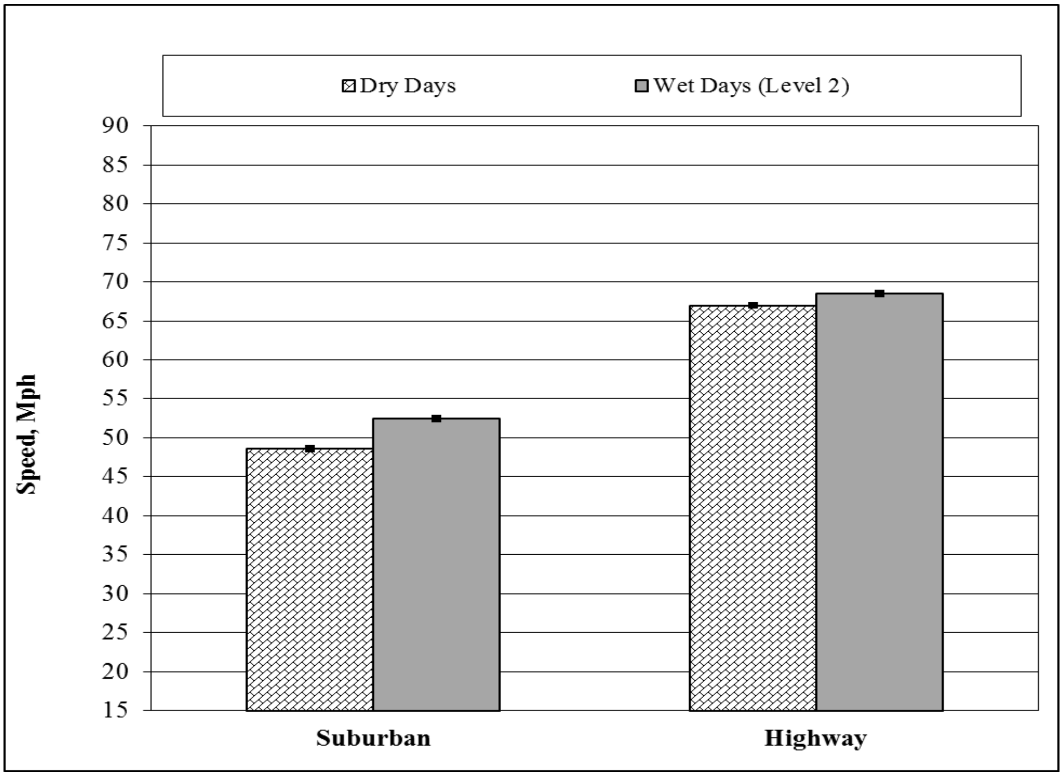

Figure E-39 Average speed during light rain condition with 95% confidence interval error bars for Participant 20

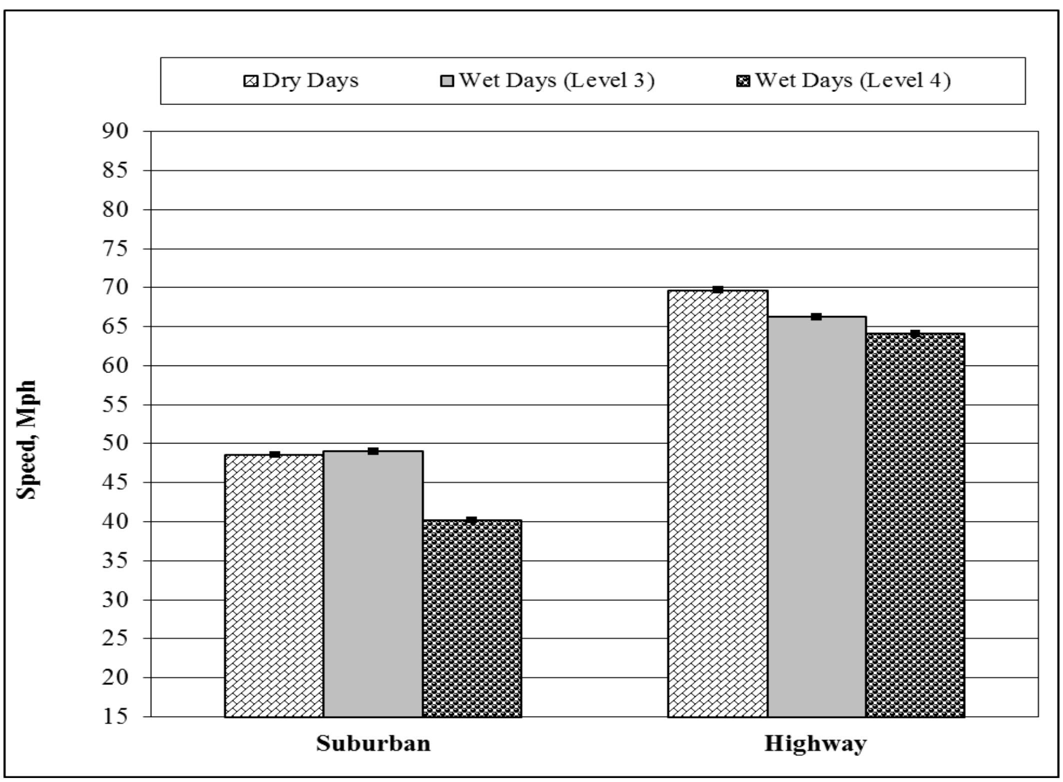

Figure E-40 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 20

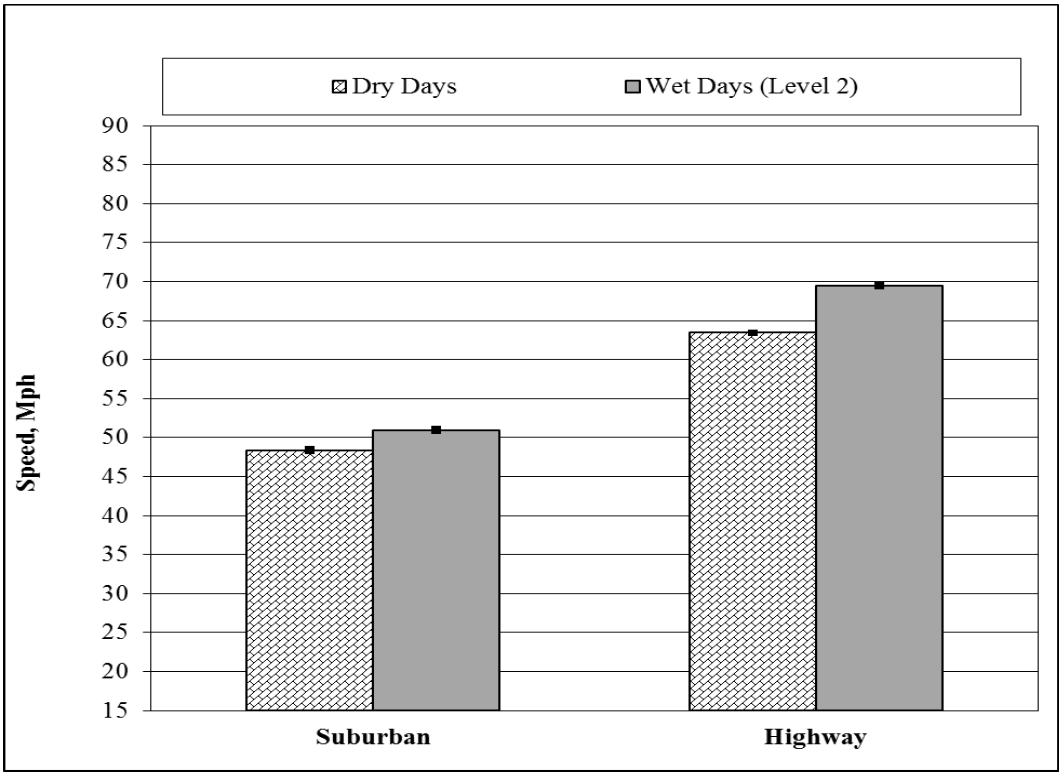

Figure E-41 Average speed during light rain condition with 95% confidence interval error bars for Participant 21

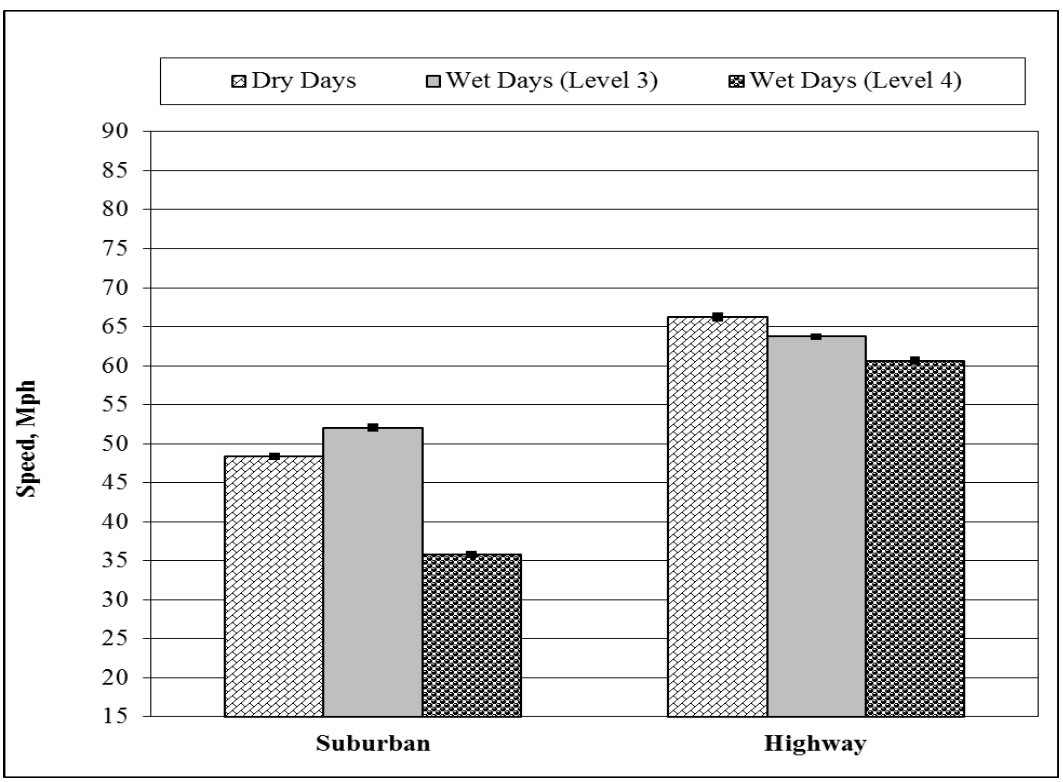

Figure E-42 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 21

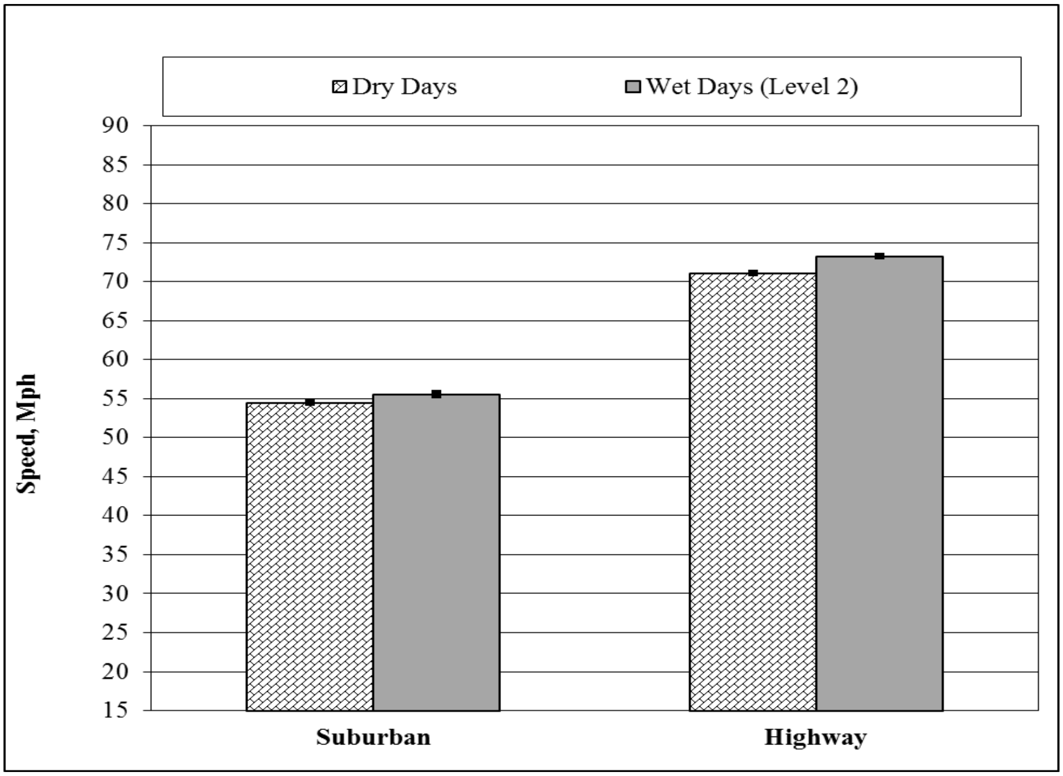

Figure E-43 Average speed during light rain condition with 95% confidence interval error bars for Participant 22

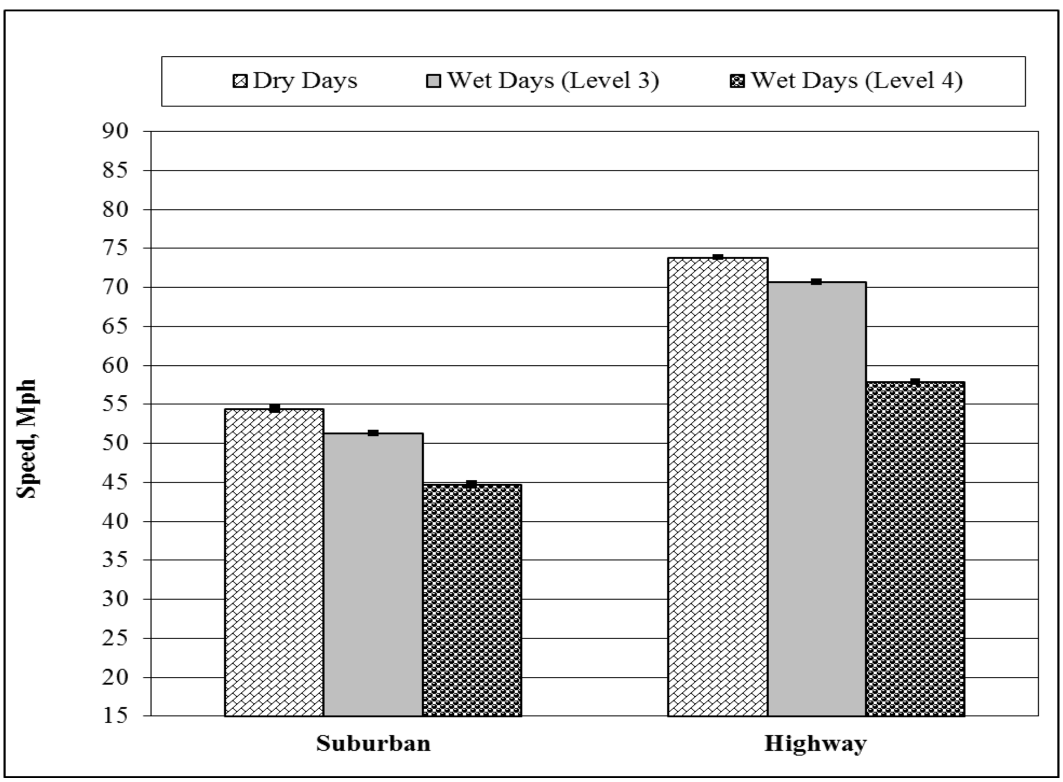

Figure E-44 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 22

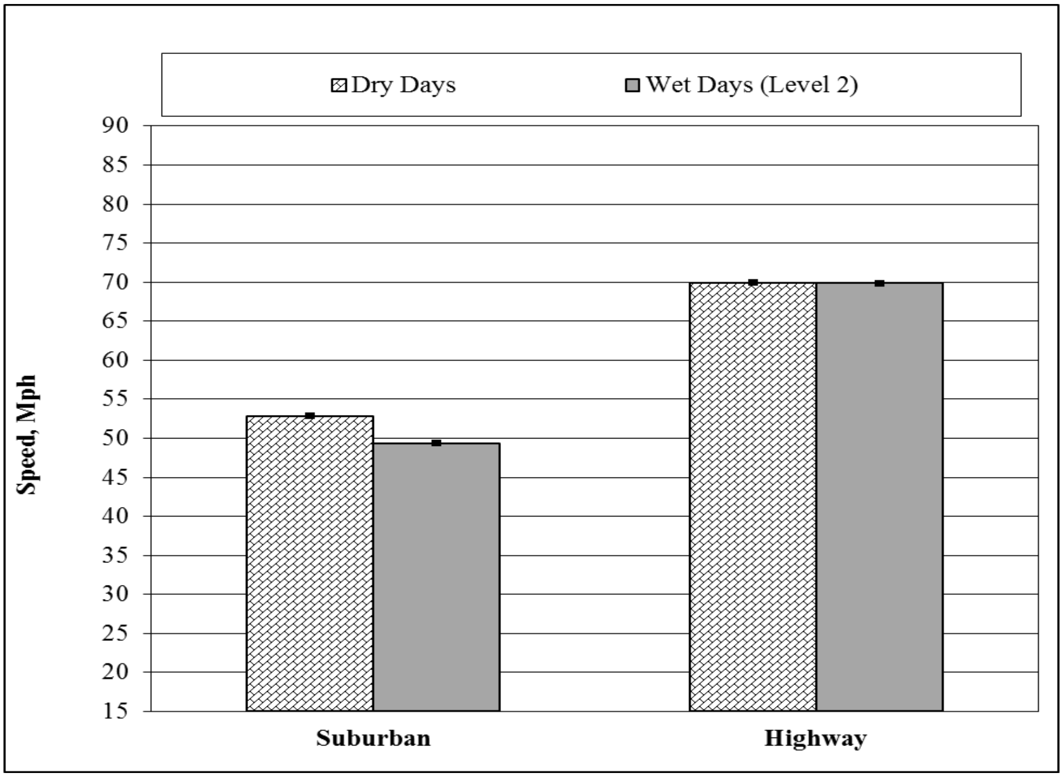

Figure E-45 Average speed during light rain condition with 95% confidence interval error bars for Participant 23

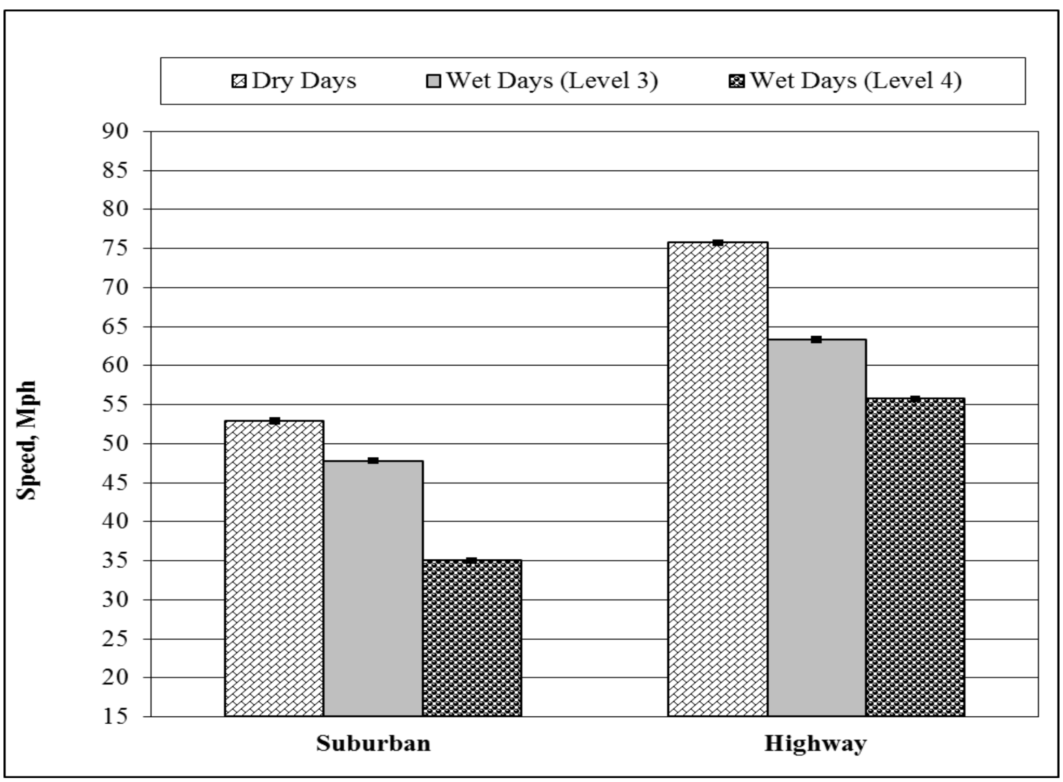

Figure E-46 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 23

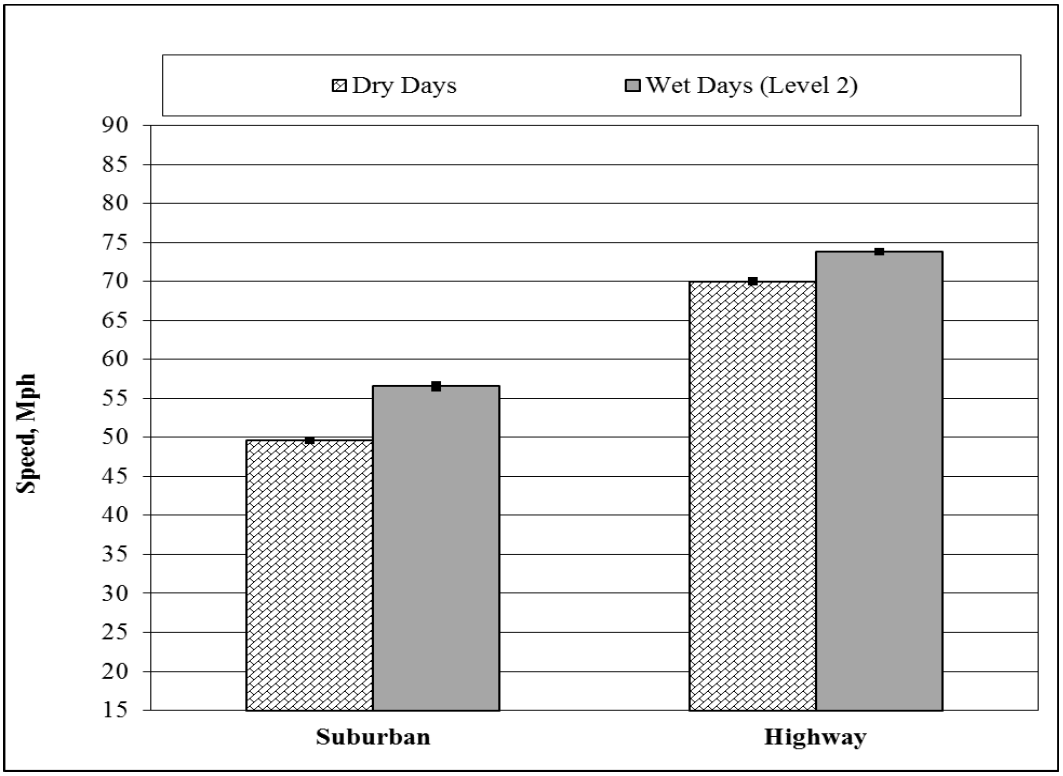

Figure E-47 Average speed during light rain condition with 95% confidence interval error bars for Participant 24

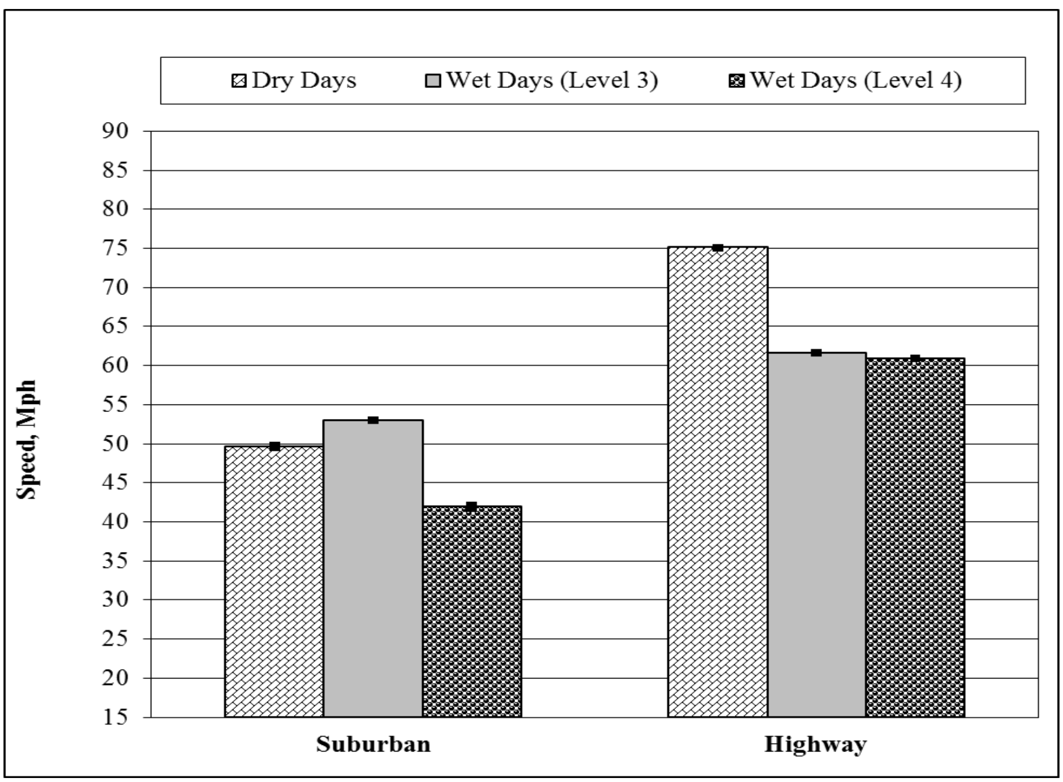

Figure E-48 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 24

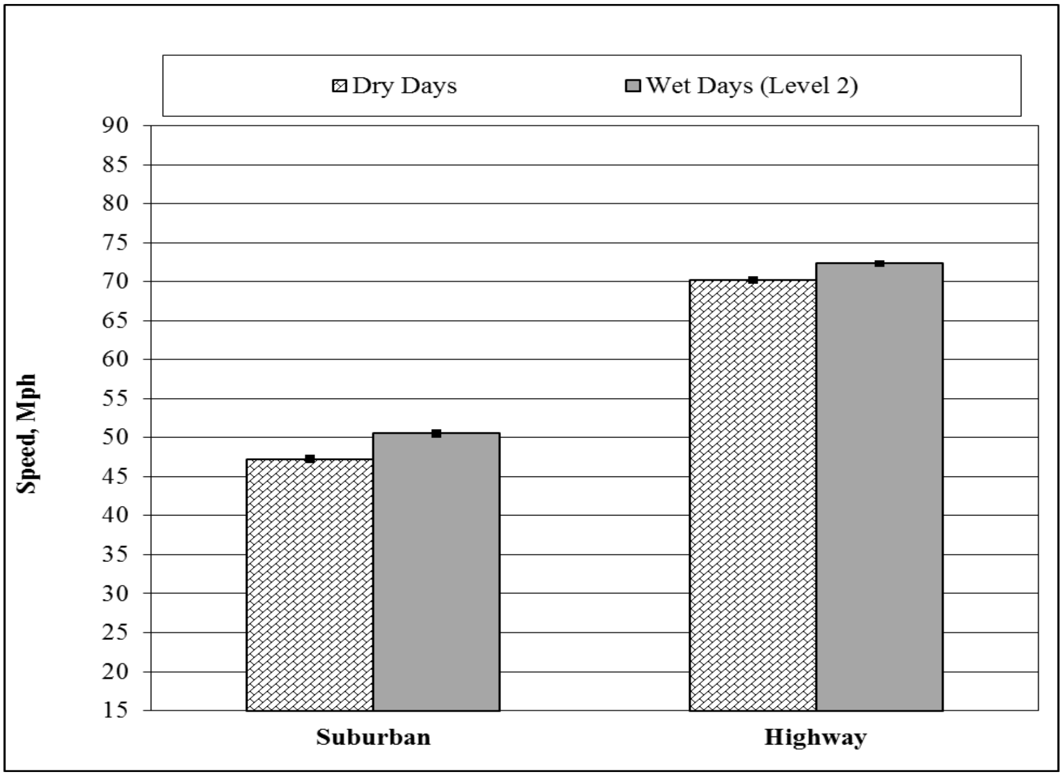

Figure E-49 Average speed during light rain condition with 95% confidence interval error bars for Participant 25

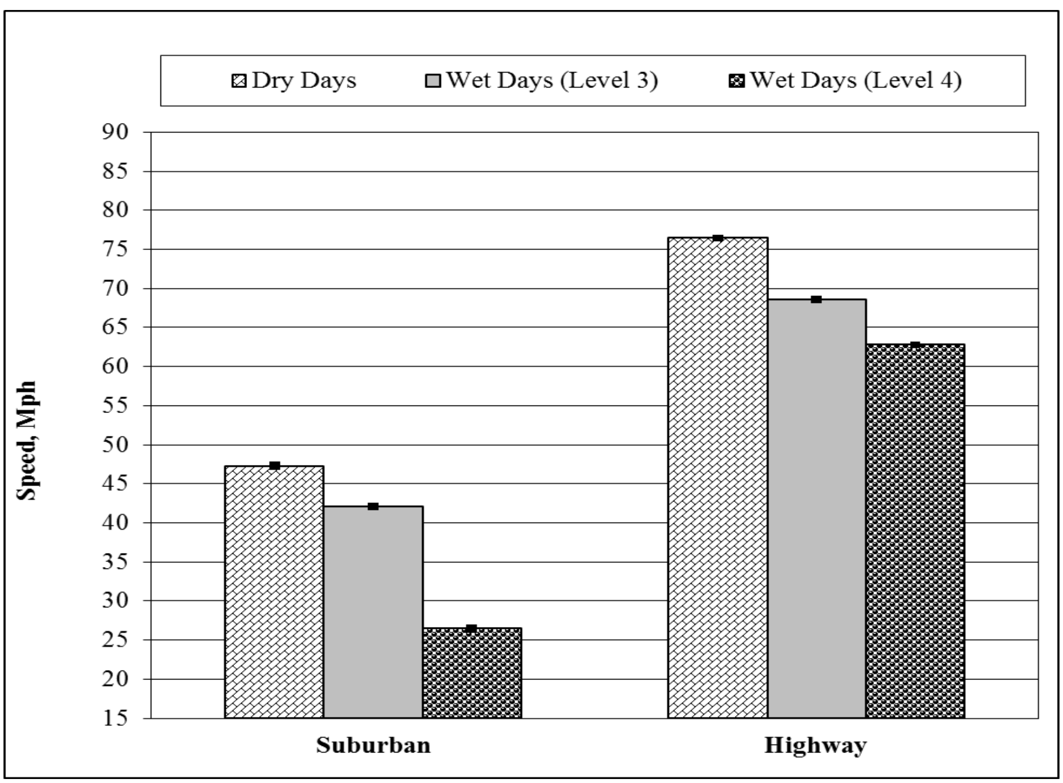

Figure E-50 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 25

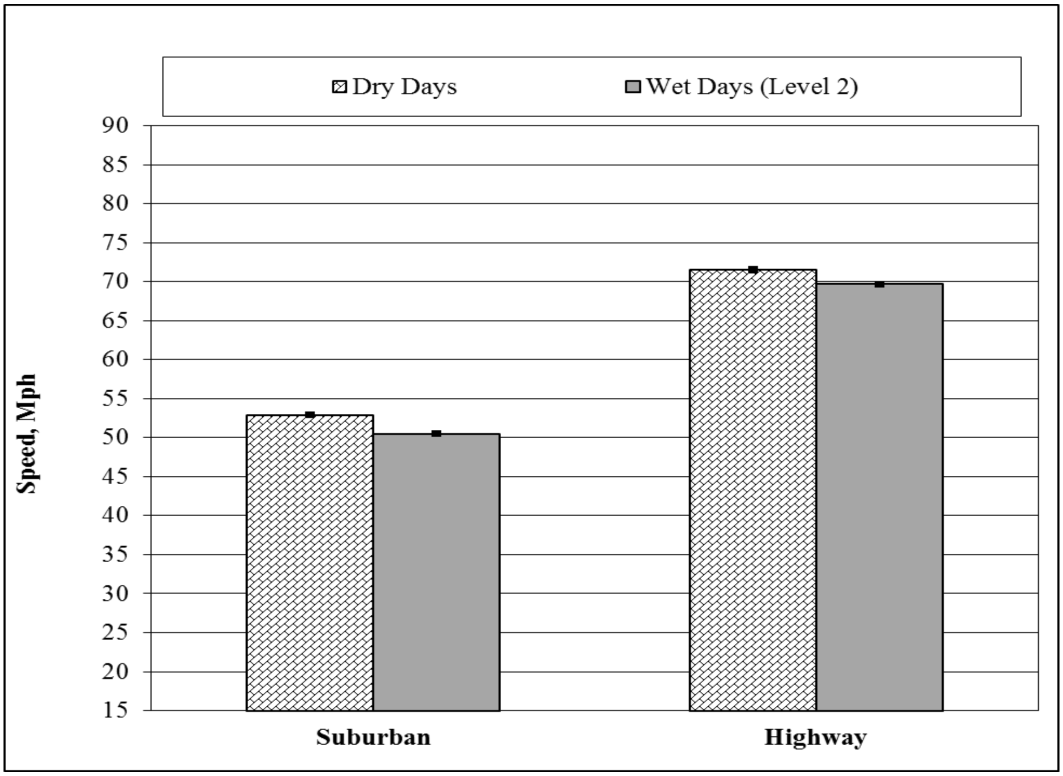

Figure E-51 Average speed during light rain condition with 95% confidence interval error bars for Participant 26

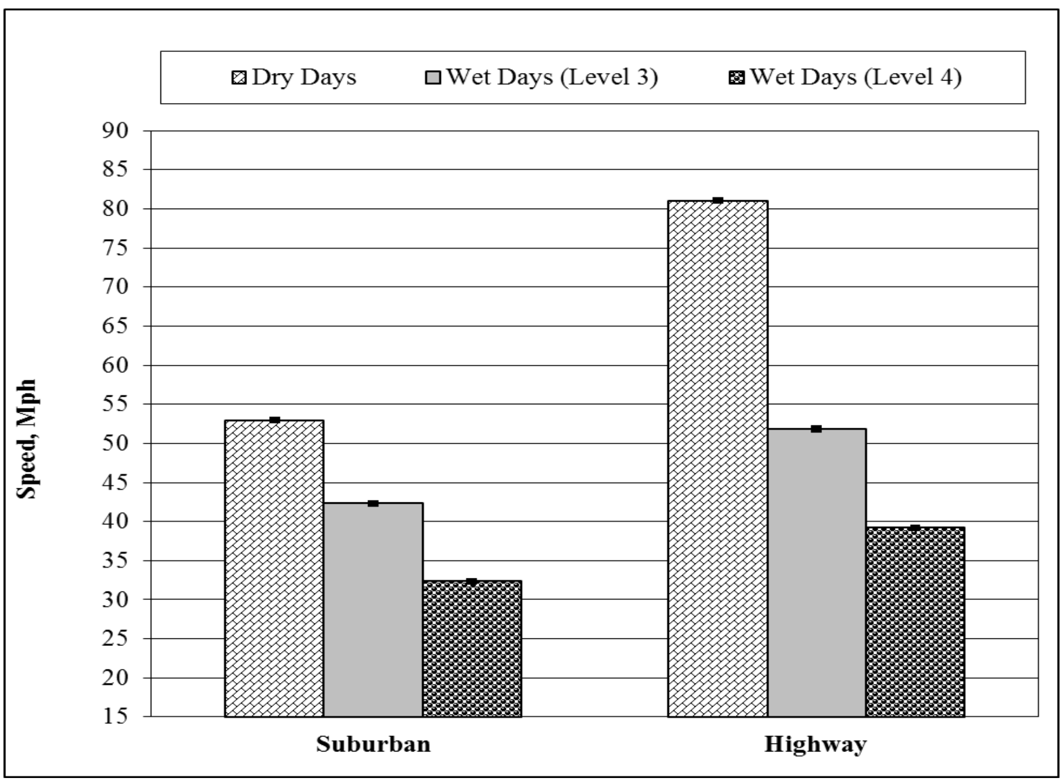

Figure E-52 Average speed during heavy rain conditions with 95% confidence interval error bars for Participant 26

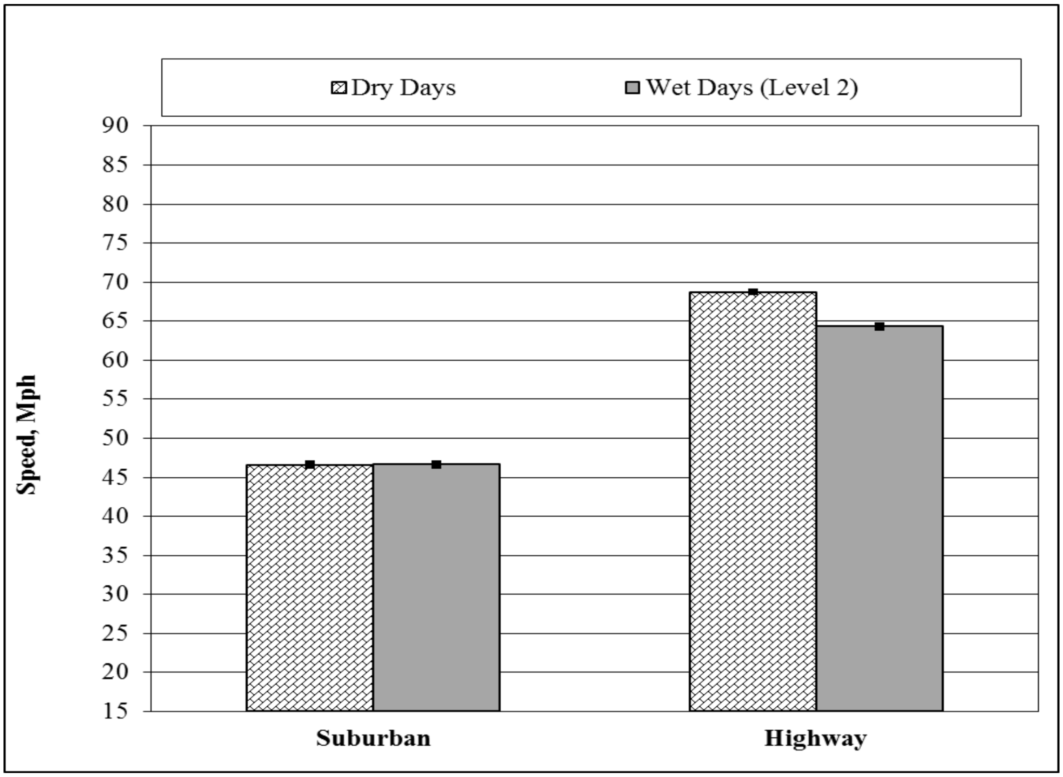

Figure E-53 Average speed during light rain condition with 95% confidence interval error bars for Participant 27

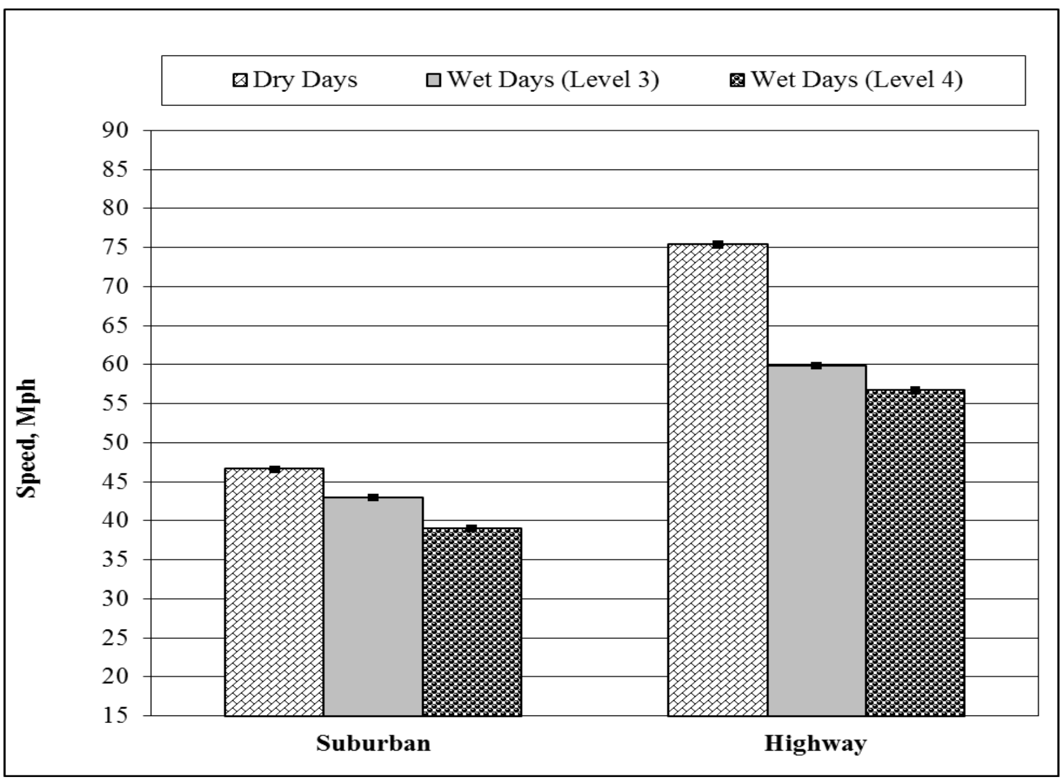

Figure E-54 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 27

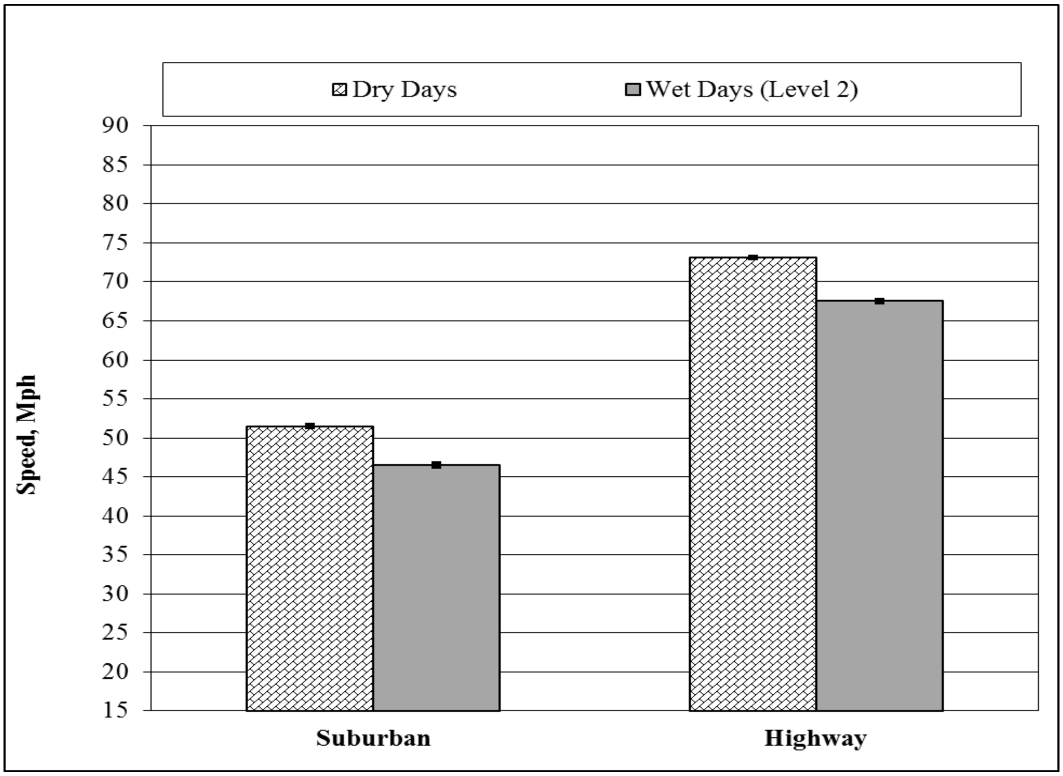

Figure E-55 Average speed during light rain condition with 95% confidence interval error bars for Participant 28

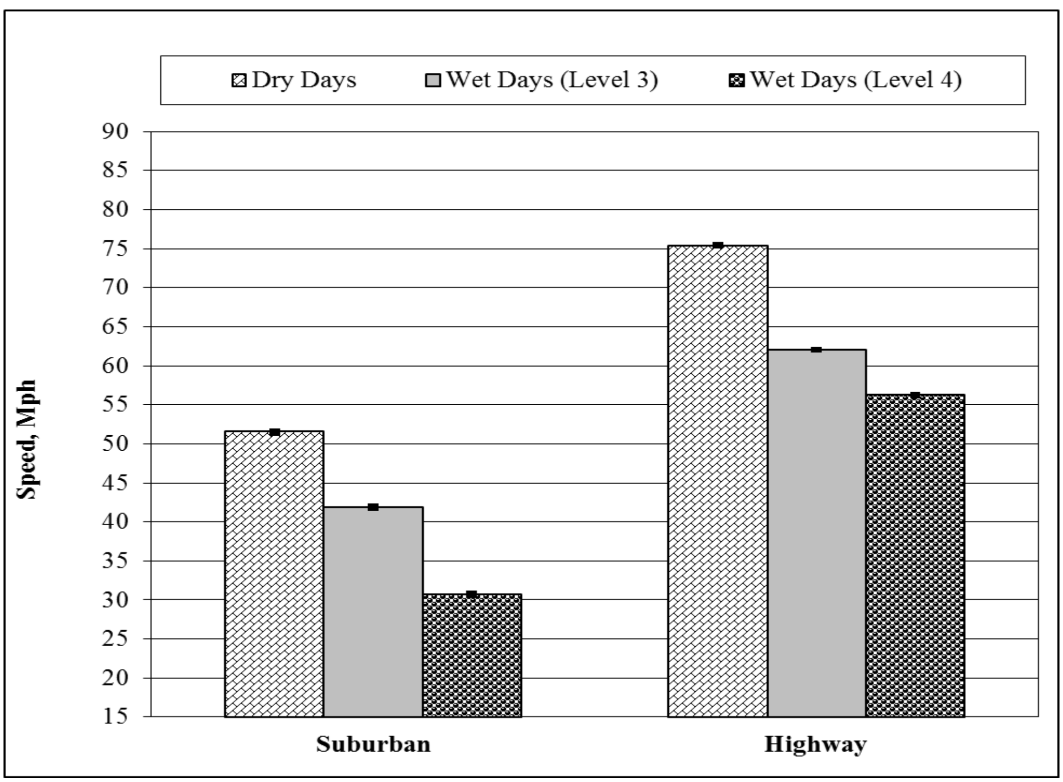

Figure E-56 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 28

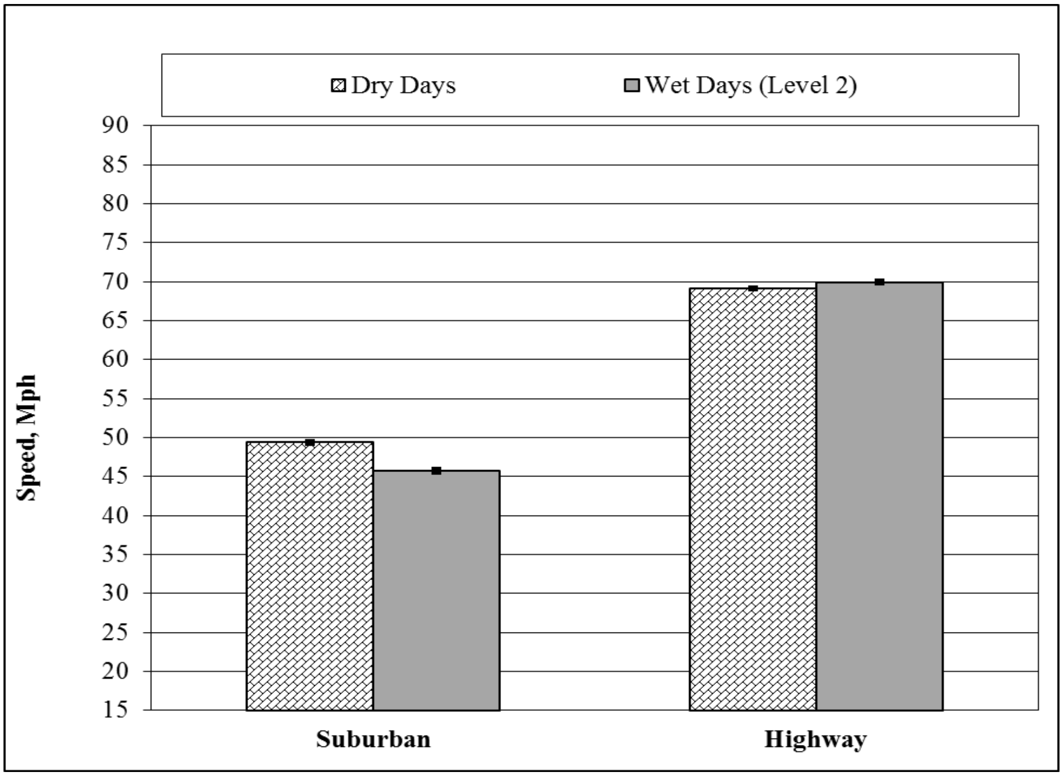

Figure E-57 Average speed during light rain condition with 95% confidence interval error bars for Participant 30

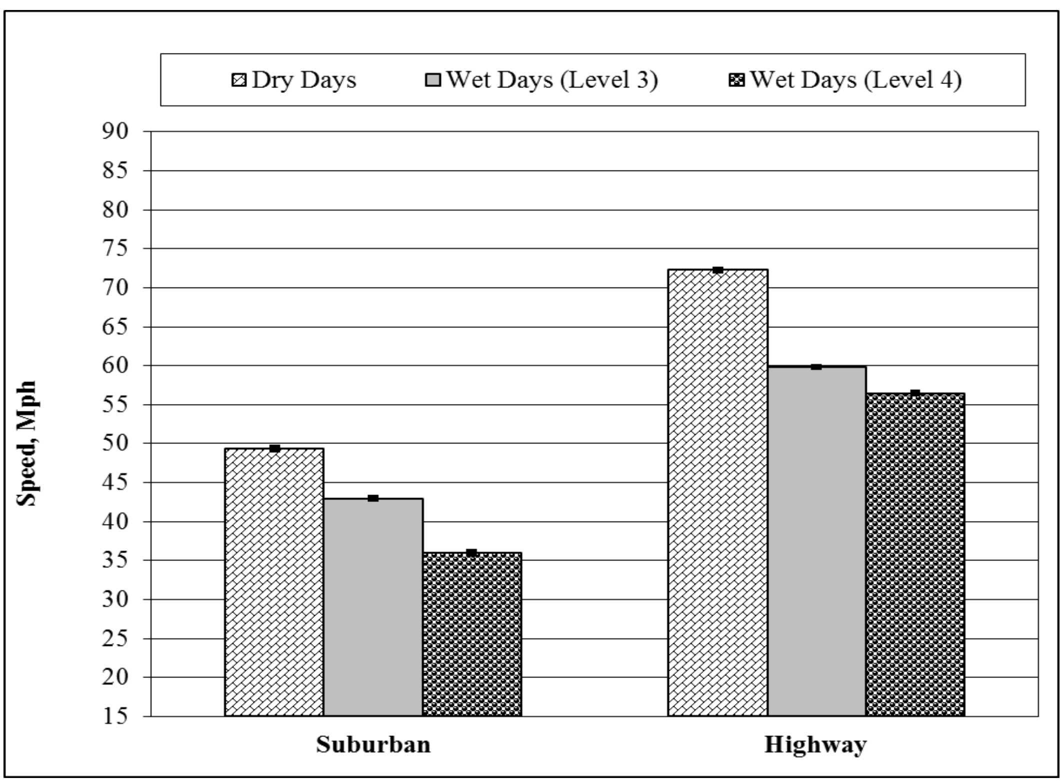

Figure E-58 Average speed during heavy rain condition with 95% confidence interval error bars for Participant 30

APPENDIX F
AVERAGE SPEED DATA USED FOR ANALYSIS OF RAINFALL CLASSIFICATION – AVERAGE OF ALL PARTICIPANTS

Table F-1 Speed (mph) data used for analysis of rainfall classification – Participant 1

		Dry	Level 2[a]	Level 3[b]	Level 4[b]
Suburban	Average	50	51	48	40
	Standard Deviation	3.608	2.755	6.813	2.605
	Minimum	40	44	31	33
	Maximum	54	54	54	44
Highway	Average	67	70	64	58
	Standard Deviation	1.002	2.372	1.759	4.450
	Minimum	64	68	61	51
	Maximum	68	79	68	65

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-2 Speed (mph) data used for analysis of rainfall classification – Participant 2

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	56	53	41	29
	Standard Deviation	2.638	1.934	4.292	2.462
	Minimum	48	47	33	25
	Maximum	59	56	47	37
Highway	Average	76	65	56	41
	Standard Deviation	5.024	1.692	5.480	14.114
	Minimum	67	63	44	26
	Maximum	83	67	64	66

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-3 Speed (mph) data used for analysis of rainfall classification – Participant 3

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	58	58	54	41
	Standard Deviation	3.884	1.586	5.533	1.948
	Minimum	47	53	40	39
	Maximum	62	59	59	55
Highway	Average	73	76	70	63
	Standard Deviation	4.019	4.107	3.681	7.174
	Minimum	66	73	61	50
	Maximum	80	88	75	75

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-4 Speed (mph) data used for analysis of rainfall classification – Participant 4

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	52	58	56	51
	Standard Deviation	5.028	2.464	6.533	7.085
	Minimum	41	55	43	34
	Maximum	58	62	65	61
Highway	Average	69	77	76	64
	Standard Deviation	5.767	0.729	0.483	8.599
	Minimum	59	74	76	48
	Maximum	76	78	77	75

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-5 Speed (mph) data used for analysis of rainfall classification – Participant 5

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	50	52	47	43
	Standard Deviation	2.661	3.592	3.302	4.203
	Minimum	41	41	39	35
	Maximum	53	56	53	48
Highway	Average	71	75	65	58
	Standard Deviation	2.346	2.557	2.412	6.334
	Minimum	66	70	61	47
	Maximum	74	81	70	68

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-6 Speed (mph) data used for analysis of rainfall classification – Participant 6

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	44	35	35	34
	Standard Deviation	4.437	4.141	2.868	2.088
	Minimum	34	28	27	28
	Maximum	49	41	39	37
Highway	Average	69	69	61	57
	Standard Deviation	2.231	2.350	3.532	4.446
	Minimum	62	65	56	51
	Maximum	71	73	68	65

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-7 Speed (mph) data used for analysis of rainfall classification – Participant 7

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	49	49	44	33
	Standard Deviation	4.267	2.831	6.044	1.942
	Minimum	37	44	33	30
	Maximum	55	54	52	38
Highway	Average	71	73	65	49
	Standard Deviation	3.158	4.702	4.371	8.996
	Minimum	62	67	57	39
	Maximum	75	84	75	73

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-8 Speed (mph) data used for analysis of rainfall classification – Participant 8

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	55	60	41	44
	Standard Deviation	3.475	7.690	2.086	5.082
	Minimum	46	44	37	33
	Maximum	58	69	44	51
Highway	Average	78	73	61	61
	Standard Deviation	3.575	3.806	5.253	7.076
	Minimum	69	68	50	49
	Maximum	81	79	68	74

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-9 Speed (mph) data used for analysis of rainfall classification – Participant 9

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	51	52	47	36
	Standard Deviation	4.330	2.555	4.119	2.175
	Minimum	39	47	35	33
	Maximum	56	57	51	39
Highway	Average	65	67	65	56
	Standard Deviation	2.885	3.284	0.973	4.398
	Minimum	58	59	63	49
	Maximum	69	71	67	63

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-10 Speed (mph) data used for analysis of rainfall classification – Participant 10

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	53	54	46	36
	Standard Deviation	5.069	4.619	7.647	2.100
	Minimum	39	39	29	31
	Maximum	58	58	55	39
Highway	Average	79	78	76	77
	Standard Deviation	0.304	1.094	0.050	0.839
	Minimum	78	76	76	76
	Maximum	80	80	76	78

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-11 Speed (mph) data used for analysis of rainfall classification – Participant 11

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	51	50	45	34
	Standard Deviation	3.194	5.917	5.102	3.383
	Minimum	41	36	37	27
	Maximum	54	56	53	38
Highway	Average	66	70	67	53
	Standard Deviation	1.297	5.141	3.440	4.855
	Minimum	62	64	61	45
	Maximum	68	83	71	61

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-12 Speed (mph) data used for analysis of rainfall classification – Participant 12

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	44	54	43	32
	Standard Deviation	3.600	1.071	2.513	2.167
	Minimum	38	50	37	29
	Maximum	52	56	46	37
Highway	Average	67	66	58	53
	Standard Deviation	1.988	2.696	3.057	6.464
	Minimum	62	61	50	40
	Maximum	71	72	62	63

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-13 Speed (mph) data used for analysis of rainfall classification – Participant 13

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	48	46	42	30
	Standard Deviation	4.509	3.307	4.232	2.183
	Minimum	33	36	32	26
	Maximum	54	51	48	35
Highway	Average	69	70	62	50
	Standard Deviation	2.240	1.186	2.846	10.726
	Minimum	64	68	56	35
	Maximum	72	73	68	71

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-14 Speed (mph) data used for analysis of rainfall classification – Participant 14

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	52	56	48	45
	Standard Deviation	5.803	4.011	6.557	3.477
	Minimum	40	45	35	38
	Maximum	61	59	57	50
Highway	Average	81	82	86	88
	Standard Deviation	1.826	2.285	0.441	1.638
	Minimum	77	79	85	85
	Maximum	84	88	87	90

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-15 Speed (mph) data used for analysis of rainfall classification – Participant 15

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	56	49	63	55
	Standard Deviation	6.103	6.842	6.430	7.785
	Minimum	43	32	51	40
	Maximum	66	56	71	68
Highway	Average	75	70	63	55
	Standard Deviation	4.848	5.216	6.430	7.785
	Minimum	65	64	51	40
	Maximum	84	83	71	68

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-16 Speed (mph) data used for analysis of rainfall classification – Participant 16

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	59	55	66	44
	Standard Deviation	7.842	4.876	8.118	2.768
	Minimum	43	48	48	38
	Maximum	70	64	74	47
Highway	Average	88	78	81	74
	Standard Deviation	3.341	3.690	0.710	2.955
	Minimum	84	72	80	69
	Maximum	94	88	82	78

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-17 Speed (mph) data used for analysis of rainfall classification – Participant 17

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	50	55	47	36
	Standard Deviation	2.741	3.767	5.810	2.879
	Minimum	43	45	32	29
	Maximum	54	61	53	40
Highway	Average	70	71	66	56
	Standard Deviation	1.257	4.283	1.439	5.406
	Minimum	67	67	61	47
	Maximum	72	80	67	65

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-18 Speed (mph) data used for analysis of rainfall classification – Participant 18

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	51	58	43	41
	Standard Deviation	3.701	3.772	6.281	3.367
	Minimum	42	49	29	33
	Maximum	56	62	51	45
Highway	Average	73	71	70	66
	Standard Deviation	2.809	4.979	1.502	6.559
	Minimum	69	60	65	54
	Maximum	79	78	71	76

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-19 Speed (mph) data used for analysis of rainfall classification – Participant 19

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	52	50	45	36
	Standard Deviation	3.145	0.683	5.220	2.246
	Minimum	45	47	32	33
	Maximum	55	52	51	40
Highway	Average	69	59	58	49
	Standard Deviation	2.676	2.286	1.878	4.538
	Minimum	63	55	52	44
	Maximum	72	62	59	59

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-20 Speed (mph) data used for analysis of rainfall classification – Participant 20

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	49	52	49	40
	Standard Deviation	3.845	2.314	3.937	3.538
	Minimum	37	45	36	33
	Maximum	52	56	53	44
Highway	Average	67	68	66	64
	Standard Deviation	2.156	2.566	3.666	4.982
	Minimum	61	65	60	56
	Maximum	70	77	71	72

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-21 Speed (mph) data used for analysis of rainfall classification – Participant 21

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	48	53	52	36
	Standard Deviation	4.002	3.472	5.061	3.184
	Minimum	37	40	38	29
	Maximum	53	59	59	40
Highway	Average	63	71	64	61
	Standard Deviation	1.628	4.747	1.218	4.416
	Minimum	59	65	62	54
	Maximum	66	81	66	69

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-22 Speed (mph) data used for analysis of rainfall classification – Participant 22

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	55	54	51	45
	Standard Deviation	3.501	3.532	5.658	1.653
	Minimum	46	45	38	39
	Maximum	58	60	59	47
Highway	Average	71	73	71	58
	Standard Deviation	1.718	1.051	2.365	4.657
	Minimum	68	72	66	49
	Maximum	74	76	73	65

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-23 Speed (mph) data used for analysis of rainfall classification – Participant 23

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	53	49	48	35
	Standard Deviation	3.097	2.020	3.152	3.309
	Minimum	44	46	39	28
	Maximum	57	53	51	40
Highway	Average	70	70	63	56
	Standard Deviation	3.063	1.206	4.051	5.230
	Minimum	63	69	56	47
	Maximum	76	73	69	65

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-24 Speed (mph) data used for analysis of rainfall classification – Participant 24

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	50	57	53	42
	Standard Deviation	3.444	5.909	4.218	2.034
	Minimum	41	42	42	38
	Maximum	54	66	57	46
Highway	Average	70	73	62	61
	Standard Deviation	5.440	2.542	7.572	8.059
	Minimum	59	67	49	45
	Maximum	75	77	72	73

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-25 Speed (mph) data used for analysis of rainfall classification – Participant 25

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	47	52	42	26
	Standard Deviation	4.333	3.836	5.247	1.309
	Minimum	37	41	28	24
	Maximum	55	57	48	29
Highway	Average	70	71	69	63
	Standard Deviation	2.957	1.619	1.786	5.980
	Minimum	66	70	65	53
	Maximum	76	75	71	73

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-26 Speed (mph) data used for analysis of rainfall classification – Participant 26

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	53	55	42	32
	Standard Deviation	2.635	1.220	2.317	2.332
	Minimum	45	50	36	28
	Maximum	56	57	46	37
Highway	Average	72	75	52	39
	Standard Deviation	6.802	1.395	12.384	6.689
	Minimum	61	71	35	34
	Maximum	81	78	70	62

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-27 Speed (mph) data used for analysis of rainfall classification – Participant 27

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	47	45	43	39
	Standard Deviation	5.452	3.066	1.807	2.127
	Minimum	33	37	38	36
	Maximum	53	51	46	44
Highway	Average	69	64	60	57
	Standard Deviation	5.540	4.795	2.591	3.798
	Minimum	59	56	53	51
	Maximum	75	75	63	65

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall

[c] Level 4 = Heaviest Rainfall

Table F-28 Speed (mph) data used for analysis of rainfall classification – Participant 28

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	52	47	42	31
	Standard Deviation	3.678	2.394	2.024	2.792
	Minimum	42	39	37	25
	Maximum	56	49	45	37
Highway	Average	73	69	62	56
	Standard Deviation	1.997	1.646	4.094	5.803
	Minimum	68	67	53	48
	Maximum	75	75	69	67

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

Table F-30 Speed (mph) data used for analysis of rainfall classification – Participant 30

		Baseline	Level 2	Level 3	Level 4
Suburban	Average	49	44	43	36
	Standard Deviation	4.027	2.640	3.754	1.961
	Minimum	38	36	33	31
	Maximum	54	49	47	38
Highway	Average	69	70	60	56
	Standard Deviation	2.679	1.302	7.915	7.809
	Minimum	62	67	44	45
	Maximum	72	72	69	73

Note:
[a] Level 2 = Light Rainfall
[b] Level 3 = Heavy Rainfall
[c] Level 4 = Heaviest Rainfall

APPENDIX G
SURVEY RESPONSE FROM THE RESEARCH PARTICIPANTS

Driver Demographics Form
Driver # 1
Date: 3 /22/ 12

Please provide the following information:

1. Sex:
☑ Female ☐ Male

2. Age:
☑ 16-21 ☐ 22-27 ☐ 28-33
☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 2
4. Approximate number of miles you drive in typical week: 30
5. How many years have you had your driver's license? 1 year
6. How long have you been driving in Florida? 1 year
7. Do you reduce your speed when driving in rain fall conditions? ☑ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☑ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☐ Yes ☑ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: ________

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 4
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) No
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
Yes , Yes .

Thank you for your time.

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Driver Demographics Form
Driver # 2
Date: 3 /22/ 12

Please provide the following information:

1. Sex:
   ☒ Female ☐ Male
2. Age:
   ☒ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over
3. Approximate number of hours you spend driving in typical week: 10
4. Approximate number of miles you drive in typical week: 30
5. How many years have you had your driver's license? 3
6. How long have you been driving in Florida? 4 years
7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☐ Yes ☒ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: ________

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (*1: very unrealistic*, *2: unrealistic*, *3: realistic*, 4: *very realistic*) 3
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (*1: not affected*, 2: *slightly affected*, *3: affected*, *4: greatly affected*) 4
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (*1: very different*, *2: different*, *3: close*, *4: very close*) 3
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) A bit of nausea & Dizziness
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

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Driver Demographics Form
Driver # 3
Date: 3/22/2012

Please provide the following information:

1. Sex:
   ☐ Female ☑ Male

2. Age:
   ☑ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 0

4. Approximate number of miles you drive in typical week: 0

5. How many years have you had your driver's license? 4 years

6. How long have you been driving in Florida? 2.5 years

7. Do you reduce your speed when driving in rain fall conditions? ☑ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☑ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☑ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 3

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 1

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) No

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    Yes, Yes.

Thank you for your time.

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Driver Demographics Form

Driver # 4

Date: 3.22/12

Please provide the following information:

1. Sex:
   ☑ Female ☐ Male

2. Age:
   ☑ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 5

4. Approximate number of miles you drive in typical week: 100

5. How many years have you had your driver's license? 1

6. How long have you been driving in Florida? 1 yr

7. Do you reduce your speed when driving in rain fall conditions? ☑ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☑ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☐ Yes ☑ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: _______

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic, 2: unrealistic, 3: realistic, 4: very realistic***) 3

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected, 2: slightly affected, 3: affected, 4: greatly affected***) 3

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different, 2: different, 3: close, 4: very close***) 3

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) _______

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes

Thank you for your time.

Page 1 of 1

Driver Demographics Form
Driver # 5
Date: 3 / 23 / 12

Please provide the following information:

1. Sex:
   ☐ Female ☒ Male

2. Age:
   ☐ 16-21 ☒ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 5
4. Approximate number of miles you drive in typical week: 100
5. How many years have you had your driver's license? 10
6. How long have you been driving in Florida? 10 years
7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 2

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 2
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) No
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

Page **1** of **1**

Driver Demographics Form
Driver # 6
Date: 3 /23/ 12

Please provide the following information:

1. Sex:
   ☒ Female ☐ Male
2. Age:
   ☐ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☒ 40-45 ☐ 46 and over
3. Approximate number of hours you spend driving in typical week: 10
4. Approximate number of miles you drive in typical week: 60
5. How many years have you had your driver's license? 30
6. How long have you been driving in Florida? Since 85
7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: Many Times

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 2
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) No
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    Yes , Yes.

Thank you for your time.

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Driver Demographics Form
Driver # 7
Date: 3 / 23 / 12

Please provide the following information:

1. Sex:
   ☒ Female ☐ Male

2. Age:
   ☐ 16-21 ☒ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 1 1/2
4. Approximate number of miles you drive in typical week: 35
5. How many years have you had your driver's license? 6
6. How long have you been driving in Florida? 6 yrs
7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☐ Yes ☒ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: /

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) yes dizziness, nausea, cold sweat
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

Page **1** of **1**

Driver Demographics Form
Driver # 8
Date: 3/23/12

Please provide the following information:

1. Sex:
   ☒ Female ☐ Male
2. Age:
   ☒ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over
3. Approximate number of hours you spend driving in typical week: 2
4. Approximate number of miles you drive in typical week: 80
5. How many years have you had your driver's license? 4
6. How long have you been driving in Florida? 4
7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 3

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 2
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 2
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) a little dizziness
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

Page **1** of **1**

Driver Demographics Form
Driver # 9
Date: 3 /26/ 12

Please provide the following information:

1. Sex:
   [x] Female [ ] Male

2. Age:
   [x] 16-21 [ ] 22-27 [ ] 28-33
   [ ] 34-39 [ ] 40-45 [ ] 46 and over

3. Approximate number of hours you spend driving in typical week: [redacted] 10-15

4. Approximate number of miles you drive in typical week: 40

5. How many years have you had your driver's license? 3

6. How long have you been driving in Florida? 3

7. Do you reduce your speed when driving in rain fall conditions? [x] Yes [ ] No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? [x] Yes [ ] No

9. Have you ever experience hydroplaning condition? [ ] Yes [x] No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: ________

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 2

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) NO

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    Yes, Yes.

Thank you for your time.

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Driver Demographics Form
Driver # 10
Date: 3 / 27 / 12

Please provide the following information:

1. Sex:
   - [ ] Female [x] Male
2. Age:
   - [ ] 16-21 [x] 22-27 [ ] 28-33
   - [ ] 34-39 [ ] 40-45 [ ] 46 and over
3. Approximate number of hours you spend driving in typical week: ~~8~~ 7
4. Approximate number of miles you drive in typical week: 25
5. How many years have you had your driver's license? 7
6. How long have you been driving in Florida? 7
7. Do you reduce your speed when driving in rain fall conditions? [x] Yes [ ] No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? [x] Yes [ ] No
9. Have you ever experience hydroplaning condition? [x] Yes [ ] No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 5

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 2
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) No
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    Yes , Yes .

Thank you for your time.

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Driver Demographics Form
Driver # 11
Date: 3/28/12

Please provide the following information:

1. Sex:
   ☒ Female ☐ Male

2. Age:
   ☐ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☒ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 4

4. Approximate number of miles you drive in typical week: 100

5. How many years have you had your driver's license? 25years

6. How long have you been driving in Florida? 10years

7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 2times

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 2

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) Dizziness when I would turn

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

Page **1** of **1**

Driver Demographics Form
Driver # 12
Date: 3 / 28/ 12

Please provide the following information:

1. Sex:
   ☐ Female ☒ Male

2. Age:
   ☐ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☒ 46 and over

3. Approximate number of hours you spend driving in typical week: 10

4. Approximate number of miles you drive in typical week: 50

5. How many years have you had your driver's license? 33

6. How long have you been driving in Florida? 10 yrs

7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 4

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) NONE

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    YES , YES.

Thank you for your time.

Page **1** of **1**

Driver Demographics Form
Driver # 13
Date: 3/29/12

Please provide the following information:

1. Sex:
   ☐ Female ☑ Male

2. Age:
   ☐ 16-21 ☑ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 9-11

4. Approximate number of miles you drive in typical week: 100-250

5. How many years have you had your driver's license? ~~4~~ 8

6. How long have you been driving in Florida? 4

7. Do you reduce your speed when driving in rain fall conditions? ☑ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☐ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☑ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 2

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic*, *2: unrealistic*, *3: realistic***, 4: ***very realistic***) 4

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected*, *3: affected*, *4: greatly affected***) 3

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different*, *2: different*, *3: close*, *4: very close***) 4

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) Dizziness

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    Yes, Yes.

Thank you for your time.

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Driver Demographics Form
Driver # 14
Date: 3 /29/ 12

Please provide the following information:

1. Sex:
   ☑ Female ☐ Male

2. Age:
   ☐ 16-21 ☑ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 8
4. Approximate number of miles you drive in typical week: 100
5. How many years have you had your driver's license? 9
6. How long have you been driving in Florida? 1 year
7. Do you reduce your speed when driving in rain fall conditions? ☑ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☑ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☑ Yes ☐ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 5

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 2
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) Dizziness when making turns
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

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Driver Demographics Form
Driver # 15
Date: 3/29/12

Please provide the following information:

1. Sex:
   ☐ Female ☒ Male

2. Age:
   ☐ 16-21 ☒ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 21

4. Approximate number of miles you drive in typical week: 231

5. How many years have you had your driver's license? 9

6. How long have you been driving in Florida? 8mnths

7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☐ Yes ☒ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: ________

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 2

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) no

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

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Driver Demographics Form
Driver # 16
Date: 3 29/12

Please provide the following information:

1. Sex:
   ☑ Female ☐ Male
2. Age:
   ☑ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over
3. Approximate number of hours you spend driving in typical week: 30
4. Approximate number of miles you drive in typical week: 3000
5. How many years have you had your driver's license? 5yrs
6. How long have you been driving in Florida? 2mo
7. Do you reduce your speed when driving in rain fall conditions? ☑ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☐ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☑ Yes ☐ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 3

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 4
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) N/A
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    NO , yes .

Thank you for your time.

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Driver Demographics Form
Driver # 17
Date: 3 / 30 / 12

Please provide the following information:

1. Sex:
   ☐ Female ☑ Male

2. Age:
   ☐ 16-21 ☑ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 7

4. Approximate number of miles you drive in typical week: 140

5. How many years have you had your driver's license? 11

6. How long have you been driving in Florida? 5.5 years

7. Do you reduce your speed when driving in rain fall conditions? ☑ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☑ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☑ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 1

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) Slight nausea

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes , yes .

Thank you for your time.

Page **1** of **1**

Driver Demographics Form
Driver # 18
Date: 03/ 30/ 12

Please provide the following information:

1. Sex:
   ☑ Female ☐ Male

2. Age:
   ☐ 16-21 ☑ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 4

4. Approximate number of miles you drive in typical week: 80

5. How many years have you had your driver's license? 6

6. How long have you been driving in Florida? 2

7. Do you reduce your speed when driving in rain fall conditions? ☑ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☑ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☑ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 5

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) very realistic (4)

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) yes, dizziness, nausea, sweating

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

Page **1** of **1**

Driver Demographics Form
Driver # 19
Date: 3 / 30/ 12

Please provide the following information:

1. Sex:
   ☐ Female ☒ Male

2. Age:
   ☒ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 1-2

4. Approximate number of miles you drive in typical week: 0-5

5. How many years have you had your driver's license? over 2 yrs

6. How long have you been driving in Florida? over 2 yrs

7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 20-25

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) None

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    N/A , yes .

Thank you for your time.

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Driver Demographics Form
Driver # 20
Date: 3 /30/ 12

Please provide the following information:

1. Sex:
   ☐ Female ☑ Male

2. Age:
   ☐ 16-21 ☐ 22-27 ☐ 28-33
   ☑ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 8
4. Approximate number of miles you drive in typical week: 100
5. How many years have you had your driver's license? 18
6. How long have you been driving in Florida? 18
7. Do you reduce your speed when driving in rain fall conditions? ☑ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☑ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☑ Yes ☐ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 2

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 4
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) Very Slight Dizziness in turns
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    Yes , Yes .

Thank you for your time.

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Driver Demographics Form
Driver # 21
Date: 4 / 2 / 12

Please provide the following information:

1. Sex:
   ☒ Female ☐ Male

2. Age:
   ☐ 16-21 ☒ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 0

4. Approximate number of miles you drive in typical week: 0

5. How many years have you had your driver's license? 5

6. How long have you been driving in Florida? 5yrs

7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☐ Yes ☒ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: ________

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 1

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 4

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) no

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

Page **1** of **1**

Driver Demographics Form
Driver # 22
Date: 4 / 3 / 12

Please provide the following information:

1. Sex:
   ☒ Female ☐ Male
2. Age:
   ☐ 16-21 ☒ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over
3. Approximate number of hours you spend driving in typical week: 20
4. Approximate number of miles you drive in typical week: 150
5. How many years have you had your driver's license? 10
6. How long have you been driving in Florida? 6mths
7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 5

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 2
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) Dizziness
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

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Driver Demographics Form
Driver # 23
Date: 4 / 3 / 12

Please provide the following information:

1. Sex:
   ☒ Female ☐ Male
2. Age:
   ☐ 16-21 ☒ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over
3. Approximate number of hours you spend driving in typical week: 8-10hs
4. Approximate number of miles you drive in typical week: ~100mi
5. How many years have you had your driver's license? 9yrs
6. How long have you been driving in Florida? 5.5mos
7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: twice

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) NO
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

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Driver Demographics Form
Driver # 24
Date: 4 / 4 / 12

Please provide the following information:

1. Sex:
   ☐ Female ☒ Male

2. Age:
   ☐ 16-21 ☐ 22-27 ☐ 28-33
   ☒ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 2

4. Approximate number of miles you drive in typical week: 55

5. How many years have you had your driver's license? 22

6. How long have you been driving in Florida? 10

7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☐ Yes ☒ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: ________

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 4

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) NO

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    Yes , Yes .

Thank you for your time.

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Driver Demographics Form
Driver # 25
Date: 4 / 5 / 12

Please provide the following information:

1. Sex:
   ☐ Female ☒ Male

2. Age:
   ☐ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☒ 46 and over

3. Approximate number of hours you spend driving in typical week: 6
4. Approximate number of miles you drive in typical week: 250
5. How many years have you had your driver's license? 34
6. How long have you been driving in Florida? 34
7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 10

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 4
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) a little dizzy
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    Yes, yes.

Thank you for your time.

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Driver Demographics Form
Driver # 26
Date: 3 / 5 / 2012

Please provide the following information:

1. Sex:
   ☐ Female ☒ Male

2. Age:
   ☐ 16-21 ☒ 22-27 ☐ 28-33
   ☐ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 7

4. Approximate number of miles you drive in typical week: 120

5. How many years have you had your driver's license? 11

6. How long have you been driving in Florida? 11

7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 5

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) no

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    —, yes.

Thank you for your time.

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Driver Demographics Form
Driver # 27
Date: 4 / 9 / 12

Please provide the following information:

1. Sex:
   ☐ Female ☑ Male

2. Age:
   ☐ 16-21 ☐ 22-27 ☐ 28-33
   ☐ 34-39 ☑ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 20

4. Approximate number of miles you drive in typical week: 280

5. How many years have you had your driver's license? 25

6. How long have you been driving in Florida? 11

7. Do you reduce your speed when driving in rain fall conditions? ☑ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☑ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☑ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 1

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 4

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) no

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    yes, yes.

Thank you for your time.

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Driver Demographics Form
Driver # 28
Date: 4 /24 / 12

Please provide the following information:

1. Sex:
   ☐ Female ☒ Male

2. Age:
   ☐ 16-21 ☐ 22-27 ☐ 28-33
   ☒ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 10
4. Approximate number of miles you drive in typical week: 350
5. How many years have you had your driver's license? 12
6. How long have you been driving in Florida? 12
7. Do you reduce your speed when driving in rain fall conditions? ☐ Yes ☒ No
8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☐ Yes ☐ No
9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No
10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 12

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 4
12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 4
13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3
14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) NO
15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    Y , Y .

Thank you for your time.

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Driver Demographics Form
Driver # 29
Date: 4 / 24 / 12

Please provide the following information:

1. Sex:
   ☐ Female ☒ Male

2. Age:
   ☐ 16-21 ☐ 22-27 ☐ 28-33
   ☒ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 4

4. Approximate number of miles you drive in typical week: 150

5. How many years have you had your driver's license? 20

6. How long have you been driving in Florida? 15 years

7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☐ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 2 times

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) Slight vertigo

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
    YES , YES .

Thank you for your time.

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Driver Demographics Form
Driver # 30
Date: 4 /25/ 12

Please provide the following information:

1. Sex:
☐ Female ☒ Male

2. Age:
☐ 16-21 ☐ 22-27 ☐ 28-33
☒ 34-39 ☐ 40-45 ☐ 46 and over

3. Approximate number of hours you spend driving in typical week: 10

4. Approximate number of miles you drive in typical week: 150

5. How many years have you had your driver's license? 19

6. How long have you been driving in Florida? 19

7. Do you reduce your speed when driving in rain fall conditions? ☒ Yes ☐ No

8. If you answered No in the last question, jump to Question 9. If you answered yes in Question 7, is the amount of your speed reduction related to the degree of the rain? ☒ Yes ☐ No

9. Have you ever experience hydroplaning condition? ☒ Yes ☐ No

10. If you answered yes in the last question, please give your best guess on how many times hydroplaning occurred to you: 20 +

Please rate your experience in the simulator:

11. Rate how realistic your driving experience was. (***1: very unrealistic***, ***2: unrealistic***, ***3: realistic***, 4: ***very realistic***) 3

12. Rate how much you think that your maneuver in the car was affected by the rain fall conditions. (***1: not affected***, 2: ***slightly affected***, ***3: affected***, ***4: greatly affected***) 3

13. Rate how much your reaction to the rain fall conditions just now was close to how you would react to rain in the real world. (***1: very different***, ***2: different***, ***3: close***, ***4: very close***) 3

14. Did you experience any motion sickness during the experiment? If so, please describe the symptoms. (Dizziness, nausea, vertigo, etc) slight dizziness when driving over bumps

15. Was the break in between the experiment runs long enough? Did you complete the experiment?
yes , yes .

Thank you for your time.

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