STATISTICAL ANALYSIS OF WEAVING

BEFORE AND AFTER MANAGED LANE CONVERSION

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STATISTICAL ANALYSIS OF WEAVING

BEFORE AND AFTER MANAGED LANE CONVERSION

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SUMMARY

This thesis presents a statistical analysis of weaving in a managed lane system which is evolving from a High-Occupancy Vehicle (HOV) system to a High-Occupancy Toll system (HOT). Weaving was, assessed along the I-85 corridor in Atlanta, during three different phases in the conversion from HOV to HOT: 1) the existing HOV managed lane system prior to conversion to HOT lanes, 2) after restriping of some weaving zones but prior to conversion of the HOV lanes to HOT lanes and, 3) after the HOT managed lane system opened. Each phase was analyzed to see how weaving behavior into and out of the managed lane system was affected by changes in the system. To accomplish the analysis, video was collected using Georgia Department of Transportation cameras along the corridor. The videos were transferred to an Android Tablet, in which an App developed by the research team was used to record data from the videos. Using the processed weaving data, a comparison of weaving activity during each phase was performed. Data were also analyzed across time of day, speed differentials, and whether the weaves in question were performed legally (within established weaving zones) or illegally (across double-solid striped lane markings). After a comparison of weaving behavior along different variables, a regression tree analysis was completed. The analysis showed that weaving intensity increased as the system was converted from HOV to HOT. However, illegal weaving decreased significantly once the HOT system was in place, perhaps due to stricter enforcement or perhaps due to driver response to illegally entering and leaving tolled lanes. The regression tree analyses indicated that weaving intensity was highly dependent upon whether it was legal or illegal to weave and upon the phase of conversion during which the weave occurred.

CHAPTER 1

INTRODUCTION

On October 1, 2011 the Georgia Department of Transportation (GDOT) and the Georgia State Road and Tollway Authority (SRTA) opened the new high-occupancy toll lanes (HOT) between the I-85/I-285 interchange and the I-85/SR-316 interchange. The new HOT lane was converted from a high-occupancy vehicle (HOV) lane. As part of the Effective Capacity Analysis and Traffic Data Collection project being undertaken for GDOT, the Georgia Institute of Technology (GT) is assessing changes in the effective capacity of the I-85 freeway corridor before and after the managed lane conversion. The effective capacity of the freeway is defined as the maximum capacity given its design and operating conditions.[1] Part of this assessment includes the analysis of the effect that weaving has on the effective capacity.

The Highway Capacity Manual (HCM) defines weaving as "the crossing of two or more traffic streams traveling in the same direction along a significant length of highway without the aid of traffic control devices" (2010). In our corridor, weaving is defined as a vehicle entering or exiting the managed lane on the leftmost side of the roadway. The easiest way to control the weaving in a managed lane system is to create physical barriers to decrease the amount of unexpected weaving. However, it is not always possible to construct physical barriers to separate managed lane traffic from traffic in the general purpose lanes due to space limitations. Many corridors use double

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[1] Guin, A. Hunter, M. Guensler, R. *Transportation Research Record: Journal of the Transportation Research Board No. 2065, pp. 47–5*

white lines to show when weaving in and out of the managed lanes is illegal, and use skip line breaks to indicate when weaving is allowed (Vu, et al., 2007). Illegal weaving causes two major issues for drivers and capacity: 1) driver expectancy is violated when vehicles shift in and out of the managed lane at other-than-designated locations, 2) illegal lane changes cause gap acceptance to decline and drivers to maintain larger headways which reduces lane capacity. Therefore, illegal weaving can result in a significant decrease in effective capacity of managed lane systems (Vu, et al., 2007). Lane changes in general have been found to decrease the amount of capacity of a lane (Cassidy, Jang, and Daganzo, 2010). However, if weaving is properly managed, carpool lanes can also increase roadway capacity due to the smoothing effect created by the lane and a higher bottleneck discharge rate, where the higher discharge rate results from a decrease in weaving into and out of the carpool lane (Cassidy, Jang, and Daganzo, 2010).

A managed lane system that properly controls where and when people change lanes can increase the capacity of the lane. It is also interesting to note how managed lane systems affect the capacity of the adjacent general purpose lane. In a study by Menendez and Daganzo (2007), lane changes from the HOV were not noted to have a significant effect on the capacity of the GP lane. However, the system that exhibited this performance characteristic was a continuous weave facility, where drivers are allowed to move in and out of the managed lane at any location, rather than specific weave points. It is also important to note that the simulation study was theoretical in nature and did not employ real-life field data to verify the results (Menendez and Daganzo, 2007).

One operational goal of managed lane systems is to reduce illegal weaving and increase the effective capacity of the lane and system as a whole. For the study reported in this thesis, traffic operations data and weaving activity were collected on both the managed lane and the leftmost general purpose lane. The goal of this study is to show how the weaving sections of the managed lanes in Atlanta changed in the transition between three managed lane conversion phases: 1) before restriping and before HOT lane conversion, 2) after restriping, but before opening of the HOT lane 3) after restriping and after the opening of the HOT lane. The data collected included traffic volumes, weaving counts, and speeds in the managed lane and the leftmost general purpose lane. The study will identify factors that appear to have affected both legal and illegal weaving activity and how the intensity of weaving has changed across the project phases.

The goal of this project is to analyze the potential impact that changes in infrastructure may have on driver behavior, specifically lane changing behavior, and effective capacity of a roadway. In addition, a statistical analysis of weaving will be completed to identify factors that appear to have affected lane changing behavior. The factors being taken into consideration include: traffic flow in the initial lane, traffic flow in the target lane, traffic flow differential between lanes, speed in the initial lane, speed in the target lane, speed differential between lanes, corridor location, time of day, and conversion phase.

The study was conducted using video collected along the I-85 corridor from the pan-tilt-zoom (PTZ) observation cameras installed by GDOT as part of the NaviGAtor system. This video was imported into tablets to conduct manual traffic counts (vehicles/hour) using an Android application (App) specifically developed by Georgia Tech for this purpose. The Traffic Counting App was used to identify and classify weaving events, so that weaving intensity (weaves/vehicle-hour or weaves/vehicle-mile) could be quantified. The tablet App provides rewind and fast-forward function so that users can double- check counts made by the initial data collector. The data used for the thesis were first counted using the App by undergraduate assistants. Each video was processed by two different individuals and then passed on to be transferred into the Excel spreadsheets. Videos that had different counts were personally checked and recounted. After data collection was complete, count and weave data were imported into Excel and two statistical programs (R and SPSS) for analysis. A substantial decrease in illegal lane changes was noted after the HOT lane system opened in October 1, 2011. A speed differential analysis showed an increase of shifts out of the HOT lane system when the general purpose lane was moving at a faster average speed. However, this was not observed when the lane was an HOV operation. Individual's criteria for usage of the managed lane may have changed because a monetary cost is included. People are probably not willing to pay to ride in a lane that is moving slower than the adjacent free-of-charge general purpose lane. The reduction in illegal weaving does increase the effective capacity of the corridor. There was also a clear difference in weaving intensity between the afternoon and morning peak hours. The afternoon peak hours had a higher weaving intensity for vehicles shifting out of the managed lane system. However, the opposite was found in the morning, when weaving intensity was higher for vehicles entering the managed lane system. This could be attributed to trip chaining in the afternoon and people wanting to commute straight to work in the morning. However, further study is necessary to prove this hypothesis.

CHAPTER 2

STUDY AREA

The location of the study area for this thesis is the I-85 HOT corridor in Atlanta, GA. The HOT corridor section is being analyzed is 14.3 miles long between I-285 and SR-316 (see Figure 1) (Toth, et al, 2012). The physical infrastructure in the study was modified two times during data collection. The first change was a restriping, which eliminated or relocated some of the weaving sections. The second change was the opening of the HOT lane.

According to a managed lane system plan presented by HNTB to GDOT (Smith, 2010) the managed lane operational goals and objectives were as follows:

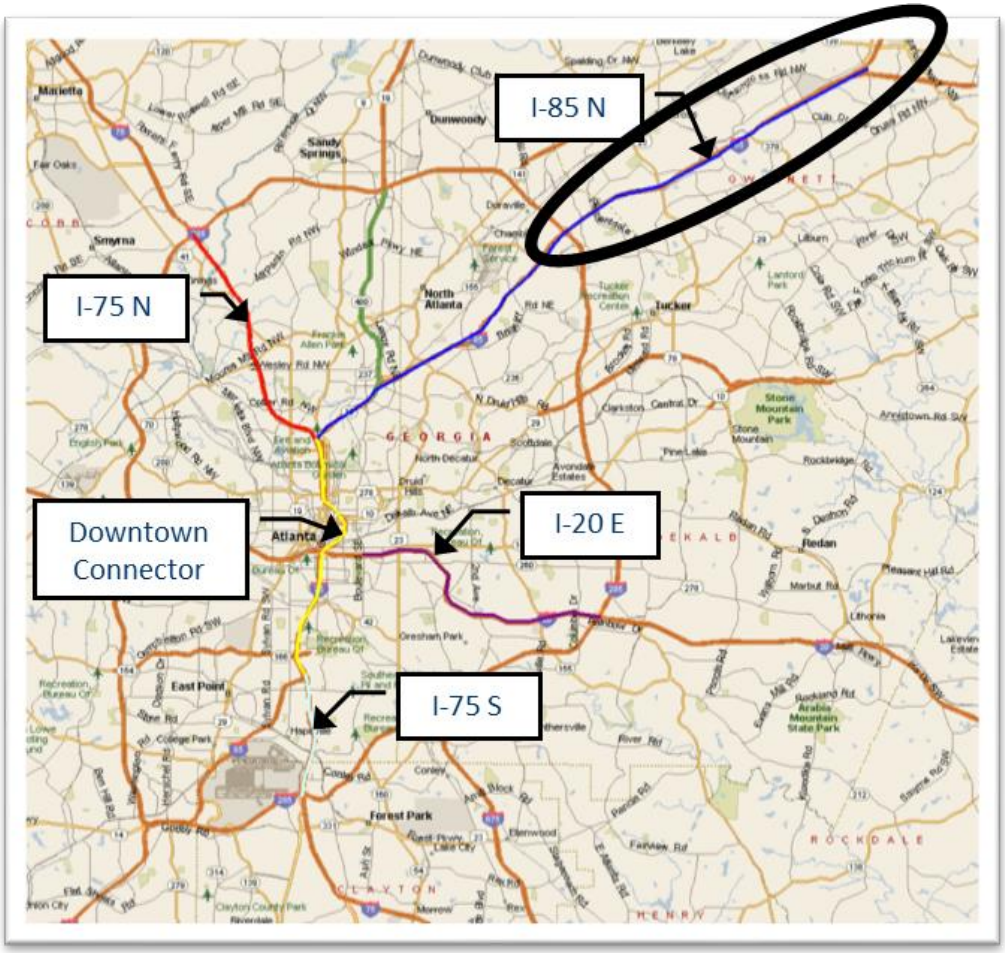
- Protect Mobility in the Managed Lanes
- Increase vehicle throughput
- Increase average travel speeds and reduce corridor travel times
- Decrease delay
- Decrease travel time variations
- Improve transit on-time performance
- Increase access to major activity centers
- Increase system efficiency

To accomplish these goals, GDOT made some major changes to the infrastructure along the corridor. The infrastructure changes included new signage for the HOT lane, carved grooves on double white lines to discourage illegal weaving across the lines, electronic collection of tolls, and implementation of an electronic barrier between the managed lane and the leftmost general purpose lane to discourage illegal weaving (see Vu, et al., 2007). Appendix A shows the signage tutorial presented by GDOT to inform and educate the public before the HOT Lanes opened.

To analyze both the restriping and the opening of the HOT lane, the study was broken into three analytical phases:

- Phase I of the study was conducted before the facility was restriped and before the HOT lanes opened for business. During this "HOV Lane Before Striping" phase, there were 15 access points (legal weaving sections) between the general purpose lanes and the managed lane between Chamblee-Tucker Road and Old Peachtree Road (seven northbound, eight southbound).
- Phase II of the study was conducted after the HOV facility was restriped, but before the HOT lanes opened for business. After restriping, the number of weaving sections into the HOT lanes decreased from 15 to nine (five northbound, four southbound), which was expected to increase the number of weaves on these sections (Toth, et al, 2012).
- Phase III of the study was conducted after the facility was restriped and after the HOT lanes opened for business. The toll lane is free for registered carpools carrying three or more occupants, motorcycles, transit vehicles, emergency vehicles, and Alternative Fuel Vehicles (AFV) with the proper license plates (GDOT). To use the HOT lanes, a Peach Pass is now required. The Peach Pass radio frequency identification (RFID) tag is used to electronically collect the toll. Even vehicles that are exempt from the toll require a Peach Pass; however, exempt vehicle Peach Passes are not charged when going through the system. Peach Pass status can be changed by any user to change from toll to toll-exempt status, and vice-versa. Police officers are placed along the system to check occupancy of the vehicle and decrease violation rates.

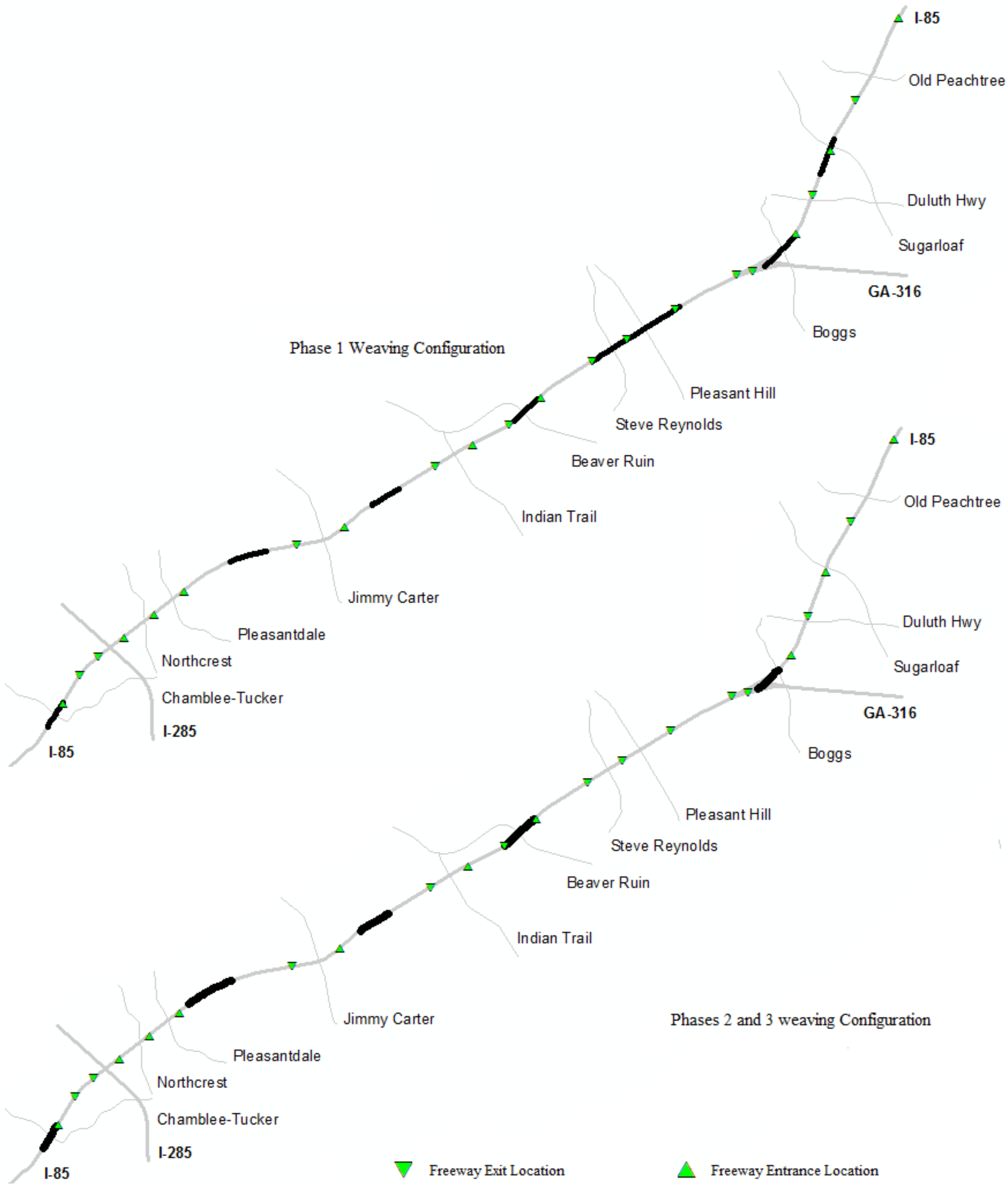
Figure 1: HOV/HOT Study Corridor



Source: K. D'Ambrosio (2011) Master's Thesis HOV-to-HOT Occupancy Data Collection Methods, Summer 2011

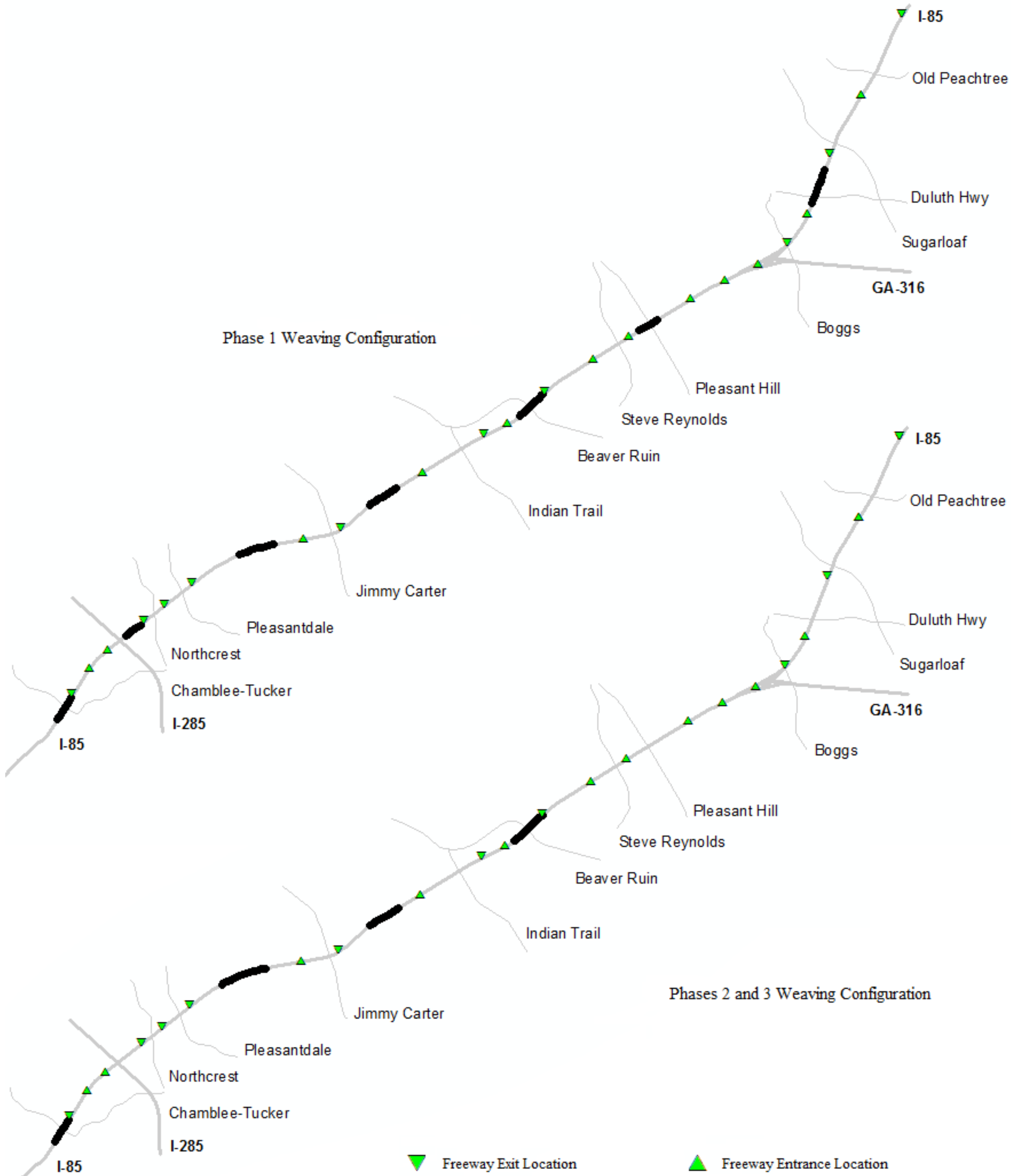
During all three Phases of study, the corridor entrance and exit locations remained constant. The I-85 corridor has 13 different interchanges that allow entry and departure from I-85. In the northbound direction, there are 11 off-ramps and 10 on-ramps. In the southbound direction, there are 10 off-ramps and 11 on-ramps (Toth, et al, 2012). All but one of the interchange ramps are located on the right side of the highway. Signage notifying drivers to begin weaving towards their exit are found on the left hand side of the roadway. The SR-316 off-ramp in the northbound direction is located on the left side of the facility to give HOT lane users a direct exit from I-85. In the southbound direction, drivers coming from the 316 HOT lanes merge directly into the left hand HOT lane on I-85. Figures 2 and 3 illustrate the spacing between weaving section, entry points, and exit points.

Figure 2: Northbound Weaving Sections and Freeway Access Points



Source: Toth, et al, 2011

Figure 3: Southbound Weaving Sections and Freeway Access Points



Source: Toth, et al, 2011

CHAPTER 3

METHODOLOGY

Weaving and traffic volume data were developed by processing video recorded from GDOT Transportation Management Center (TMC) pan-tilt-zoom (PTZ) cameras along the HOV/HOT corridor. The Georgia Tech research team selected cameras to record weaving activity at specific locations along the corridor, in accordance with a sampling plan. These cameras were used to collect both legal and illegal weaving activity. The video facilitated the collection of volume counts on managed lane and general purpose lanes, number of weaves from general purpose to managed lane, and the number of weaves from the managed lane to the general purpose lane. The Georgia Tech research team analyzed a total of 164.75 hours of video across the three operational phases. Speed data were obtained from the Georgia NaviGAtor system, and are derived from video-based, machine-vision systems located approximately every 1/3 mile along the corridor (Guin, et al, 2008).

The GDOT TMC uses pan-tilt-zoom and machine-vision cameras for incident identification and quick response dispatch of Highway Emergency Response Operators (HERO) units. The GDOT TMC is the center for a transportation management system named Georgia NaviGAtor. This program monitors more than 220 miles of freeway in Atlanta's metropolitan area in order to improve safety and efficiency. Georgia NaviGAtor uses advanced signage, video, computer and communications systems (Lee and Bradford, 2004).

Because the TMC uses these PTZ cameras for incident management, TMC staff intermittently sweep the cameras through their fields of view to search for incidents, direct emergency response crews to incidents, and monitor the clearance of these incidents (Toth, et al, 2012). These GDOT activities necessarily take precedence over the goals of the weaving study. A set of remote camera operations protocols address issues pertaining to use of the cameras for recording video data to ensure that TMC operations will not be disturbed (see Appendix B). During this research effort, it was expected that video collection would be interrupted occasionally and camera angles changed. Georgia Tech viewed all videos and selected dates for the study in which interruptions and camera movements were minimal. This study focuses on the effect of HOT weaving rather than incident-related weaving. Hence, videos were chosen for days where incidents did not affect the flow of traffic, because incidents would likely affect the number of weaves and usage of the managed lanes. A different study design would be needed for incident weaving.

The before and after study of the weaving activity will indicate whether managed lane weaving section activity was affected by the restriping, and then later affected by the opening of the HOT lanes. It is important to see which factors affected weaving intensity and the capacity of the manage lane and the leftmost general purpose lane. The three phases had major changes in the system which will change driver expectation and weaving behavior.

3.1 Data Collection

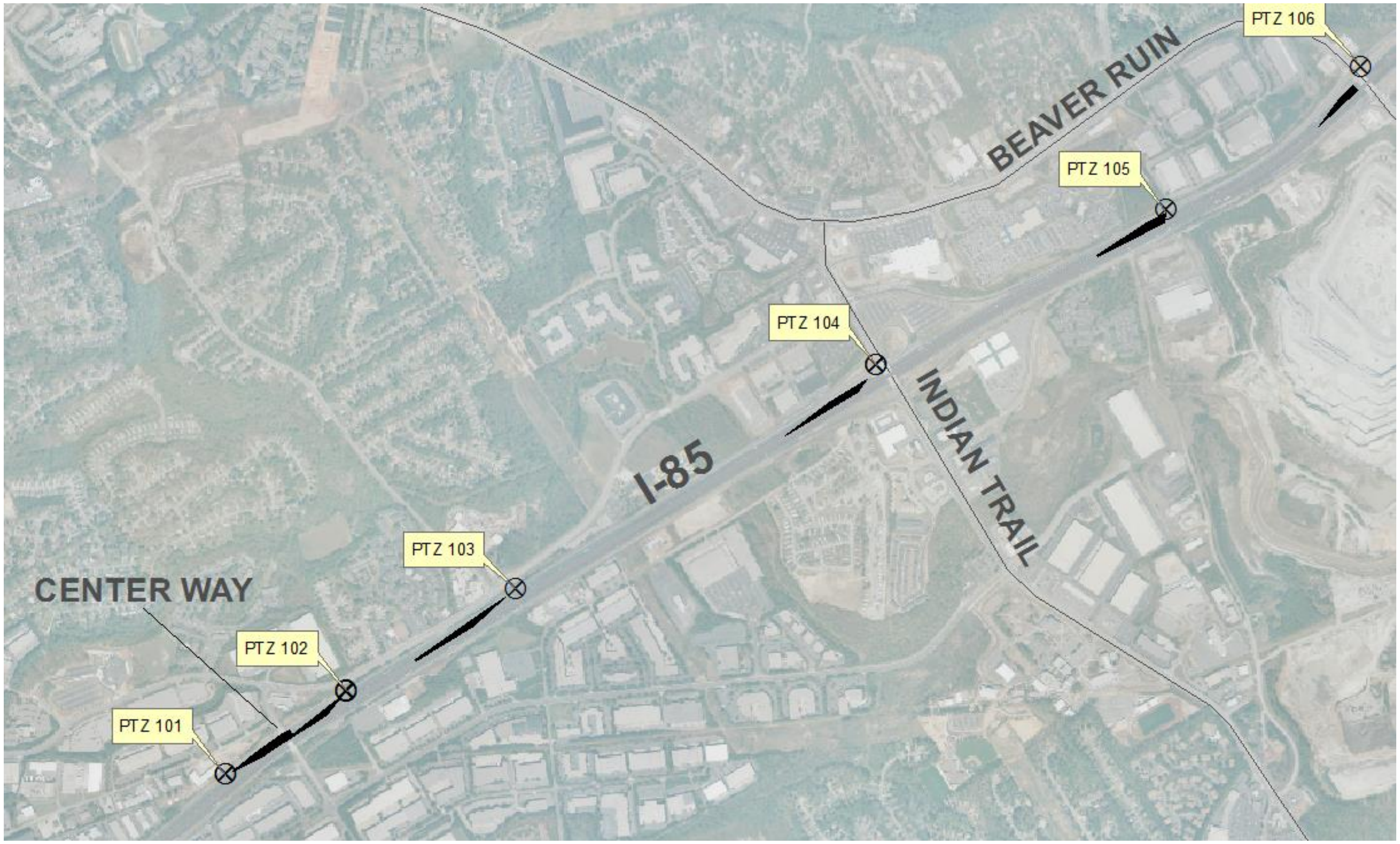
Data collection for the study was performed using a remote TMC monitoring station on the GDOT network that is located at Georgia Tech. The remote connection allows for concurrent recording of PTZ camera views. Recording of the corridor is still ongoing as Georgia Tech continuously collects data; however, this study employs only videos collected in during or before August, 2012. The videos collected were logged and organized according to the quality of the video. Videos that were not used included: videos that were affected by rain or other weather condition, videos where the recording was corrupted and not visible, videos in which the desired view was moved by GDOT staff to monitor an incident, and videos in which the resolution made it hard to accurately count vehicles and observe weaves. Videos were chosen by date where a continuous view was provided for at least one hour. The traffic state (free flow or congested) was not limited in this study as the weaves will be normalized by volume, distance, and time. The study employs the data that were available and does not selectively use or discard video data other than for the reasons outlined above. Future studies may be performed to identify the effect of weaving during specific traffic states and when driver behavior is changed by incidents, darkness, rain, or other weather conditions.

The PTZ camera views that were provided via the GDOT monitoring system are limited in scope along the corridor. Cameras views do not cover the entire highway. Figure 4 shows all of the cameras along the corridor and the area covered at a high enough resolution for data collection (i.e. high enough resolution such that an observer can visually count vehicles and identify weaves between lanes). Figure 4 was prepared as part of a restriping assessment proposal by Georgia Tech. More detailed maps of the coverage of each camera can be found in Appendix C. The areas between the yellow and the white lines in Figure 4 is a 600' zone where vehicles can be tracked. The yellow line has a radius of 400', while the white line has a radius of 1000'. To obtain the maximum vehicle tracking distance, the camera must be pointed at this 600' area. Figure 5 shows the legal weaving section being covered by each PTZ camera (Toth, 2011). The camera views shown in Figure 5 are the ones used for data collection along the corridor. Figure 5 shows that the PTZ cameras do not cover the entire corridor. According to a study done by the Georgia Tech research group, the PTZ cameras cover about 25% of the weaving corridor (Toth, 2011). Screenshots of camera views used during recording can be found in Appendix D.

Figure 4: Camera Coverage on I-85 Corridor

Source: (Toth, et.al. 2011)

Figure 5: Coverage from Existing PTZ cameras



Source: (Toth, et.al. 2011)

Table 1 shows the cameras selected for the study, as labeled for the restriping. In the table, the letter L labels a legal weaving section and I labels and illegal weaving section. The time of day shows which direction the camera is recording traffic. The AM cameras are recording southbound traffic, while the PM cameras record northbound traffic (Toth, 2011).

Table 1: Identification and Naming of Weaving Sections

Location ID	Weaving Section	TMC Camera #	Location Description	Time of Day
L1	Center Way	101	I-85 S of Center Way	AM
		102	I-85 N of Center Way	
L2	Beaver Ruin	106	I-85 at Beaver Ruin	PM
L3	Center Way	101	I-85 S of Center Way	AM
		102	I-85 N of Center Way	
L4	Beaver Ruin	106	I-85 at Beaver Ruin	PM
I1	-	87	I-85 at Jimmy Carter Blvd	AM
I2	-	104	I-85 at Indian Trail	AM
I3	-	124	I-85 at SR-316 Interchange	AM
I4	-	46	I-85 S at I-285 (north side)	PM
		84	I-85 S of Pleasant Hill Rd.	
I5	-	104	I-85 at Indian Trail	PM

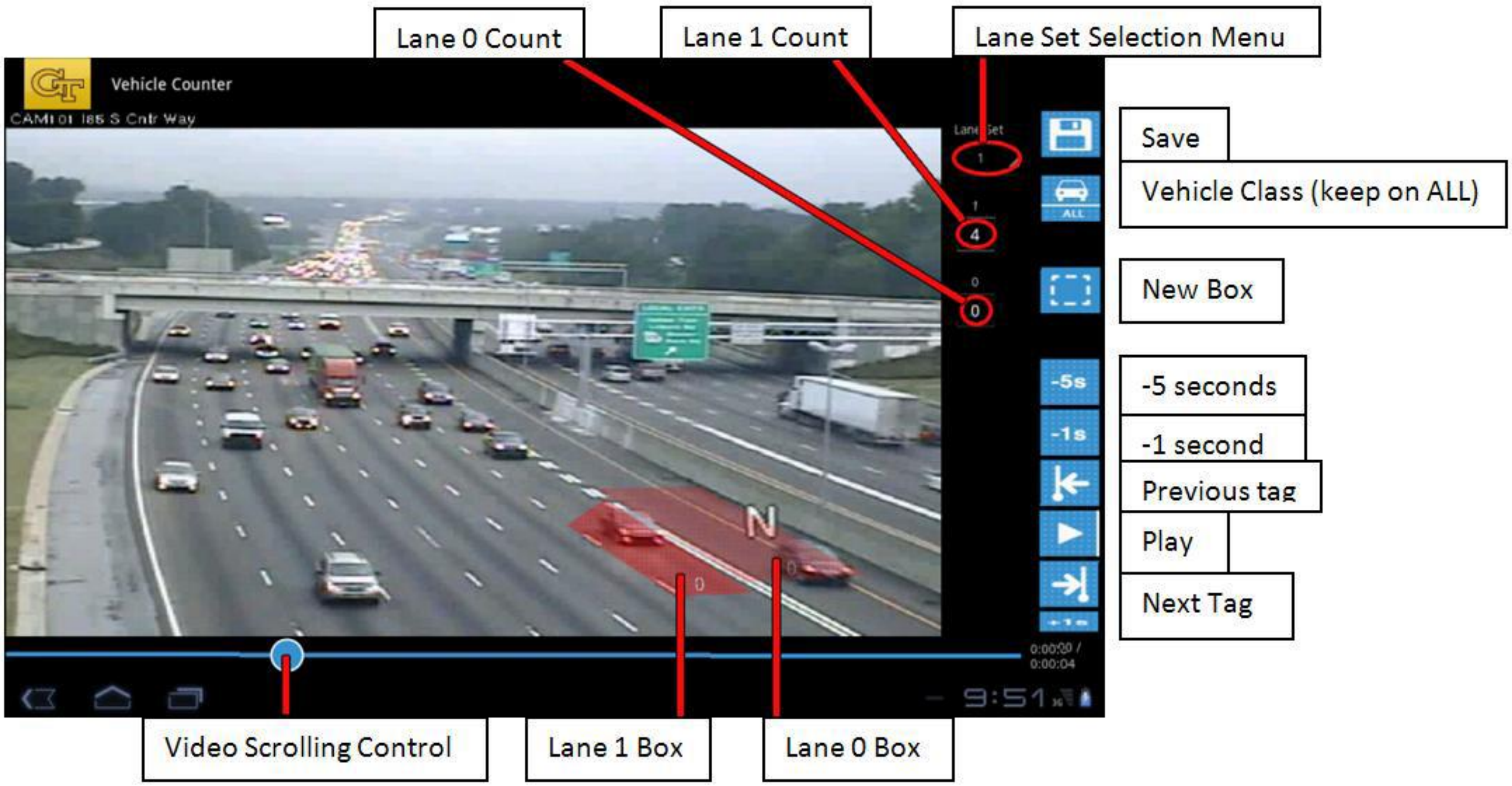
Source: (Toth, et.al. 2011)

3.2 Tablet Data Analysis

Accurate traffic counts are crucial for transportation impact studies and planning for future projects. To collect volume counts and weaving counts for this study, an Android Application (App) developed at Georgia Tech for Android tablets was employed (Toth, et al., 2013). The Traffic Count App serves as an alternative for current intrusive technologies. Traffic video is processed by an observer, who first draws detection zones on the tablet screen. As each vehicle in the video passes through a lane detection zone in the App, the observer touches the screen to record a count. The tablet system is designed to minimize counting errors across data collectors by providing a video record of the observed data for quality assurance and quality control (QA/QC) purposes (Toth, et al., 2013). The main advantages of tablet data collection is that it allows collectors to: 1) playback the recorded video on Android tablets, and 2) identify vehicle arrivals by clicking directly on the vehicle when the vehicle enters the pre-specified detection zone. The data collection results are recorded and the video can be played back for a QA/QC by a second data collector (Toth, et al, 2013). Each time the detection zone is tapped, the zone lights up, allowing a subsequent data collector reviewing the work to check to see if the count was conducted correctly. The tablet application also allows the user to pause, rewind, and fast-forward through the video at his or her convenience. This is important because it allows collectors to count in a laboratory rather than in the field where they may be distracted, and when they are fresh rather than fatigued (Toth, et al., 2013).

Figure 6 shows a screen shot of the App along with a description of the control buttons and their functions. The software operation is simple and efficient. The user must first open the application and chose the video that needs to be counted. Once the video is open, the user creates a new detection zone or “box”. Detection zones can be placed anywhere on the screen; however, it is preferable to place the detection zone over the lane at the location where vehicles will be counted. Each detection zone is assigned a unique name. The program is capable of having multiple lane sets which allows to count volumes and weaves separate. Once all detection zones are drawn and labeled, the user can hit play on the video screen and start counting vehicles as they enter each lane.

Figure 6: Traffic Counting Application Buttons



Source: (Toth, et.al. 2013).

3.3 Weaving Types

The Android App was used for counting volumes as well as for counting weaves (lane changes) and weave types. Using the same detection zone approach, a vehicle can be counted when it weaves. Each weave is labeled as either a 01 (out of the managed lane) or 10 (into the managed lane). The weaves were labeled as legal or illegal according to the section of the corridor it was taken from according to Table 1.

The analyses are focused on legal and illegal weaving activity. A legal weave constitutes a vehicle entering or leaving the managed lane at a designated weaving area across a double dashed line. An illegal weave constitutes a vehicle crossing the solid double line. Legal and illegal weaves occur into, or out of, the managed lane from or to the adjacent general purpose lane (general purpose lane 1, i.e. the fast lane). Figures 7a and 7b show diagrams of both legal and illegal weaves.

Legal weaving zones should be placed such that vehicles are able to use them appropriately. If a weaving zone is too close to an exit ramp, drivers weave across all of the lanes over a short distance. If the weaving zones are placed too far away from an exit ramp, drivers may not have the needed sense of urgency to change lanes in the zone, which could lead to illegal weaving downstream. For HOT lane corridors, it is also important that the weaving sections are accessible to vehicles coming from entrance ramps. The entering vehicles must have enough distance and time to shift across all of the lanes to reach the HOT lane weave zone. As explained above, illegal weaves into or out of the managed lane violate driver expectancy and have the potential to decrease the effective capacity of the system by increasing the gap between vehicles (Guin, et al., 2008)

Figure 7a: Legal Weave Diagram

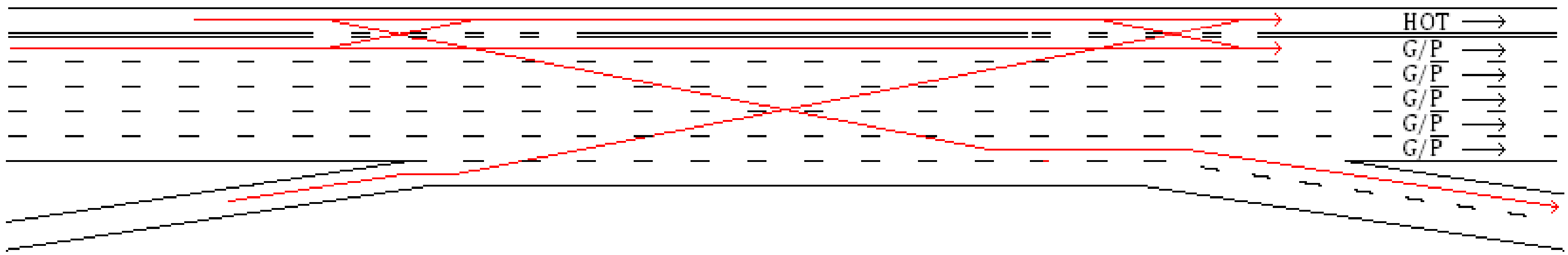
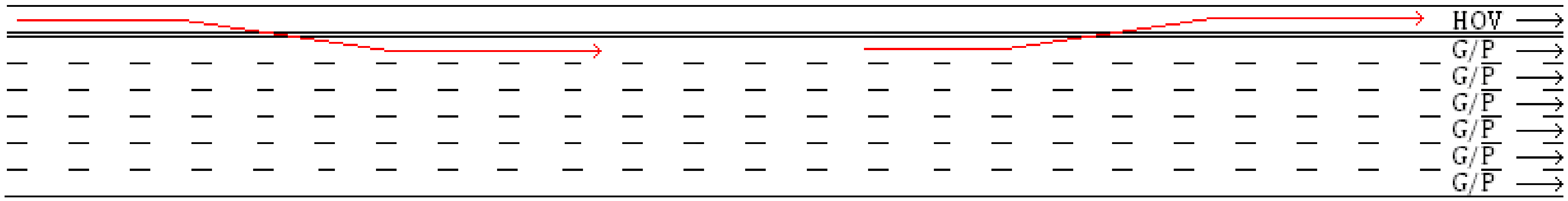


Figure 7b: Illegal Weave Diagram



Source: (Toth, et.al. 2011)

CHAPTER 4

DATA COLLECTION

This study required accurate data collection and manipulation. Video was collected by PTZ cameras and analyzed by the Georgia Tech research Group using the Android Tablet Vehicle Counting App. Data were collected during all three phases. In addition, VDS data was used in order to determine speeds for the sites, and time periods used in the study. Some VDS data were not available. Although lane speed can be calculated from the videos using the App and the data collected, resources were not available to complete a speed analysis using the tablets. A total of 9,885 minutes of data were collected for the study along the entire corridor. The data for each of the phases is described in detail below.

4.1 Data Collection Phases

Video was recorded during three different phases: Phase I, the time period before the facility was restriped and before the HOT lanes opened for business; Phase II, the time period after the facility was restriped, but before the HOT lanes opened for business; and Phase III, the time period after the facility was restriped and after the HOT lanes opened for business. Legal and illegal weaving activities were analyzed during each phase and changes across the phases are assessed. All videos used were from weekdays at either the morning or afternoon peak hours. The statistical analysis will compare the weaving intensity in each phase and examine the factors that appear to have significantly affected weaving activity.

4.1.1 Phase I

The conversion from HOV to HOT included the elimination and relocation of several weaving sections along the I-85 corridor. The restriping took place on two different dates and decreased the total length of weaving sections from 7.48 miles before the conversion to 4.45 miles after the conversion. The initial restriping was done on April 18, 2011 and eliminated the southbound weaving zone on I-285 and the northbound weaving zone on Pleasant Hill Road. Also, the first change relocated both the northbound and southbound weaving sections on Jimmy Carter Parkway, Center Way, and Beaver Ruin. The second restriping event took place seven days later on April 25, 2011. This restriping eliminated the southbound weaving sections on Pleasant Hill Road, SR-120, and Old Peachtree Road and the northbound weaving section on Sugarloaf Parkway. Also, the SR-316 weaving section was relocated. Table 2 shows a summary of the dates of the elimination and relocation for each weaving section.

Table 2: Weaving Section Restriping

Location	Direction	Conversion	Date of Restriping
Chamblee-Tucker	NB/SB	None	-
I-285	SB	Elimination	4/18/11
Dawson/Jimmy Carter	NB/SB	Relocation	4/18/11
Center Way	NB/SB	Relocation	4/18/11
Beaver Ruin	NB/SB	Relocation	4/18/11
Pleasant Hill	NB	Elimination	4/18/11
Pleasant Hill	SB	Elimination	4/25/11
SR-316	NB	Relocation	4/25/11
SR-120	SB	Elimination	4/25/11
Sugarloaf	NB	Elimination	4/25/11
Old Peachtree	SB	Elimination	4/25/11

Source: (Toth, et.al. 2011)

All Phase I videos used were taken before either of the restriping steps described above took place. A total of 2,505 minutes of Phase I video were collected and analyzed. Table 3 shows the details on the videos used during this phase.

Table 3: Phase I Weaving Videos

Location ID	TMC Camera #	Date	Direction	Length (min)
I4	46	3/22/2011	NB	105
I4	46	3/24/2011	NB	15
I4	46	4/7/2011	NB	60
I4	46	4/21/2011	NB	115
I4	46	4/22/2011	NB	90
I4	84	3/24/2011	NB	120
I4	84	4/13/2011	NB	55
I4	84	4/21/2011	NB	110
I1	87	3/23/2011	SB	105
I1	87	4/19/2011	SB	75
L1	102	3/16/2011	SB	105
L3	102	3/16/2011	NB	120
L3	102	3/18/2011	NB	60
L1	102	3/22/2011	SB	120
L3	102	3/24/2011	NB	60
L3	102	4/18/2011	NB	60
L3	102	3/14/2011	SB	120
I5	104	3/14/2011	NB	120
I5	104	3/24/2011	NB	120
I5	104	3/25/2011	NB	120
I2	104	4/4/2011	SB	60
I5	104	4/7/2011	NB	120
I2	104	4/20/2011	SB	30
I5	104	4/22/2011	NB	60
L4	106	3/22/2011	NB	75
L2	106	4/1/2011	SB	120
L2	106	4/4/2011	SB	120
L2	106	4/13/2011	SB	30
L2	106	4/25/2011	SB	35
Total				2505

4.1.2 Phase II

Phase II began after the two-stage restriping was finished and continued until the HOT lanes opened for business (4/25/2011-10/1/2011). Phase II analyses how the HOV weaving was affected after the restriping took place and before the HOT lane opened. As stated before, there are fewer weaving sections, but the enforcement of illegal weaving did not change. This is a relatively short period (9.2 months) and video data were limited. Some location ID's had no video recorded because cameras were not in control of the Georgia Tech group and the PTZ cameras had views that were not usable. Data were taken from the month of June to match the dates that would be used in Phase III. A total of 3,335 minutes of video was collected during Phase II. Table 4 shows the details of the videos used during this phase.

Table 4: Phase II Weaving Videos

Location ID	TMC Camera #	Date	Direction	Length (min)
I4	46	6/9/2011	NB	180
I4	46	6/10/2011	NB	185
I4	84	6/9/2011	NB	150
L1	101	6/7/2011	SB	165
L1	101	6/11/2011	SB	180
L3	101	6/14/2011	NB	180
L3	101	6/15/2011	NB	180
L1	101	4/27/2011	SB	120
L1	102	4/27/2011	SB	120
L1	101	4/28/2011	SB	120
L1	102	4/28/2011	SB	120
I2	104	6/8/2011	SB	150
I2	104	6/9/2011	SB	180
I5	104	7/3/2011	NB	150
I5	104	7/4/2011	NB	180
L2	106	6/6/2011	SB	30
L2	106	6/14/2011	SB	180
L2	106	6/15/2011	SB	180
L4	106	6/8/2011	NB	165
L4	106	6/9/2011	NB	180
I3	124	6/22/2011	SB	70
I3	124	6/29/2011	SB	30
I3	124	6/30/2011	SB	60
L3	102	4/18/2011	NB	80
Total				3335

4.1.3 Phase III

Phase III began on October 1, 2011, at the opening of the new HOT lanes. The video chosen was from the same time period as Phase II to provide similar seasonal traffic characteristics. Phase III includes the restriping and the addition of an electronic barrier system designed to identify illegal weaving, with the potential to receive tickets by mail, and therefore was intended to reduce the frequency of illegal weaving. In addition, GDOT carved rumble strips along the solid double lines to discourage illegal weaving. The rumble strips create significant vibration at high speed and are meant to remind and/or deter people from crossing the double lines. Also, the increased presence of police officers may discourage illegal weaving. This phase has the most video available because the Georgia Tech team was able to control the views for the PTZ cameras in use. All cameras at all sites were available in Phase III and a total of 4,045 minutes of video were analyzed. Table 5 shows the details of the videos used during Phase III.

Table 5: Phase III Weaving Videos

Location ID	TMC Camera #	Date	Direction	Length (min)
I4	46	5/21/2012	NB	170
I4	46	6/5/2012	NB	165
I4	84	5/25/2012	NB	165
I4	84	6/21/2012	NB	160
I1	87	6/21/2012	SB	180
I1	87	6/22/2012	SB	180
L1	101	6/20/2012	SB	180
L3	101	6/20/2012	NB	180
L1	101	6/21/2012	SB	165
L3	101	6/21/2012	NB	180
L3	102	6/21/2012	NB	180
L1	102	6/20/2012	SB	155
L3	102	6/20/2012	NB	180
L1	102	6/21/2012	SB	180
I5	104	6/5/2012	NB	70
I2	104	6/20/2012	SB	165
I2	104	6/21/2012	SB	180
I5	104	6/21/2012	NB	165
L2	106	6/20/2012	SB	165
L4	106	6/20/2012	NB	180
L2	106	6/21/2012	SB	180
L4	106	6/21/2012	NB	180
I3	124	6/5/2012	SB	180
I3	124	6/6/2012	SB	160
Total				4045

4.2 Data Processing

The data were processed using the Android App developed by the Georgia Tech Research group. The video clips were distributed to undergraduate assistants who were each assigned a tablet. Each undergraduate counted volume for the two lanes and then re-watched the video to count the number and direction of the weaves. The tablet was then returned and re-assigned to another undergraduate for QA/QC. If there were differences found in the counts, a final check was undertaken to resolve the discrepancy. Once all videos were checked, the data were moved into Excel. In Excel, traffic volume and weave data were disaggregated into five-minute bins to provide uniform time duration for data analysis. The videos also provided other variables for use in the analysis. Additional data included: date of the video, legal or illegal weaving section location, PTZ camera number, phase, distance, and time of day. Distance was measured by counting the number of dashes during each camera view (40' between dashes).

In addition to the TMC data, average speeds for each five-minute section were taken from the NaviGAtor Vehicle Detection Systems (VDS). The VDS perform live image processing to detect vehicles from cameras (Guin, et al, 2008). Along the I-85 corridor VDS cameras are spaced every 250 feet between the I-285 interchange and the Pleasantdale Road interchange. The speeds were collected for all lanes along the corridor. However, only the managed lane and the leftmost general purpose lanes were used in this study. In some cases, the VDS data were not available due to system outages during collection, bad data, or weather issues. Using the speed data, speed differential was computed between the managed lane and the general purpose lane. The formula used was the following:

$$\text{Speed differential} = \text{ML Speed} - \text{GP Speed}$$

Using all of these variables, an analysis was completed to see how each may be affecting the amount of weaving in and out of the managed lane system. Also, analyses were undertaken to assess how the illegal weaving was affected after the change in the corridor during the conversion from an HOV system to an HOT system.

4.3 Weaving and Traffic Operations Data

After data collection was finished, a working database was created to analyze the data. New variables were created to further see the potential effects of the changes made in the corridor. The dependent variables created included percent weaving vehicles (weaving/volume), weaves per mile (weaves/distance), and weaving intensity (weaves/vehicle miles of travel). A total of 1,977 five-minute periods were available for analysis. Table 6 shows a description of each of the variables used. The legal and illegal variable was changed into a discrete variable; "0" was used to represent an illegal weave and "1" was used to represent a legal weave. The time of day variable was divided into morning and afternoon peak. In the morning, the data were collected from southbound traffic. During the afternoon, data were collected from northbound traffic. This coincides with peak-hour traffic. The morning peak period was defined as 6 AM to 9 AM and the afternoon peak was defined as 3 PM to 6:30 PM. Each video had a different starting time and ending time, but was always within the peak period time ranges described above. The time variable was coded as 1 for an AM time period and 2 for a PM time period. Phases were coded as 1, 2, and 3. Weaving intensity may be affected by infrastructure design as well as operational conditions. Infrastructure design was identified by location of weaving. The length of weave section observed was labeled by the variable "distance" and given in feet. Finally speed was given in miles per hour (mph).

Table 6 provides a description of each of the variables, data type, and range/coding. Table 7 contains descriptive statistics for all of the continuous variables used in the analyses. The average general purpose volume for a five-minute period was higher than that of the managed lane. However, the standard deviation of speed is also higher for the general purpose lane. The average number of weaves entering and exiting the managed lane in a five-minute period was about the same. However, the standard deviation for weaves entering the system was higher than those exiting. The average distance analyzed was 625', with a standard deviation of about 184'. As explained above, speed data were not available for all of the five minute periods (37% of speed data was missing). Therefore, the N for the speed data was much lower than that of the rest of the variables. The average speed for the general purpose lane was lower than that of the managed lane by only about 2 mph. The general purpose standard deviation was higher by almost the same amount.

Table 6: Variable Description

Variable	Description	Data Type	Coding
MLvol	Managed Lane Volume	Continuous	-
GPvol	General Purpose Lane Volume	Continuous	-
TotalVol	Total Volume	Continuous	-
MLtoGP	Weave Exiting Managed Lane	Continuous	-
GPtoML	Weave Entering Managed Lane	Continuous	-
Total	Total Weaves	Continuous	-
Date	Date of video	Continuous	-
Legal/Illegal	Legal or Illegal weave	Discrete	(0,1)
Site	PTZ Camera Number	Continuous	-
Phase	Phase Number	Discrete	(1,2,3)
Distance	Distance of Video Analysis	Continuous	-
Time	Time of Day (AM, PM)	Discrete	(1,2)
ML_Spd	Managed Lane Average Speed	Continuous	-
GP_Spd	General Purpose Lane Average Speed	Continuous	-
Speed_Difference	ML Speed - GP Lane Speed	Continuous	-
Percent_Weaving_MLtoGP	Percent Weaving Existing Managed Lane	Continuous	-
Percent_Weaving_GPtoML	Percent Weaving Entering Managed Lane	Continuous	-
Percent_Weaving_Total	Total Percent Weaving	Continuous	-
MLtoGP_weaves_per_mile	Weaves Per Mile Exiting Managed Lane	Continuous	-
GPtoML_weaves_per_mile	Weaves Per Mile Entering Managed Lane	Continuous	-
Total_weaves_per_mile	Total Weaves Per mile	Continuous	-
MLtoGP_weaves_per_VMT	Weaves Per VMT Exiting Managed Lane	Continuous	-
GPtoML_weaves_per_VMT	Weaves Per VMT Entering Managed Lane	Continuous	-
Total_weaves_per_VMT	Total Weaves Per VMT	Continuous	-

The next step of the analysis was to analyze the data compiled using the Traffic Counting App. Descriptive statistics are used in order to identify variables that may affect weaving activity. In addition, correlation analysis will be done in order to find variables with significant correlation to weaving changes. Finally, because means and standard deviations are not enough to communicate variability a regression tree analysis will be prepared.

CHAPTER 5

DATA ANALYSIS

Statistical analysis of the data set was performed using Excel, R, and SPSS. The data from the tablet was imported into Excel. Excel was then used to summarize the volumes and weaves for both the managed lane and the leftmost general purpose lane. Descriptive statistics were prepared using SPSS and modeling will be undertaken later using R. Table 7 shows the descriptive statistics for all the variables used in the analysis.

Table 7: Variable Descriptive Statistics

	N (5 min bins)	Minimum	Maximum	Mean	Std. Deviation
MLvol	1977	4.00	359.00	98.0395	34.51539
GPvol	1977	6.00	801.00	146.4497	48.38728
TotalVol	1977	10.00	1014.00	244.4891	67.94222
MLtoGP	1977	0	23	.99	1.936
GPtoML	1977	0	22	1.00	2.523
Total_Weaves	1977	0	24	2.00	3.423
Distance	1977	320.00	800.00	623.6520	183.65116
ML_Spd	1341	4.41	75.43	46.4003	13.16823
GP_Spd	1244	3.73	85.21	44.4702	15.29004
Speed_Difference	1244	-33.00	34.91	2.8307	8.48225
MLtoGP_weaves_per_mile	1977	.00	303.60	13.1199	25.55121
GPtoML_weaves_per_mile	1977	.00	290.40	13.2601	33.30449
Total_weaves_per_mile	1977	.00	316.80	26.3800	45.17808
MLtoGP_weaves_per_VMT	1977	.00	2.84	.1493	.31757
GPtoML_weaves_per_VMT	1977	.00	2.29	.1003	.26086
Total_weaves_per_VMT	1977	.00	1.48	.1111	.18859
Valid N (listwise)	1244				

Figures 8-9 show that there were some outliers with the potential to influence the mean and standard deviation of the volume data. Figure 8 shows all of the managed lane volume data. Figure 9 shows all of the general purpose lane volume data. Two data points were removed from the analysis due to the volume being unachievable. The two points are highlighted on Figure 9. The mean manage lane volume after the points were removed was 145.86 vehicles/five-minutes decreasing from 146.45 vehicles/five-minutes and the standard deviation was 44.65 decreasing from 48.39. The points did not have major impact and therefore were not removed from the analysis.

Figure 8: Five-minute Managed Lane Volume

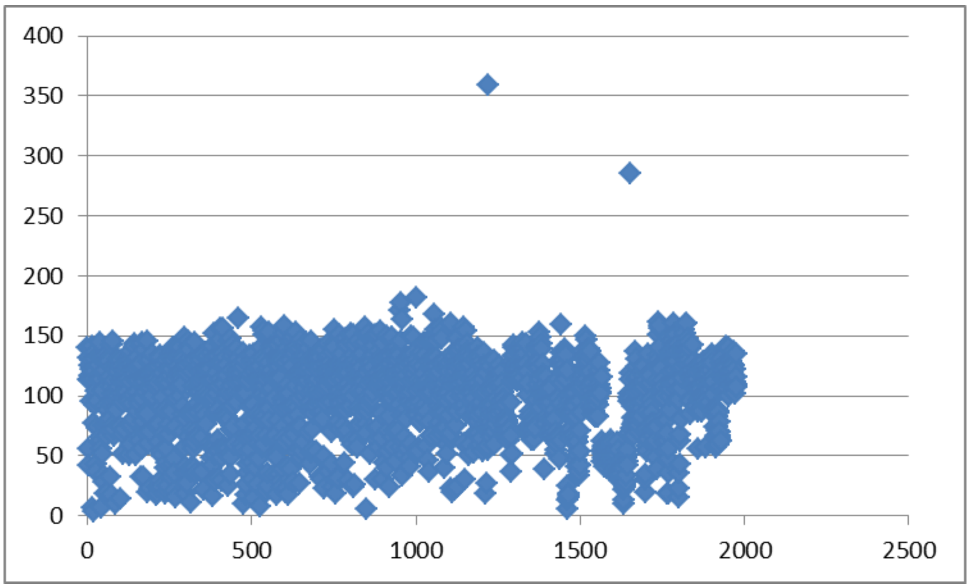
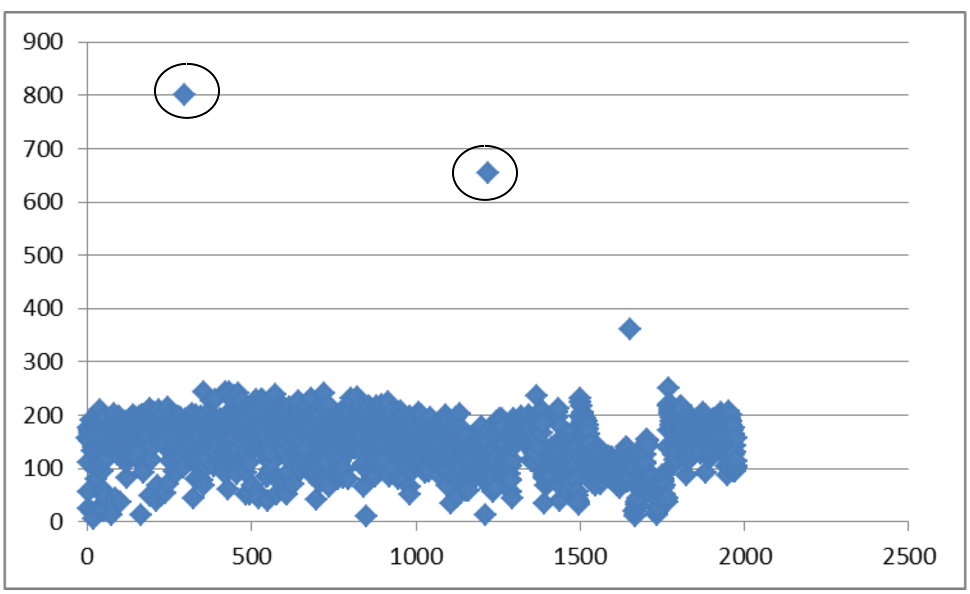


Figure 9: Five-minute General Purpose Lane Volume



5.1 Phases

The data were collected from three different phases as detailed in Section 4.1. Each phase was analyzed to see how the weaving changed from phase to phase. Phase I included 501 Five-minute records of data, Phase II included 667 records, and Phase III included 809 records. Table 8 shows the average five-minute volume and weaving data for each of the phases. The average five-minute volume decreased from Phase I to Phase II and increase again during Phase III. The changes in volume could be due to people choosing not to use the system after striping changes were made. The five-minute weaving average out of the system showed a similar pattern of decrease during Phase II; however, there was a steady increase of average weaving into the system from phase to phase. The average number of weaves was also higher during Phase III which was the opening of the HOT system.

Table 8: Phase Analysis

	ML Volume	GP Volume	ML to GP	GP to ML
Phase 1 Total	105.054	152.317	1.172	0.749
Phase 2 Total	92.039	139.57	0.574	0.913
Phase 3 Total	98.643	148.49	1.229	1.239

It is important to look at the data used in each of the phases. Tables 10-12 show the descriptive statistics for the variables in each of the phases. Table 9 shows the descriptive statistics for Phase I. Table 10 shows the descriptive statistic for Phase II and finally Table 11 shows the descriptive statistics for Phase III.

Table 9: Phase I Statistics for Five-minute Records

Variables	N	Minimum	Maximum	Mean	Std. Deviation
MLvol	501	4.00	165.00	105.0539	25.04067
GPvol	501	6.00	241.00	152.3174	36.27866
TotalVol	501	10.00	406.00	257.3713	52.88994
MLtoGP	501	0	23	1.17	2.054
GPtoML	501	0	11	.75	1.455
Total_Weaves	501	0	24	1.92	2.611
Distance	501	400.00	800.00	752.0958	130.00230
ML_Spd	221	9.00	72.00	37.7582	13.52515
GP_Spd	221	9.00	80.00	39.9596	15.59309
Speed_Difference	221	-33.00	23.00	-2.2014	9.24142
MLtoGP_weaves_per_mile	501	.00	303.60	15.4659	27.11138
GPtoML_weaves_per_mile	501	.00	145.20	9.8802	19.20418
Total_weaves_per_mile	501	.00	316.80	25.3461	34.46594
MLtoGP_weaves_per_VMT	501	.00	2.84	.1697	.33361
GPtoML_weaves_per_VMT	501	.00	1.34	.0677	.13752
Total_weaves_per_VMT	501	.00	1.12	.1082	.15842
Valid N (listwise)	221				

Table 10: Phase II Statistics for Five-minute Records

Variables	N	Minimum	Maximum	Mean	Std. Deviation
MLvol	667	6.00	159.00	92.0390	35.19911
GPvol	667	12.00	244.00	139.5652	47.57807
TotalVol	667	24.00	348.00	231.6042	74.42018
MLtoGP	667	0	6	.57	.984
GPtoML	667	0	19	.91	1.992
Total_Weaves	667	0	19	1.49	2.225
Distance	667	400.00	800.00	632.0840	187.06442
ML_Spd	448	4.41	75.43	45.1475	13.36317
GP_Spd	418	3.73	85.21	45.3504	15.21965
Speed_Difference	418	-19.87	23.64	.5356	6.04708
MLtoGP_weaves_per_mile	667	.00	79.20	7.5796	12.99099
GPtoML_weaves_per_mile	667	.00	250.80	12.0522	26.29552
Total_weaves_per_mile	667	.00	250.80	19.6318	29.36789
MLtoGP_weaves_per_VMT	667	.00	1.02	.0925	.16833
GPtoML_weaves_per_VMT	667	.00	2.16	.1078	.25254
Total_weaves_per_VMT	667	.00	1.25	.0986	.15960
Valid N (listwise)	418				

Table 11: Phase III Statistics for Five-minute Records

Variables	N	Minimum	Maximum	Mean	Std. Deviation
MLvol	809	8.00	359.00	98.6428	37.99420
GPvol	809	11.00	801.00	148.4920	54.59745
TotalVol	809	32.00	1014.00	247.1347	68.89099
MLtoGP	809	0	15	1.23	2.352
GPtoML	809	0	22	1.24	3.299
Total_Weaves	809	0	24	2.47	4.462
Distance	809	320.00	800.00	537.1570	159.38100
ML_Spd	672	16.77	75.35	50.0777	11.32080
GP_Spd	605	7.91	74.62	45.5097	14.95227
Speed_Difference	605	-17.09	34.91	6.2546	8.18902
MLtoGP_weaves_per_mile	809	.00	198.00	16.2349	31.05146
GPtoML_weaves_per_mile	809	.00	290.40	16.3491	43.54969
Total_weaves_per_mile	809	.00	316.80	32.5839	58.89587
MLtoGP_weaves_per_VMT	809	.00	2.48	.1833	.38771
GPtoML_weaves_per_VMT	809	.00	2.29	.1144	.31819
Total_weaves_per_VMT	809	.00	1.48	.1232	.22399
Valid N (listwise)	605				

The distribution for each variable during each phase is also important. Figure 10 shows the distribution of five-minute volumes for each phase. Figure 11 shows the distribution for five-minute weaving in each phase. Figure 12 shows the speed difference distribution for each phase. Figure 13 shows the weaves /mile distribution. Finally, Figure 14 shows the weaves/VMT distribution. All of the figures show a distribution change from phase to phase. This distribution changes may affect the weaving intensity both across and within each phase.

Figure 10 illustrates the shift into a flatter distribution from Phase I to Phase II, with a decrease in mean from 257.5 vehicles/five-minutes to 231.6 vehicles/five-minutes, and an increase in standard deviation from 52.8 to 74.42. Phase III shows a more peaked distribution than both Phase I and II. Figure 11, shows a flatter distribution in Phase III than in the previews two phases. The average increased by 65% and the standard deviation doubled for total weaves/five-minutes. The speed differential distributions in Figure 12 show a shift of the distribution to the right as the mean goes from -2.2 mph in Phase I to 6.25 mph in Phase III. The standard deviation shows a dip from Phase I to Phase II, but the standard deviation was 9.24 in Phase I and 8.18 in Phase III. Figure 13, shows a large change in standard deviation change in average weaves per mile. The standard deviation increased from 34.47 to 58.9 from Phase I to Phase III. In Figure 14, weaving intensity is similar in Phase I and II the mean is 0.108 weaves/VMT and 0.0986 weaves/VMT respectively. However, the standard deviation is the same in the two phases (0.159). Phase III mean increased from 0.108 weaves/VMT to 0.123 weaves/VMT from Phase II to Phase III, and the standard deviation increased by 41%. Figures 10-14 show that there are some similarities between Phases I and II, but for the most part Phase III showed significant differences in all distributions. This is expected since Phase I and II have the same managed lane system (HOV), and Phase III has a new system (HOT).

Figure 10: Five-minute Volume Distributions by Phase

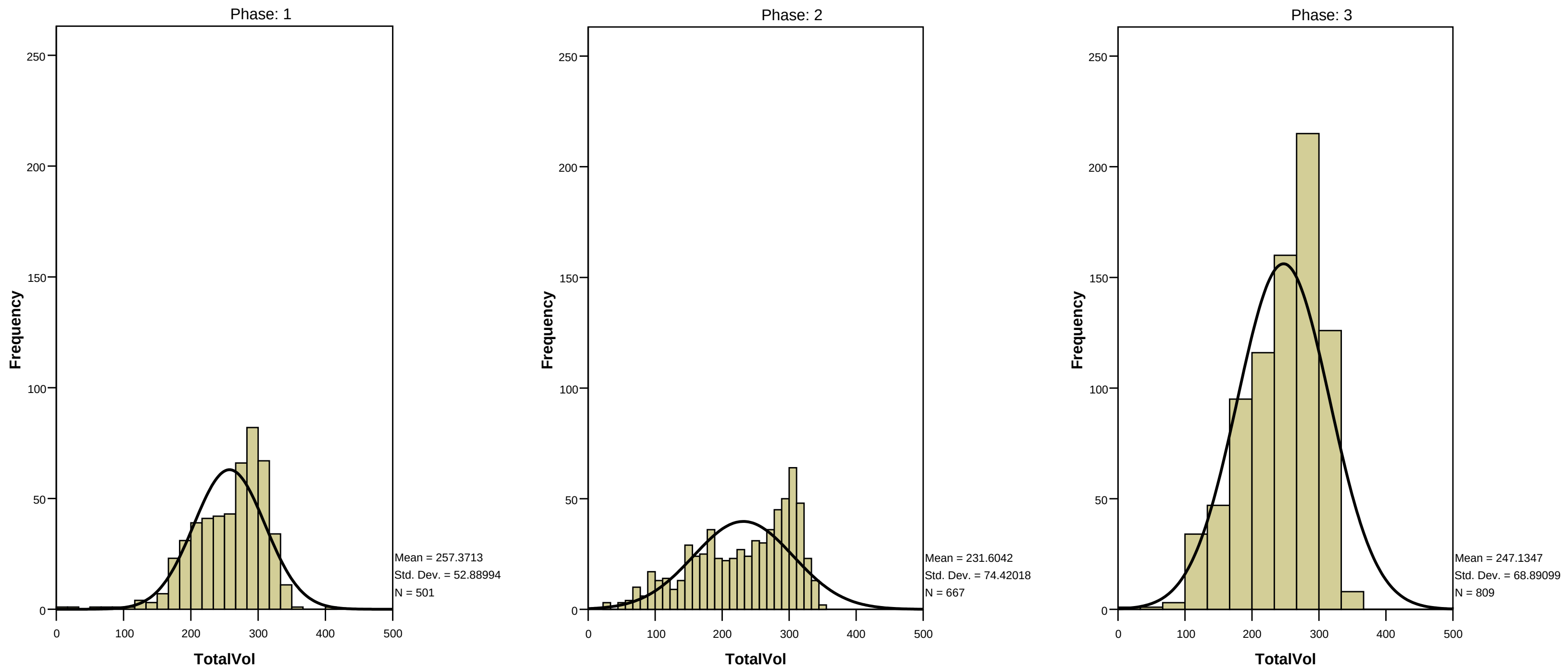


Figure 11: Five-minute Total Weaving Distributions by Phase

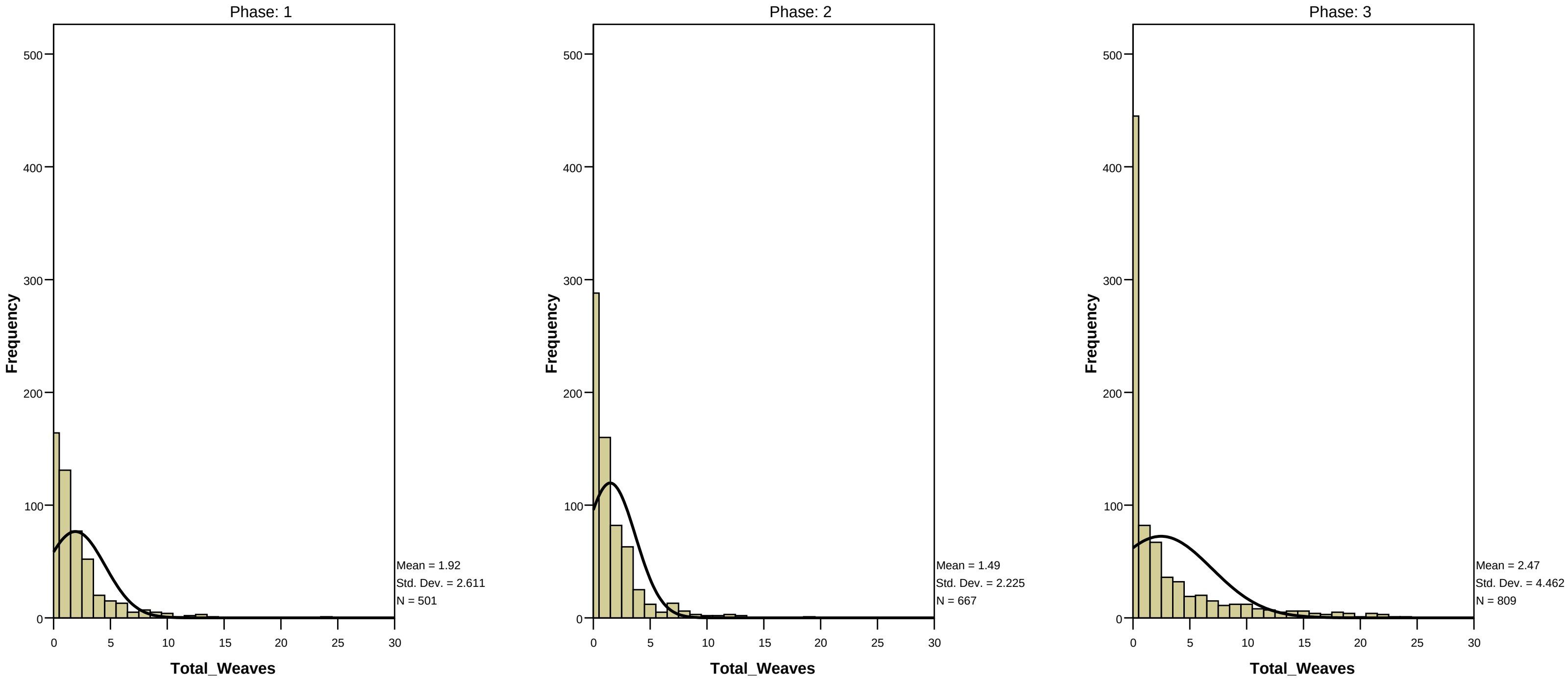


Figure 12: Five-minute Speed Difference Distributions by Phase

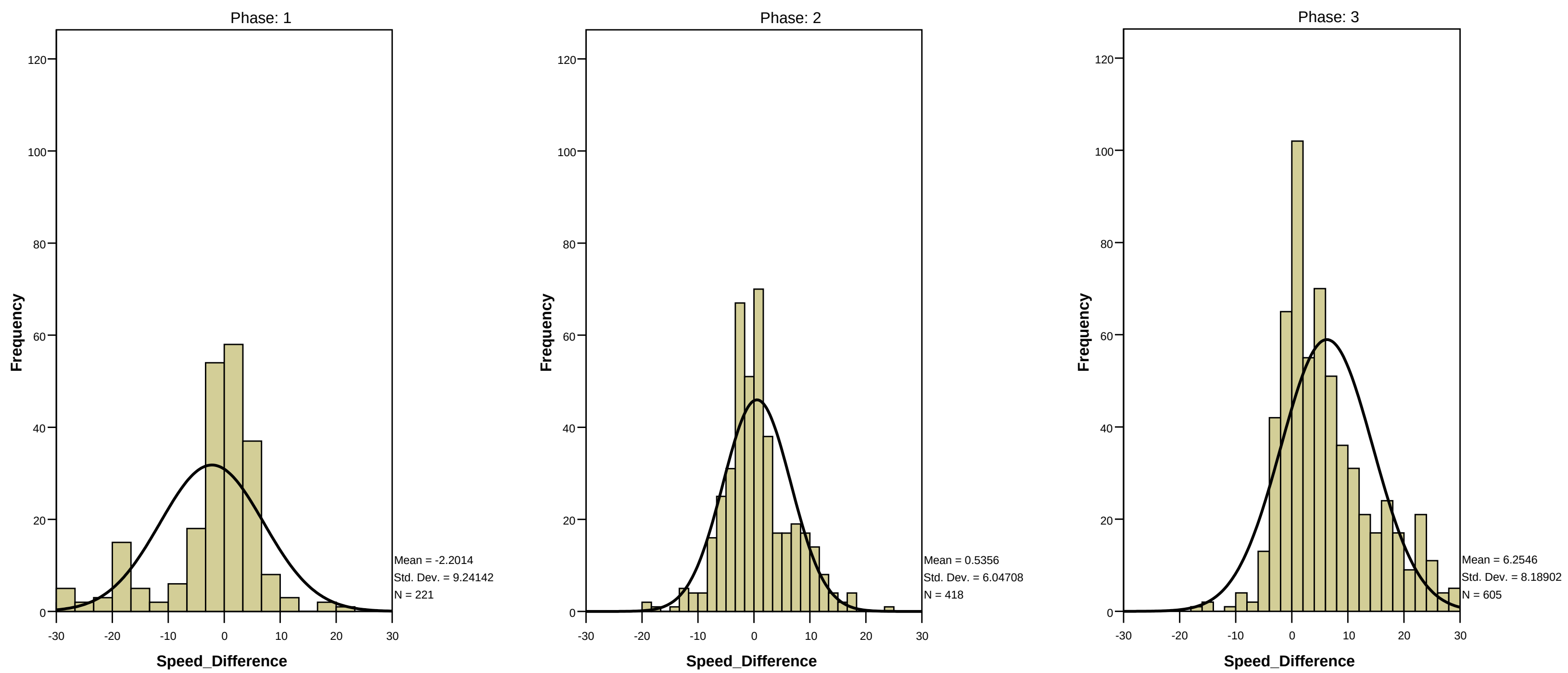


Figure 13: Five-minute Weaves Per Mile Distributions by Phase

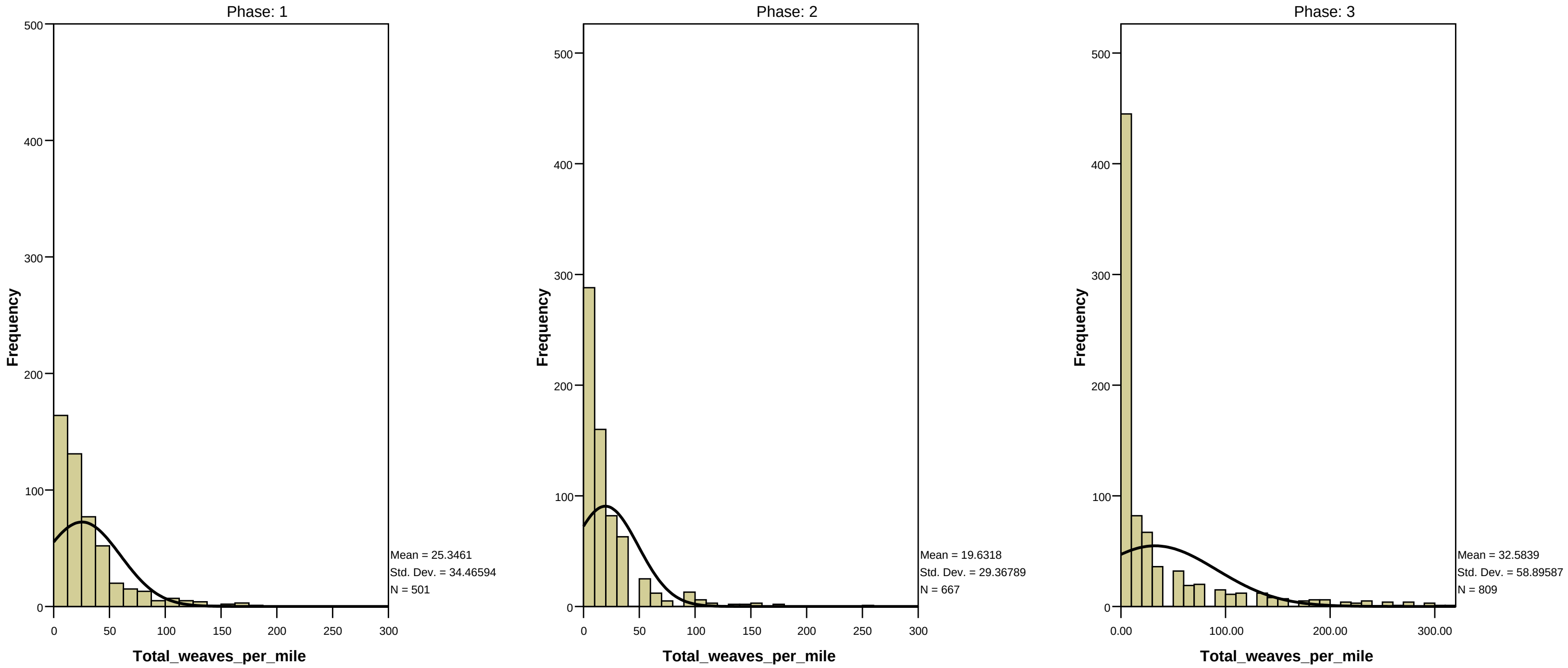
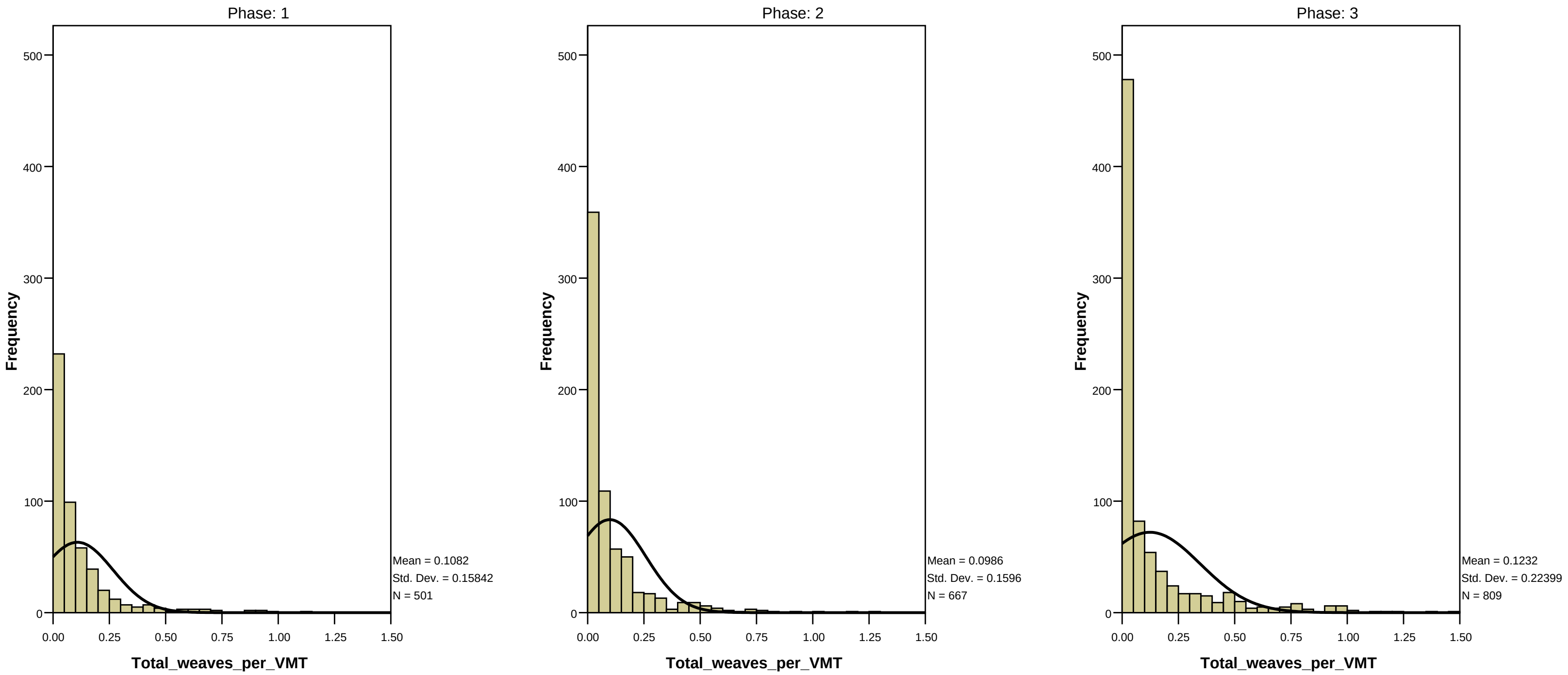


Figure 14: Five-minute Weaves Per VMT by Phase



5.2 Time of Day

There were 4,670 minutes of data in the AM (934 five-minute records) and 5,185 minutes of data in the PM. Just like in the phase analysis, the time of day data were analyzed in Figures 14 and 15. Figure 15 shows that the weaving intensity out of the system in the PM is significantly higher than the AM. Figure 16 also shows that weaving density in weaves/mile was higher in the PM period. In the AM, the weaving intensity was higher for weaves into the system, as well as more weaves/mile into the system. In total, the weaving intensity and weaves/mile were slightly higher in the PM. The difference in weaving out of the system in the PM may be due to vehicles undertaking trip chaining (stopping for other errands on the way home); therefore, exiting at different times and shifting out of the managed lane to prepare to exit. On the other hand, in the morning commute, drivers may be more inclined to head straight to work.

Figure 15: Average Weaves/VMT (Time of Day)

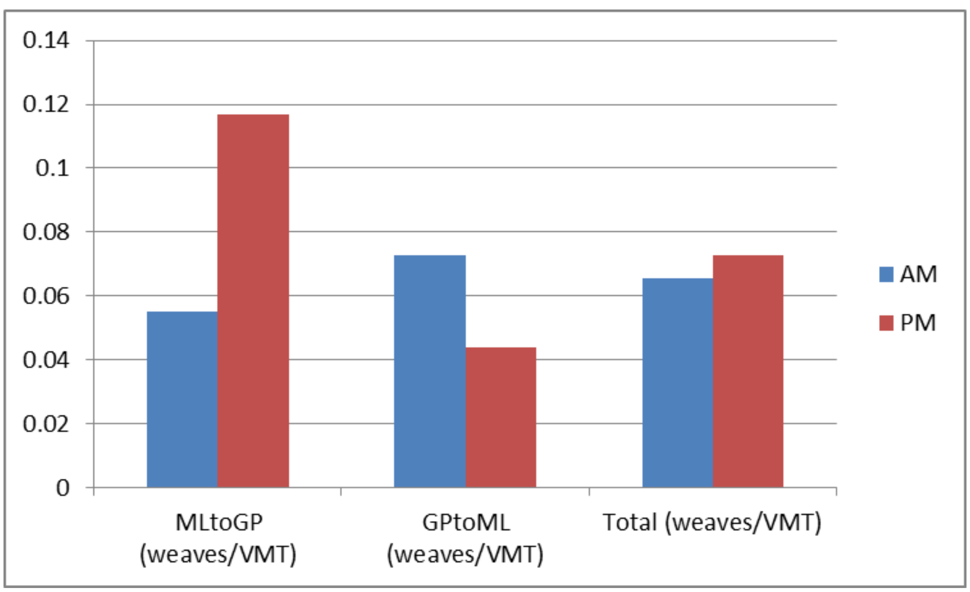
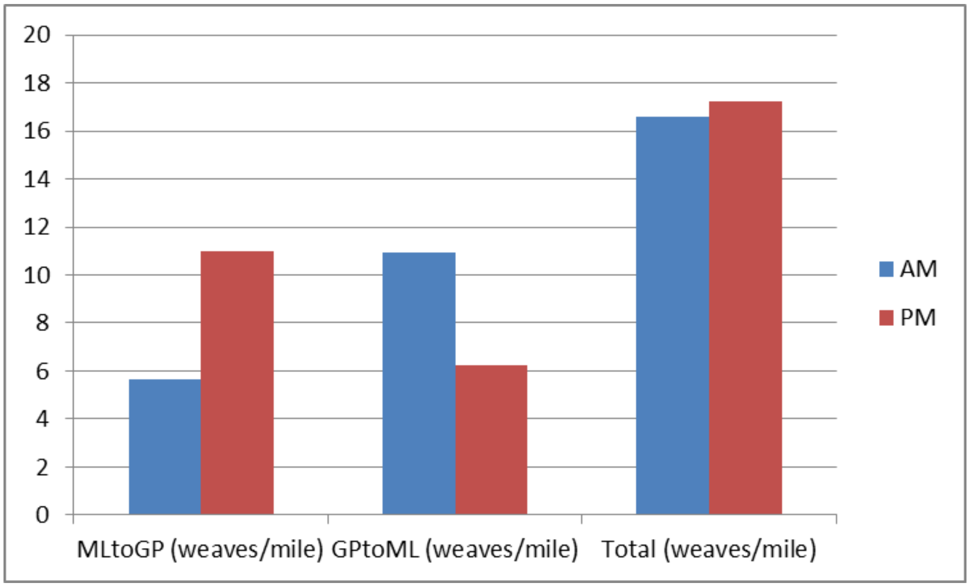


Figure 16: Average Weaves per Mile (Time of Day)



5.3 Legal vs. Illegal Weaving

Legal and Illegal weaves were defined in Section 3.3. In this analysis there were 952 five-minute records or 4,760 minutes of monitoring of the illegal weave sections. For the legal weaving analysis, there were 1,025 five-minute records comprising 5,125 minutes of monitoring of legal weaving sections. Figures 17, 18 show how average weaving intensity and average number of weaves/mile are affected by the type of weave. Using all data collected, Figure 17 shows that the weaving intensity was much higher in the legal weaving sections of the corridor. Also, weaving intensity was much higher for legal weaves into the system than out of the system. Figure 18 shows that the weaves/mile were similar entering and exiting the system; however, there were still more weaves/mile in legal corridors. Because it is so important for a managed lane system like an HOT to reduce illegal weaves, it was crucial to analyze legal vs. illegal weaves during each phase. Figures 19-21 show this comparison.

Figure 17: Average Weaves/VMT (Type of Weave)

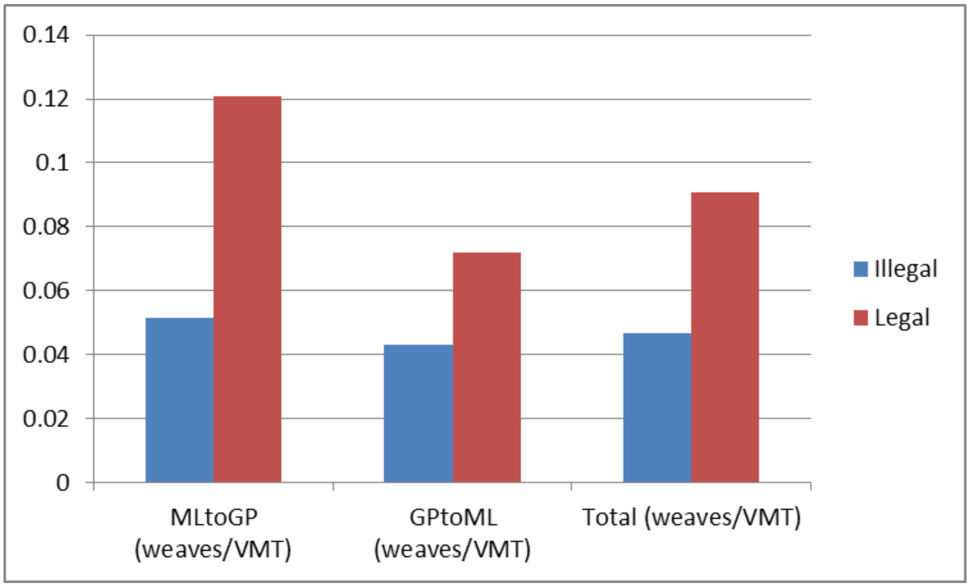
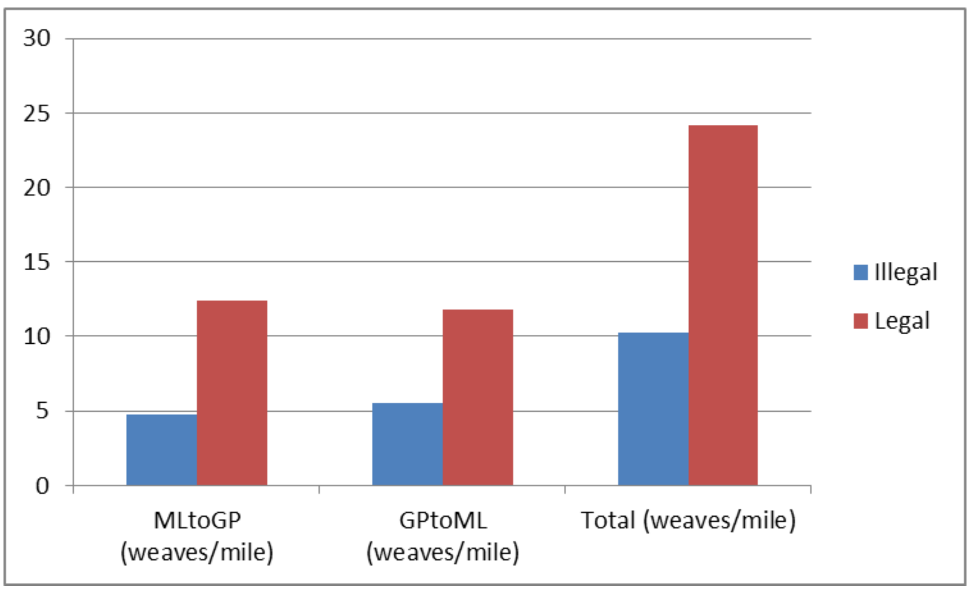


Figure 18: Average Weaves per Mile (Type of Weave)



The average total number of weaves in a five-minute period is shown in Figure 19. The illegal weaves in Phase III were minimal (0.08). As expected, legal weaves were the highest in and out of the system. Interestingly, during Phase II illegal weaves increased from 2.02 to 2.24. This could be in part due to the restriping and reduction in legal weaving sites. However, in Phase III, with the introduction of tolls and new enforcement for the HOT lane, illegal weaving rate decreased substantially from 2.24 average weaves per five-minutes in Phase II to 0.08 average weaves per five-minutes in Phase III. There was also a decrease from 2.02 average weaves per five-minutes in Phase I to 0.08 average weaves per five-minutes in Phase III. Figure 20 shows the average weaves/mile that weaved into and out of the system. Figure 20 shows that just as the average number of total weaves the illegal weaves/mile in Phase III were minimal (0.89 weaves/mile) and the legal weaves/mile was much higher than any other type of weave (46.84 weaves/mile). As seen before, the number of Phase II illegal weaves/mile was higher (18.58 weaves/mile) than the number of Phase II legal weaves/mile (10.76 weaves/mile). The number of illegal weaves/mile in Phase II were the second highest and consistent, conforming with the hypothesis that people were not accustomed to the new restriped weaving sites. The weaving might also be impacted by operational conditions; hence, weaving intensity which tends to help control traffic volumes must be analyzed to see how operational conditions may affect weaving. Figure 21 shows the analysis for weaving intensity. In Figure 21, the illegal weaving intensity in Phase III is once again minimal (0.004). The illegal weaving intensity increased substantially from Phase I to Phase II by 56%. In Phase I and II, the weaving intensity was higher for illegal weaves than legal weaves; a difference of 0.00856 in Phase I and 0.0565 in Phase II. During Phase III, the legal weaving intensity is the highest (0.174) than in any other phase. Legal weaving intensity out of the system in Phase III was significantly higher than any other type of weaving intensity, legal or illegal. Once again, illegal weaving intensity in Phase II saw a major increase and once again supports the hypothesis that people not being used to the restriping of the weaving system.

Figure 19: Average Number of Weaves per Five-minute Period by Phase and Type of Weave

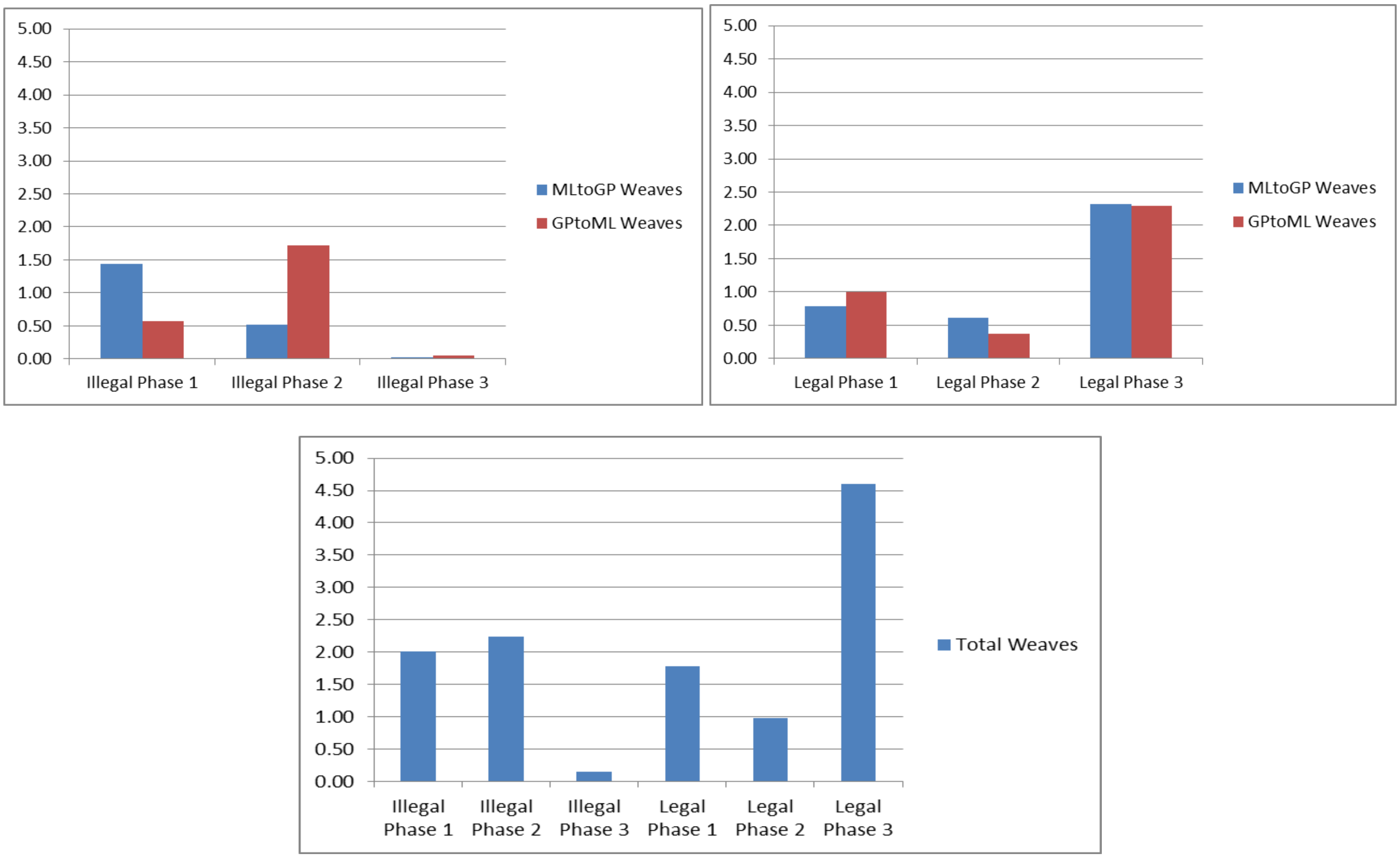


Figure 20: Average Number of Weaves Per Mile by Phase and Type of Weave

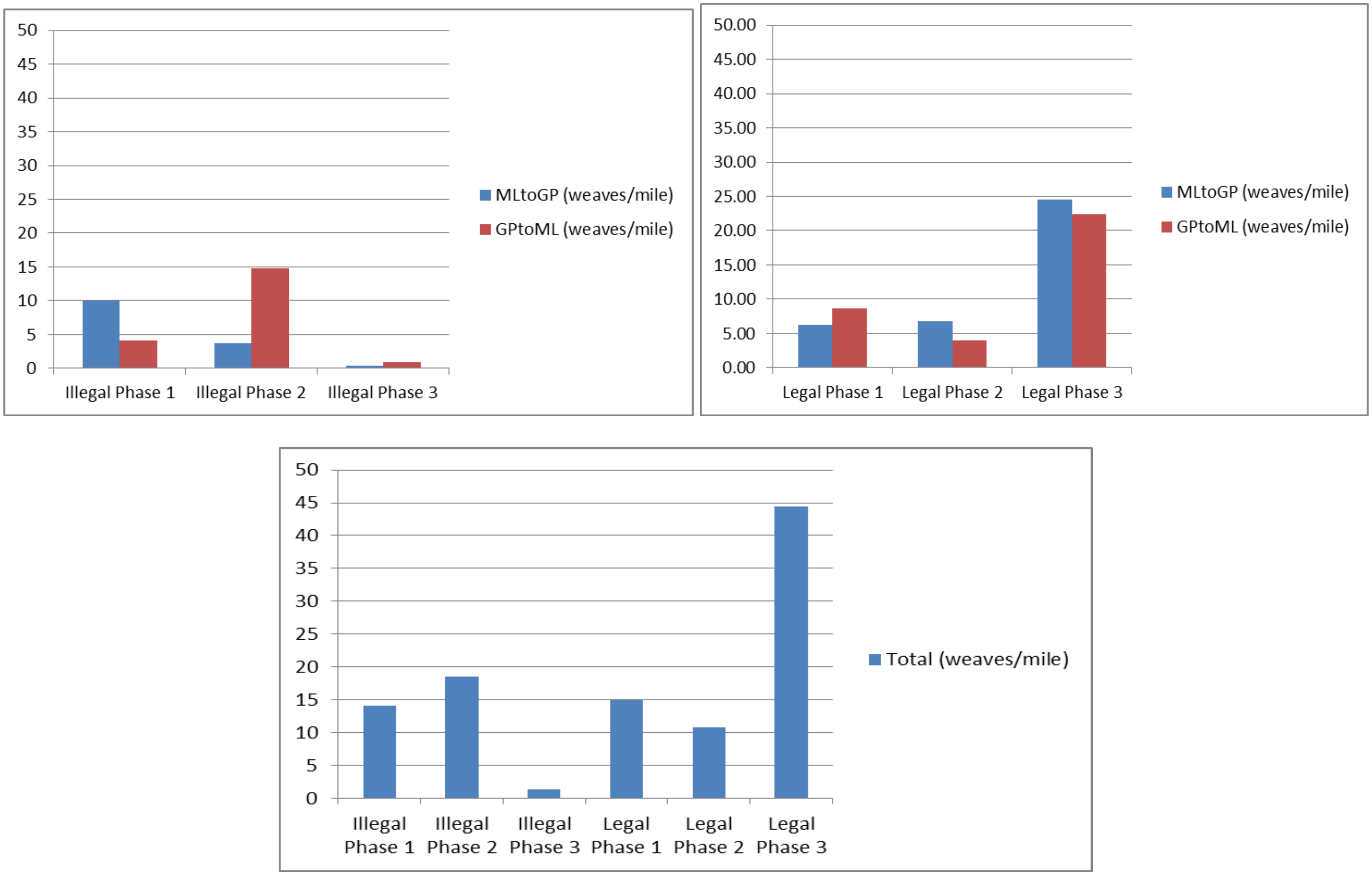
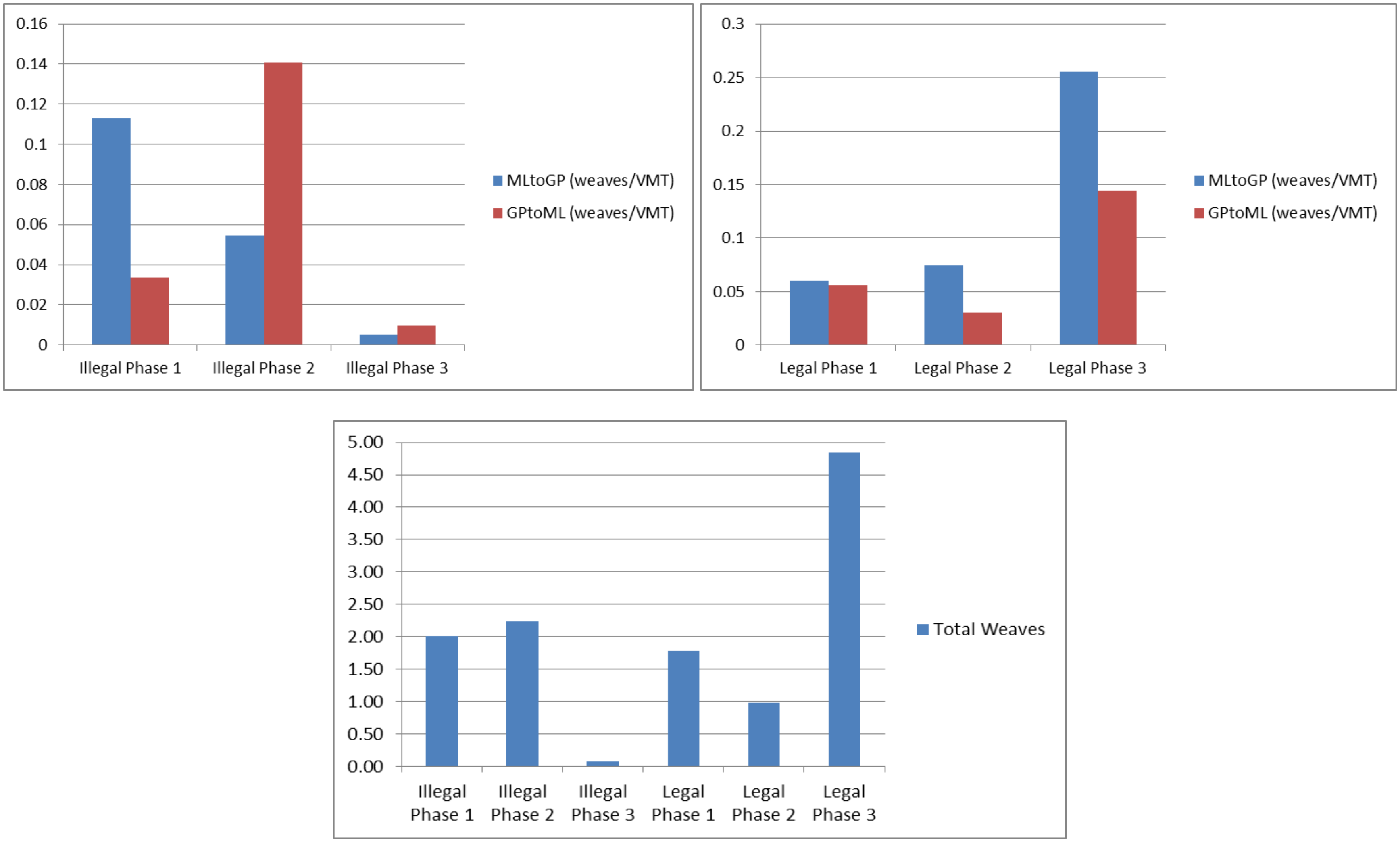


Figure 21: Average Weaving Intensity (Weaves/VMT) by Phase and Type of Weave



5.4 Speed Differential

Traffic volumes were collected as explained in Chapter 4 using TMC cameras and tablets. The volumes were aggregated into five minute periods. The speed differential data collected through VDS was given in integers. The speed differential was divided into two groups. The groups were: positive speed differential and negative speed differential. Positive speed differential is found when the managed lane has a higher average speed than the general purpose lane. A negative speed differential means the general purpose average speed was higher than that of the average speed of the managed lane. Figure 22 shows the distribution for speed differentials. The distribution of speed differentials is not centered on the zero bin. There were more positive speed differentials in the data than negative. The data also included some zero speed differentials, and cases with no data available. Out of the 1,977 five minute periods analyzed there was speed data for both the managed lane and the general purpose lane in 1,244 cases. Table 12 shows the number of data and the percentage of the type for each type of speed differential. Table 12 also shows the mean and standard deviation for each type of speed differential. The average positive speed differential was 7.25 mph, while the average negative was speed differential was 4.64 mph.

Figure 22: Speed Differentials Distribution

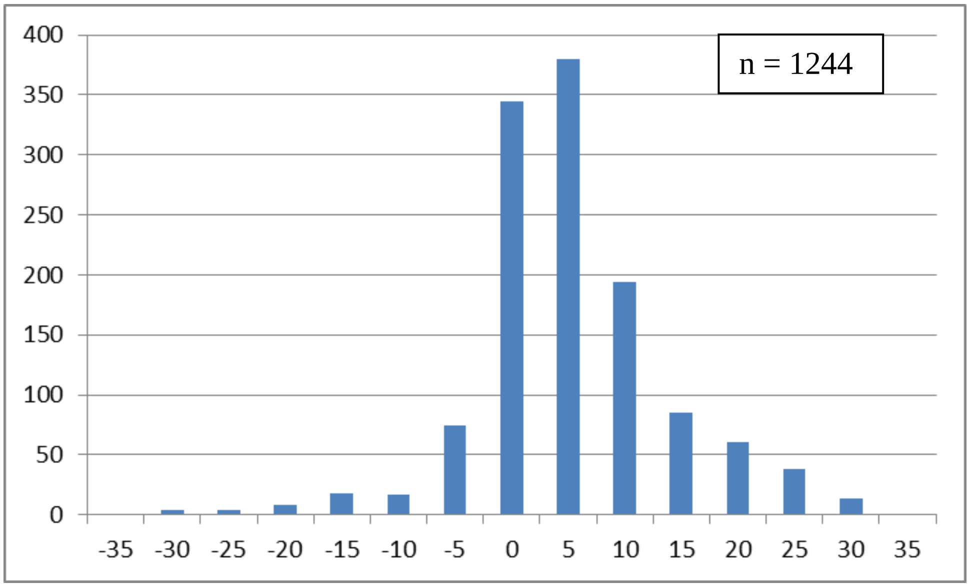


Table 12: Speed Differential Statistics by Type

	N	Percent	Mean	Standard Deviation
Positive	772	39.07%	7.25	0.0218
Zero	22	1.11%	0.00	0.00
Negative	449	22.72%	-4.64	0.0309
Missing	733	37.10%	-	-

Table 13 shows some descriptive statistics on the average speed differentials in the data used. Table 13 shows the average speed in the managed lane is slightly higher than that of the general purpose lane. The average speed differential is 2.83 mph with a standard deviation of 8.48. Further analysis was completed to examine the potential impact on weaves by the speed differential between lanes. Speed differential data were separated into positive and negative to analyze if the number of weaves in and out of the system increased as the speed differential increased.

Table 13: Average Speed Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
ML_Spd	1244	4.41	75.43	47.3009	13.24570
GP_Spd	1244	3.73	85.21	44.4702	15.29004
Speed_Difference	1244	-33.00	34.91	2.8307	8.48225
Valid N (listwise)	1244				

Figure 23 shows the distribution for weaves/mile for positive speeds and negative speed speed differentials. Figure 24 shows the distribution for weaving intensity in the same split with the same labeling for each type of speed. For the analysis the data for the five-minute time periods where the speed differences were exactly zero were excluded as the N for these speed difference was equal to 22 cases out of 1244 cases. Figures 22 and 23 show a clear difference in the distribution of weaving. This shows that the type of speed difference maybe a factor for weaving intensity.

Figure 23: Distriubution of Weaves/Mile by Positive and Negative Speed Difference Class

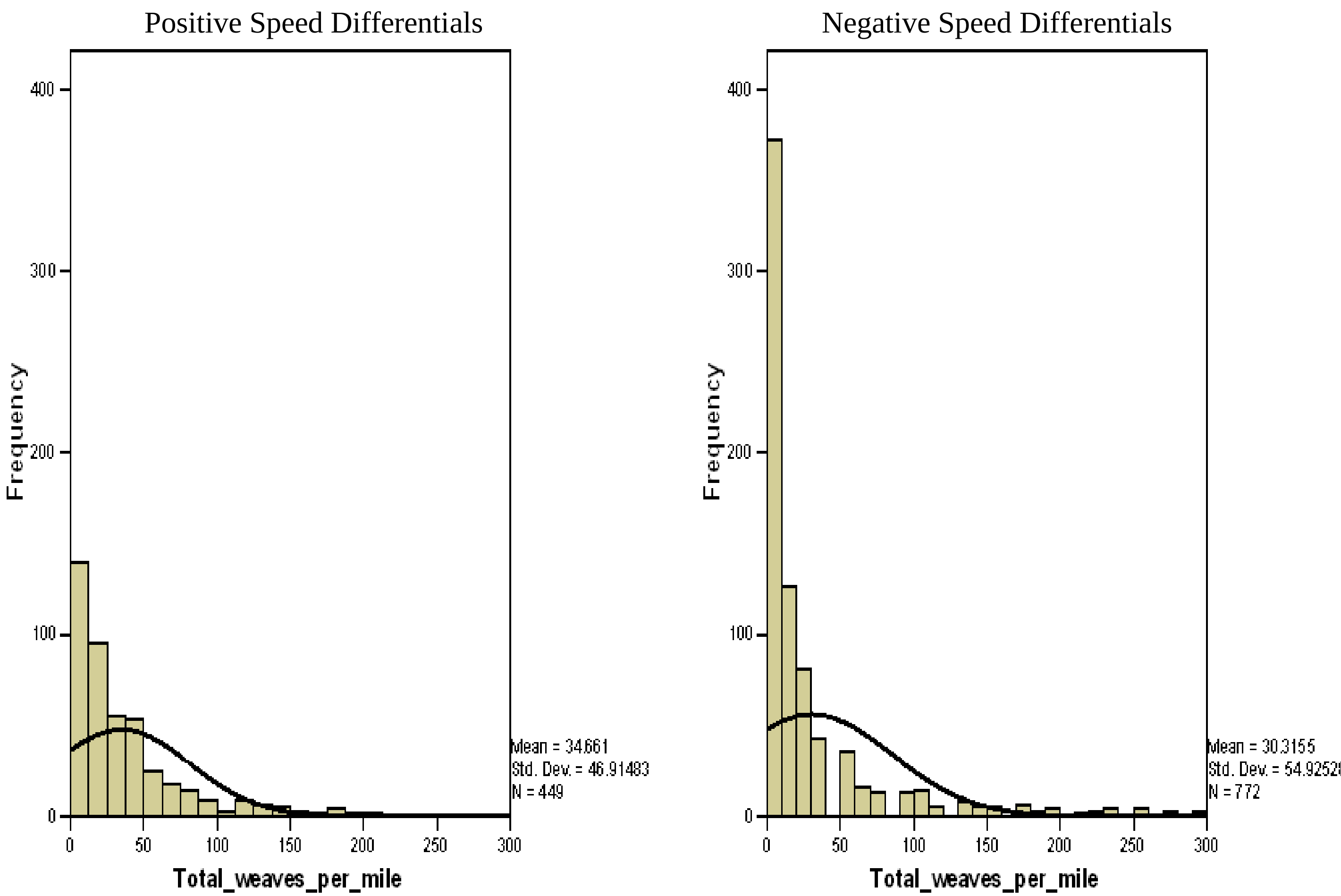


Figure 24: Distriubution of Weaves/VMT by Positive and Negative Speed Difference Class

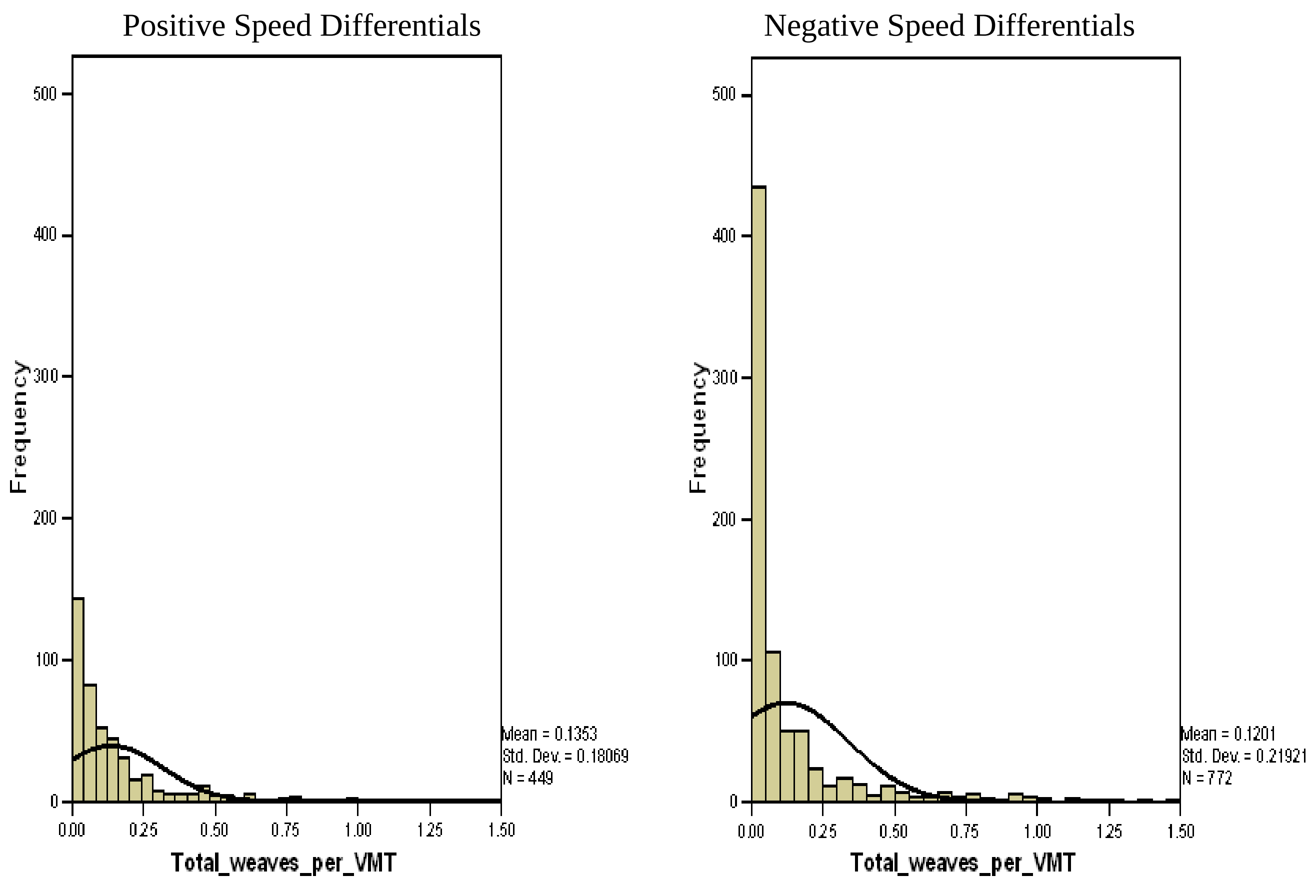


Figure 25 compares weaving intensity by positive and negative speed difference. A negative difference means the general purpose lane is moving at a faster average speed than the managed lane. In this case, weaving intensity out of the system was much higher than when the speed difference positive. Similarly, when vehicles are traveling at a higher average speed in the managed lane (positive speed difference) the weaving intensity is higher into the system. Figure 26 shows the same pattern in the weaves/mile as vehicles shift more often to the lane with the higher average speed.

Figure 25: Average Weaves/VMT by Positive and Negative Speed Difference

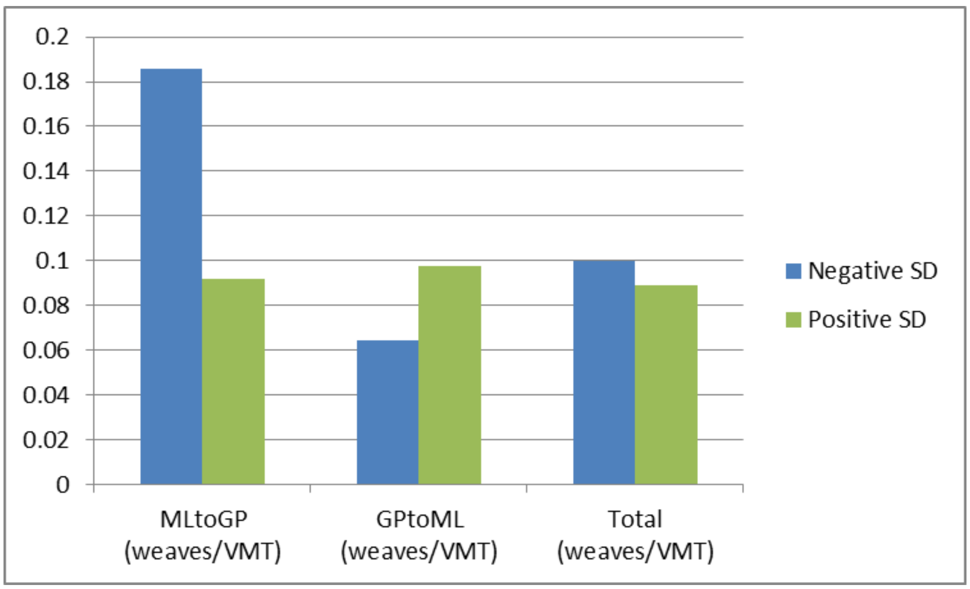
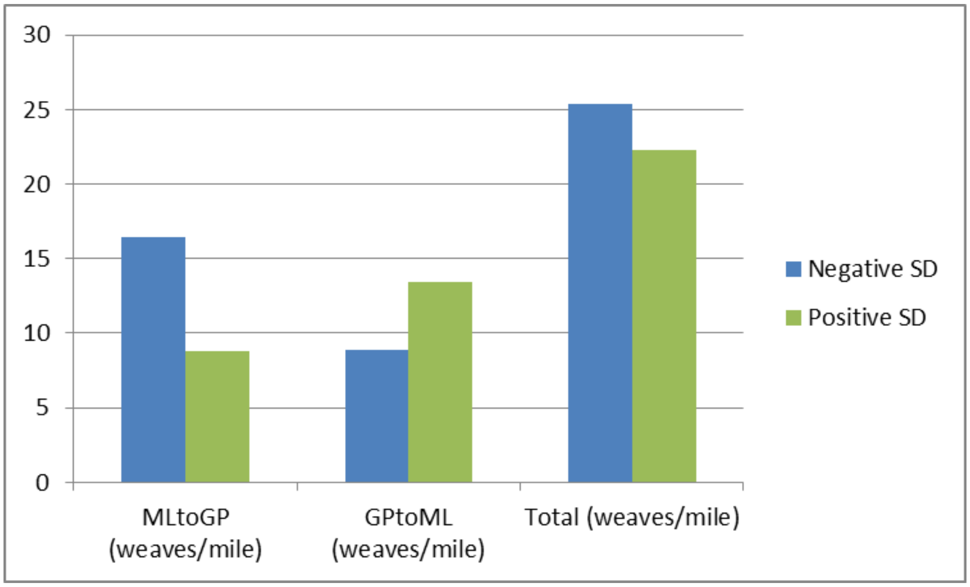


Figure 26: Average Weaves Per Mile by Positive and Negative Speed Difference



Figures 27-29 show the speed difference and phase and how weaving patterns change. Figure 27 shows when there is a negative speed differential, the average number of weaves in Phase I is very similar. In Phase I, the average number of weaves is similar for a positive speed difference. Phase II does not show the same trend as there is a higher average number of weaves out of the system when the managed lane is traveling at a lower speed. The opposite occurs when the managed lane is traveling at a higher speed. Once again this is seen during Phase III. During Phase III, there is also a large spike in average number of weaves per five-minute period. A high percentage of this increase is due to weaves out of the system when the managed lane is moving at a lower speed.

Figure 27: Average Total Weaves (Phase vs. Speed Difference)

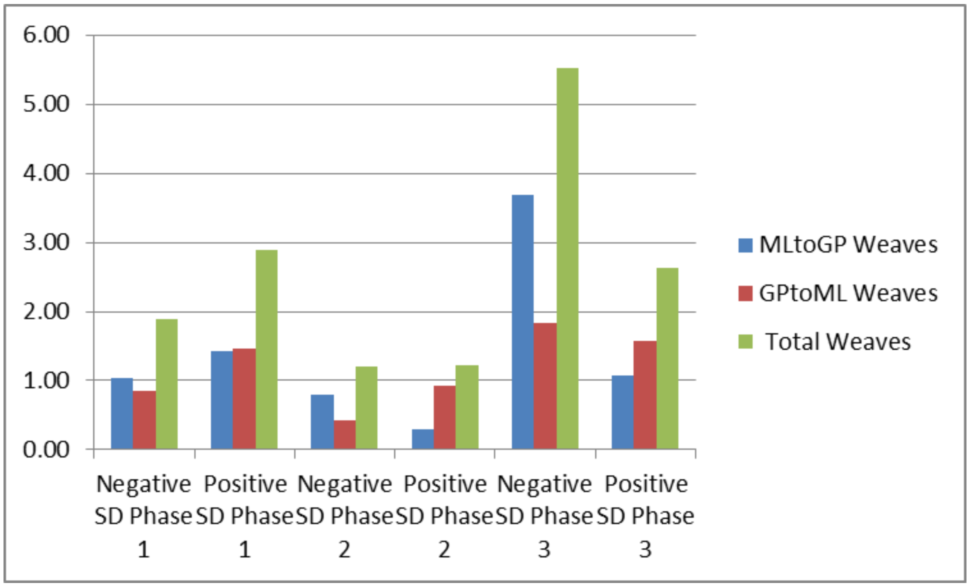


Figure 28 shows how the weaves/mile compare to different speed difference scenarios. As with average number of weaves, weaves/mile experience the same trends. A final comparison between weaving intensity and speed differential is shown in Figure 29. Figure 29 once again shows the same trends as the two previous figures. A significant increase in overall weaving is noted during Phase III after the HOT lanes opened. The increase in weaving out of the managed lane indicates that once the HOT went into operation some driver behavior changed. Because the managed lane had a monetary cost, it is expected to be a quicker alternative. When the general purpose lane is traveling at a higher average speed, it is unlikely that users of the managed lane will stay and pay the extra monenatry cost. Therefore drivers leave the managed lane under these conditions

Figure 28: Average Weaves Per Mile (Phase vs. Speed Difference)

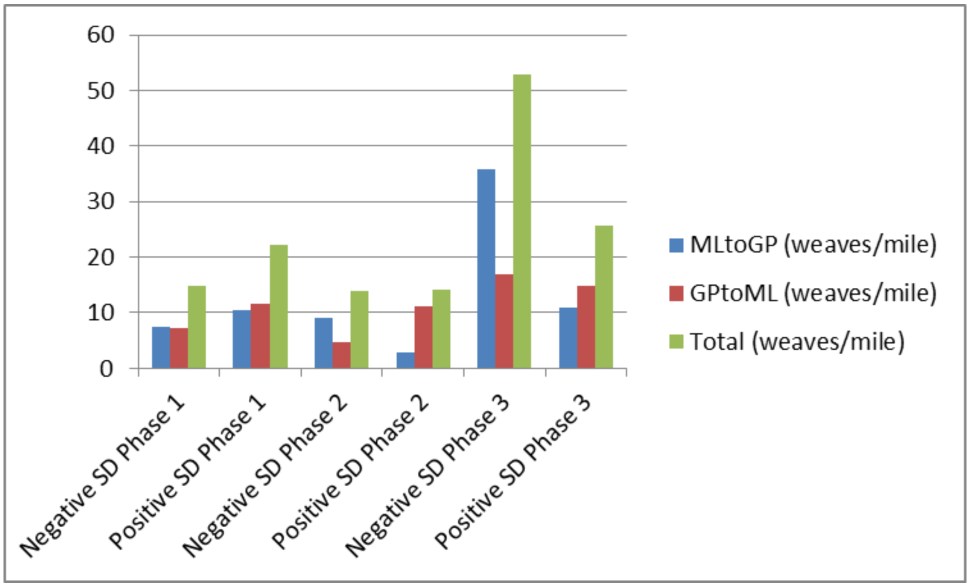
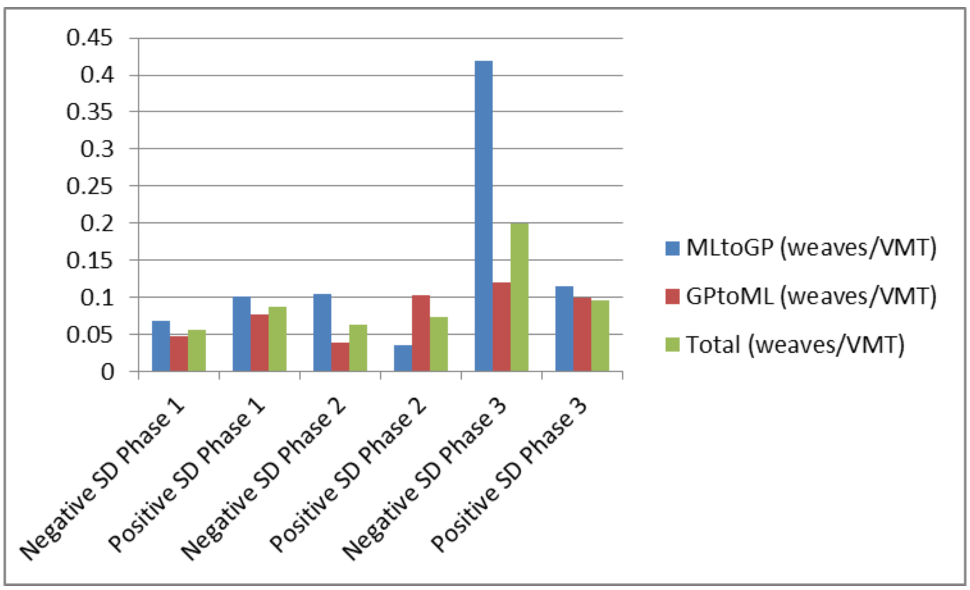


Figure 29: Average Weaves/VMT (Phase vs. Speed Difference)



Breaking up data into positive and negative speed differentials is important; however, it is not enough to assess the effects of speed on weaving. Regression tree and other analyses will be used to look for potential relationships between weaving activity and speed differential as well as other variables.

5.5 Regression Tree Analysis

Before any detailed analyses were performed, a 2-tailed Pearson correlation test was first performed to identify correlated variables. The correlation test was performed to compare the following variables: total volume of both lanes, total weaves to and from both lanes, speed difference, distance, phase, site, total weaves/mile to and from both lanes, and total weaves/VMT to and from both lanes. Table 14 shows the results for the Pearson correlation test. The test showed that there is a significant correlation between many of the variables used in the experiment. As expected total weave, weaves/mile and weaving intensity have a very significant correlation and should not be used in an analysis together. Regression models will focus on weaving intensity as the dependent variable. In addition, the site variable has a high correlation with both time-of-day and type of weave. The distance over which weave monitoring was conducted in each video was used to calculate weaving intensity making it a dependent variable and must be excluded from the analysis.

Table 14: Pearson Correlation Test

Variable		Total Vol	Weaves	Legal/Illegal	Site	Phase	Distance	Time	Speed Difference	Weaves per mile	Weaves per VMT
Total Vol	Pearson Correlation	1	.070(**)	.335(**)	.293(**)	-.040	-.169(**)	-.118(**)	-.067(*)	.070(**)	-.061(**)
	Sig. (2-tailed)		.002	.000	.000	.074	.000	.000	.018	.002	.006
	N	1977	1977	1977	1977	1977	1977	1977	1244	1977	1977
Total Weaves	Pearson Correlation	.070(**)	1	.192(**)	.029	.078(**)	.020	.005	-.067(*)	1.000(**)	.962(**)
	Sig. (2-tailed)	.002		.000	.198	.001	.370	.838	.018	.000	.000
	N	1977	1977	1977	1977	1977	1977	1977	1244	1977	1977
Legal/Illegal	Pearson Correlation	.335(**)	.192(**)	1	.398(**)	.071(**)	-.282(**)	-.184(**)	-.232(**)	.192(**)	.117(**)
	Sig. (2-tailed)	.000	.000		.000	.002	.000	.000	.000	.000	.000
	N	1977	1977	1977	1977	1977	1977	1977	1244	1977	1977
Site	Pearson Correlation	.293(**)	.029	.398(**)	1	.112(**)	-.031	-.392(**)	-.266(**)	.029	-.050(*)
	Sig. (2-tailed)	.000	.198	.000		.000	.164	.000	.000	.198	.026
	N	1977	1977	1977	1977	1977	1977	1977	1244	1977	1977
Phase	Pearson Correlation	-.040	.078(**)	.071(**)	.112(**)	1	-.463(**)	-.106(**)	.400(**)	.078(**)	.038
	Sig. (2-tailed)	.074	.001	.002	.000		.000	.000	.000	.001	.093
	N	1977	1977	1977	1977	1977	1977	1977	1244	1977	1977
Distance	Pearson Correlation	-.169(**)	.020	-.282(**)	-.031	-.463(**)	1	-.034	-.267(**)	.020	.041
	Sig. (2-tailed)	.000	.370	.000	.164	.000		.130	.000	.370	.070
	N	1977	1977	1977	1977	1977	1977	1977	1244	1977	1977
Time	Pearson Correlation	-.118(**)	.005	-.184(**)	-.392(**)	-.106(**)	-.034	1	.050	.005	.038
	Sig. (2-tailed)	.000	.838	.000	.000	.000	.130		.076	.838	.089
	N	1977	1977	1977	1977	1977	1977	1977	1244	1977	1977
Speed Difference	Pearson Correlation	-.067(*)	-.067(*)	-.232(**)	-.266(**)	.400(**)	-.267(**)	.050	1	-.067(*)	-.061(*)
	Sig. (2-tailed)	.018	.018	.000	.000	.000	.000	.076		.018	.032
	N	1244	1244	1244	1244	1244	1244	1244	1244	1244	1244
Total weaves Per mile	Pearson Correlation	.070(**)	1.000(**)	.192(**)	.029	.078(**)	.020	.005	-.067(*)	1	.962(**)
	Sig. (2-tailed)	.002	.000	.000	.198	.001	.370	.838	.018		.000
	N	1977	1977	1977	1977	1977	1977	1977	1244	1977	1977
Total weaves Per VMT	Pearson Correlation	.061(**)	.962(**)	.117(**)	-.050(*)	.038	.041	.038	-.061(*)	.962(**)	1
	Sig. (2-tailed)	.006	.000	.000	.026	.093	.070	.089	.032	.000	
	N	1977	1977	1977	1977	1977	1977	1977	1244	1977	1977

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).)

The next step was to perform a regression tree analysis and identify variables appear to affect weaving intensity. The objective of a regression tree is to identify which variable should be selected to split the data into two groups that will produce the maximum reduction in variability (Washington, et al, 1997). The tree analysis employs variables to split the sample at breaks that reduce variance creating nodes. Each node contains part of the observations is then analyzed again and split by the variable which once again reduces the variance of the cases in each node. The tree stops once the variance can't be reduced beyond a set criteria or a minimum number of data points remain on each side of a split.

The rpart function in R was used to create the regression tree. Only five minute time periods where speed difference data are available were used (n =1222). The regression tree analysis will use weaving intensity as the depended variable. The independent variables used will include**:** volume, type of weave, time of day, and speed difference. Volume was divided into a dummy variable of congested and uncongested, where five-minute periods have a total volume higher than 1200 vehicles per lane per hour (100 vehicles per lane per five minutes). Analyzing both lanes at the same time sets the threshold at 200 vehicles. Congested five-minute periods are coded as 1, while uncongested are coded as 0.

Figure 30 shows the results for the regression tree. The results split the data into a tree with eight terminal nodes. Along that path, each binary split of the tree is labeled with a decision rule that determines the correct path to take. The terminal nodes of the tree are labeled with values that represent the expected value of the dependent variable weaving intensity. The lowest expected weaving intensity value is for cases where the weaves are illegal and occur during Phase III, with a value of 0.008666 (N = 183). The highest expected value is close between two separate cases. The first is for illegal weaves during Phase II under uncongested situations;

weaving intensity of 0.218 (N = 48). The second case is for legal weaves during Phase III with a positive speed differential; weaving intensity 0.219 (N = 116).

The first split of the tree is between legal and illegal weaves. Legal/illegal weaves are divided into binary code 0, 1 and are split at 0.5. The split sends all illegal weaves to the left and all legal weaves to the right.

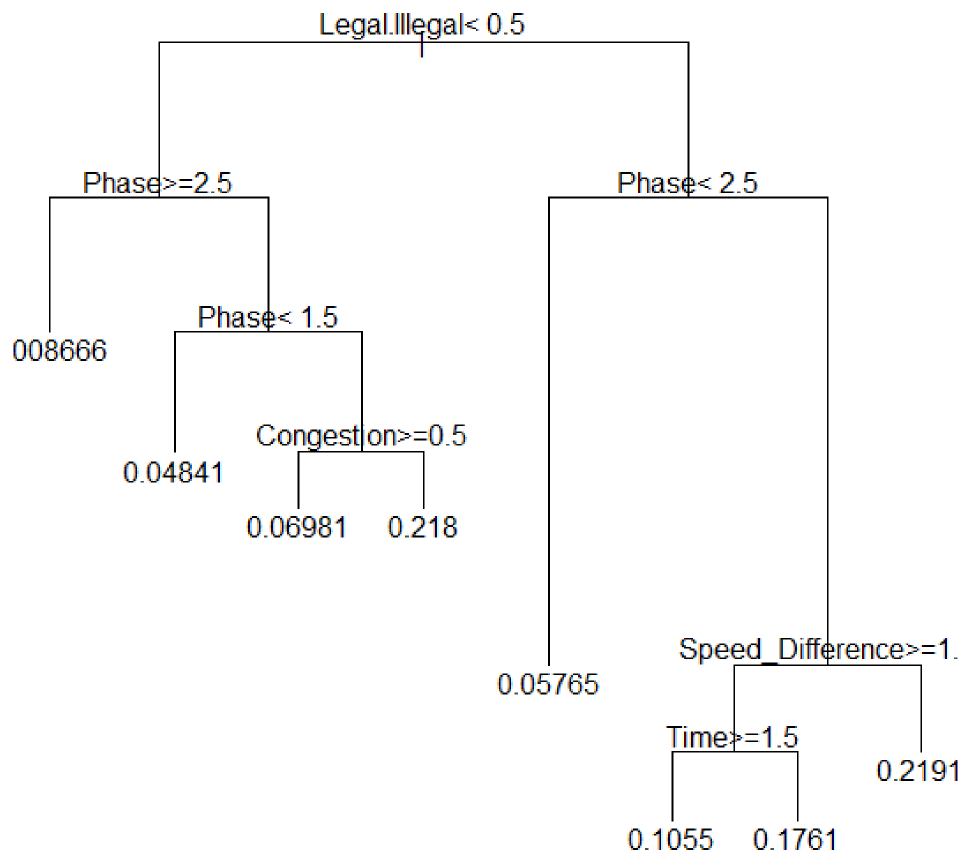
On the illegal side of the regression tree, the next variable split is by phase. The division occurs for Phase greater than or equal to 2.5. This means the analysis grouped Phase I and II (right) together and Phase III (left) stood alone. This split makes sense due to the fact that Phases I and II have an HOV managed lane system, but Phase III has an HOT managed lane system. Phase III illegal weaves was not split anymore and resulted in the lowest weaving intensity (0.00866). Phases I and II on the other hand, were once again split by Phase by sending all data whose phase was less than 1.5 to the left (Phase I) and the rest to the right (Phase II). The Phase I illegal weaves were not split again and gave a weaving intensity of 0.048. This value is approximately twice the weaving intensity found in Phase III illegal weaves. The final split on the illegal side of the regression tree was congestion. Congestion was separated by moving all data with a congestion value less than 0.5 to the left (uncongested) and all the rest to the right (congested). The two values for weaving intensity were 0.069 for uncongested illegal Phase II weaves and 0.218 for congested illegal Phase II weaves. The congested weaving intensity was three times that of the uncongested. As stated above the restriping of the weaving zones may have altered the way people use the managed lane system. The restriping, combined with a high level of congestion may have resulted in the higher illegal weaves. Congestion was not an important enough factor to affect the weaving intensity between the two lanes during Phases I and III.

On the right side of the tree, the data contained all legal weaves. Once again the second split was Phase and it split up the phases by anything greater than 2.5 to the left and the rest goes to the right. The split is the same as the split noted on the illegal side of the tree as the model determines that Phase III affects weaving intensity on its own. The weaving intensity for Phase III legal weaves 0.058.

Phase I and II on the legal side of the tree (right), are then split by the speed difference. Speed difference is split between positive and negative. Negative speed difference, or cases when the general purpose lane is traveling at a faster average speed than the managed lane, were moved to the left side of the node and split once again by time of day. The afternoon data were moved to the left because they were assigned the label “2” and the rule split the data by time of day greater than or equal to 1.5. The afternoon data had a predicted weaving intensity of 0.105 compared to the 0.176 predicted weaving intensity for the morning data. The regression tree states that for legal weaves during Phase I and II in the morning, there was a higher weaving intensity when the general purpose was moving faster. Alternatively, for scenarios in which the managed lane is traveling faster, or the right side of the speed difference node, the predicted value was 0.219 which was the highest value.

Time and speed difference variables did not change the variability of the tree model for weaving intensity on the illegal weaving branch. Congestion was not a factor in weaving intensity during legal weaving. The same tree resulted when continuous variables were employed for both speed difference and total volume. No interaction variables have been tested to date.

Figure 30: Regression Tree



The final step in the analyses reported in this thesis was to develop a regression model to predict weaving intensity based upon regression tree results. The variables used for the model are the same ones used for the regression tree. Table 15 shows the results of the regression model. The adjusted R-Squared for the model was only 0.054 which is very low. This indicates that further detailed analysis of the data is warranted both in the regression tree step as well as the regression modeling step.

Table 15: Regression Results Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.240	.057	.054	.14489	.057	14.830	5	1216	.000

The regression analysis creates a function with a Beta coefficient for each variable. Table 16 shows the Beta coefficient for each of the variables used in the regression. The function for weaving intensity is the following:

$$\text{weaving intensity } (\text{density}^{-1}\text{mile}^{-1}) = .06^*\text{Legal/Illegal} + .029^*\text{Phase} + .011^*\text{Time}$$
$$- .013^*\text{Speed Differential} - .032^*\text{Congestion}$$

Table 16 shows that there is no major collinearity issue with the model. The significance shows that type of weave and phase are the most significant variables. As in the regression tree this variables created the initial splits. In addition, looking at the t-statistic type of weave and phase had the highest t-statistic (6.104 and 4.95 respectively). Time and speed had the lowest t-stat and were the least significant when predicting weaving intensity. However, these two variables were very broad and can be refined in future models. Congestion shows a high enough level of significance and t-statistic value to use as a predictor for weaving intensity. Nevertheless, congestion is also a variable that could be defined more specifically in order to create a better model for predicting weaving intensity.

Table 16 Regression Coefficient

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
(Constant)	.014	.026		.528	.598	-.038	.065					
Legal/Illegal	.060	.010	.184	6.104	.000	.041	.080	.177	.172	.170	.853	1.172
Phase	.029	.006	.146	4.950	.000	.017	.040	.144	.141	.138	.897	1.115
Time	.011	.008	.036	1.281	.200	-.006	.028	.008	.037	.036	.962	1.039
Speed	.013	.009	.041	1.377	.169	-.031	.005	-.035	-.039	.038	.857	1.167
Congestion	.032	.012	.080	2.755	.006	-.055	-.009	-.028	-.079	.077	.929	1.076

Finally, Table 17 shows the ANOVA analysis for the regression model. Table 17 shows the residual found in the model was 27.026 with a mean square of 0.022. The significance of the F value of the model shows that the variables do not show a linear relationship.

Table 17: Model ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.056	3	.019	.844	.470(a)
	Residual	27.026	1218	.022		
	Total	27.082	1221			

The model created is not a very good predictor of weaving intensity. However, it is the first step toward developing a reasonable model. Another regression tree with variables manipulated in a different way could potentially identify important variables and interactions that have not yet been considered. This study did not have the resources to study all the possible models and simply shows the initial step to creating a model. Ultimately it is likely that a choice model will be needed to more accurately predict weaving intensity.

CHAPTER 6

CONCLUSIONS

6.1 Results Discussion

The analyses reported in this thesis examined how different aspects of lane markings and freeway operation affected the weaving intensity into and out of a managed lane system. The analysis took three different time periods (Phases I, II, and III) and collected all volumes and weaving data. Each phase represented a different period in the managed lane system on the I-85 corridor in Atlanta, Georgia. The variables that were collected and studied were type of weave (legal vs. illegal), time of day (AM vs. PM), and speed difference between the managed lane and the leftmost general purpose lane. The variables were used to predict weaving intensity (weaves/VMT). After a statistical analysis of each variable individually and together the results showed the following:

- Weaving intensified after the change from a HOV lane to a HOT lane from 0.062 weaves/VMT in Phase I, to 0.090 weaves/VMT in Phase III (a 45% increase in weaving intensity).
- A decrease of 27% in weaving intensity out of the managed lane system was observed between Phases I and II after restriping but before the HOT lane opened. Illegal weaving intensity after restriping of the HOV lane increased by 58%, likely because of the reduction in presence and length of legal weaving sections.
- Weaving intensity out of the managed lane was 112% percent higher during the afternoon peak period than in the morning peak period for both HOV and HOT operations.

- A difference of 0.073 in weaving intensity was observed between weaving out of the managed lane and into the managed lane in the afternoon, compared to a difference of -0.018 in the morning for both HOV and HOT operations.
- Illegal weaving intensity was nearly eliminated (93% decrease) during Phase III, decreasing from 0.064 weaves/VMT in Phase I to 0.004 weaves/VMT in Phase III at the locations monitored.
- Weaving intensity into and out of the managed lanes (for all phases) were similar when the managed lane had an average speed higher than the general purpose lane (0.097 weaves/VMT into vs. 0.092 weaves/VMT out of the managed lane). However, when the managed lane (both HOV and HOT) had an average speed lower than the general purpose lane weaving intensity was much higher out of the managed lane (0.186 weaves/VMT) than into the managed lane (0.065 weaves/VMT).
- During HOT operation (Phase III), the difference between weaving intensity out of the managed lane and into the managed lane was even bigger (0.419 vs. 0.120) for a negative speed difference.
- Regression trees indicated that the type of weaving sections (legal vs. illegal) and the conversion phases were the most important aspect when predicting weaving intensity.

The opening of the HOT system clearly affected weaving along the corridor. After the HOT lane opened, illegal weaving decreased significantly. Before conversion, drivers using the managed lane would weave into the general purpose lane when the general purpose lane was moving at a higher speed. However, after the opening of the HOT, this weaving out of a slower

HOT lane increased significantly, indicating that drivers are not probably willing to pay for HOT lane use unless they see clear benefits. A higher weaving intensity in the afternoon may indicate a potential correlation between commute behavior and weaving. The morning commute is more likely to be a non-stop commute trip, while in the afternoon trip chaining and travel variability may increase resulting in increased weaving. The trends found in this thesis are important; however, additional data collection and detailed analysis should yield a better model and prediction of weaving intensity.

6.2 Future Research

A number of additional analyses are recommended to improve and expand this research. It will be important to see the effects of the magnitude of speed differential on weaving. In addition, a more specific analysis of time of day could be added to the regression tree analysis. Time of day could be divided into hours or closest half hour in order to further analyze how weaving intensity changes throughout the AM and PM peak hours. Finally, it would be interesting to see how congestion affects weaving if it is looked at by lane instead of using the total density for both lanes combined. Future research should include a similar regression tree and regression analysis with more specific variables. In addition, a choice model may be necessary to truly predict how a corridor and a particular managed lane system affect weaving intensity and effective capacity.

APPENDIX A

I-85 EXPRESS LANE SIGNS

Georgia Department of Transportation

I-85 EXPRESS LANE SIGNS – WHAT ARE THEY SAYING?

SIGN CHANGE BEGINS FRIDAY, SEPTEMBER 16

The process to change Express Lane signage to its permanent text is scheduled to begin Friday, September 16. The 10-day sign change process is planned for overnights only from 8 p.m. to 5 a.m. with up to triple lane closures on the interstate. Six crews will make the necessary changes to 105 signs on 60 support structures in the 16-mile corridor in DeKalb and Gwinnett counties. The changes also require removal of 94 HOV signs.

Pavement markings will also be changed from HOV Only to Express Lane Only as signs are changed. Crews will work in both directions of I-85 at the same time. Changes will begin on I-85 southbound at Suwanee and continue south. Changes will begin on the northbound lanes of the interstate north of Clairmont Road and continue north.

Based on new federal guidelines (2009 MUTCD) all new Express Lane signs must have a purple background for the Peach Pass header and a green background for the sign body. Consistent express lane signage colors across the U.S. ensure that motorists will quickly recognize express lanes and toll lanes wherever they travel.

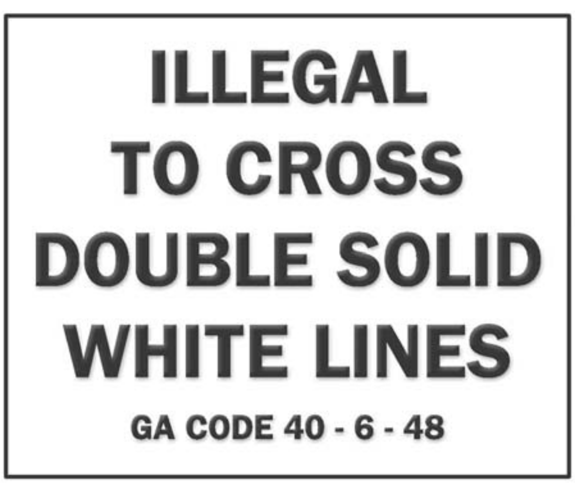
This sign is located one mile before the beginning of the express lane, both NB and SB. It gives potential express lane users adequate notice to safely move to the left to enter the designated lane.

- **Users must have a registered Peach Pass transponder before entering the lane.**
- These **registered** vehicles can use the lane for free: carpools with three or more occupants; transit vehicles (e.g. GRTA Xpress coaches, MARTA buses, van pools); motorcycles; on-call emergency vehicles; and alternative fuel vehicles (AFV) with the proper AFV license plate (does not include hybrid vehicles).
- Other **registered** vehicles can use the lane by paying a variable toll.

The sign above gives potential Express Lane users the toll rate or range for that entry point and are strategically placed prior to each entry point.

- The sign states that this is an Express Lane to be used only by Peach Pass customers.
- The top rate is the charge from that entry point to the next exit.
- The bottom rate is the charge from that entry point to the last exit on the Express Lane stretch.
- If a motorist exits in between, their toll rate will be between the two stated rates.
- Once a motorist enters at an entry point, their rate or range will not change.

This sign is at the beginning of the Express Lane and at all entrance (access) points to the Express Lane system. It specifies that only registered Peach Pass customers may use this lane, which is the far left lane.



This sign reminds motorists according to Georgia Code §40-6-48, it is illegal to cross the double solid white lines to enter or exit the Express Lane. Doing so is a violation and offenders will be fined $25.00 plus the amount of the toll.

This sign is visible throughout the Express Lanes corridor and advises that only registered Peach Pass customers are allowed to use the Express Lane.

This sign gives the Express Lane user ample notice to exit the lane at the upcoming broken white lines for the specified interstate exits.

- Entrance and exit points from the Express Lanes do not always coincide with interstate entrance and exit ramps.
- Express Lane users must pay attention to their upcoming interstate exit and leave the Express Lane accordingly.

This sign located throughout the Express Lanes corridor, indicates fines of up to $150 for each express lane violation including:

- Use of Express Lane by non-registered vehicles
- Crossing double solid white line to enter or exit Express Lane
- Vehicle registered in the wrong toll mode. For example, driver not changing a three- person toll mode to a two-person toll mode when appropriate.

Appendix B: Proposed Procedures for Changing TMC PTZ Camera Views During I-85 Video Data Collection Efforts (Toth, 2012)

December 14, 2010

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Jorge Laval, Professor

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Proposed Procedures for Changing I-85 TMC PTZ Camera Views

The GDOT Traffic Management Center uses pan-tilt-zoom (PTZ) cameras to monitor incidents and adverse traffic conditions. Using the cameras for any other purpose is of secondary priority to this incident monitoring function. Beginning in January 2011, Georgia Tech Faculty and Staff Assistants will be collecting video data from the PTZ cameras along the I-85 corridor for weaving and effective capacity analysis. Georgia Tech staff plan to move the cameras for the purposes of video data collection only when TMC staff members are not actively using the camera views. This report describes the proposed protocols that Georgia Tech staff will follow in changing PTZ camera views along the I-85 corridor for data collection purposes.

Background

Beginning in January 2011, the Georgia Tech team will begin collecting video data from the I-85 HOV-to-HOT corridor for the purposes of assessing effective capacity of the managed lanes before and after HOT conversion.

Processing of video data for weaving analysis involves assessment of the gap separation between vehicles when a weave occurs. Baseline camera views for each camera are pre-assigned and distance calibration is performed for each baseline view. With proper calibration, video post-processing provides reasonable estimates of gap separation based upon the pixel separation of vehicles on the video image. To be useful, weaving analysis video must be collected from each camera's baseline camera position.

The primary use of the cameras is for the TMC operators to monitor incidents and adverse traffic conditions. The Georgia Tech data collection effort is secondary to TMC use of the cameras. The team will be collecting a very large amount of video data to ensure that data loss associated with the relocation of camera views by TMC operators to monitor incidents should not cause any major problems in analytical efforts. However, the Georgia Tech team will need to return each camera to its baseline position before the video will provide useful data for weaving analyses.

TMC Notification

Maintaining continuous baseline camera positions significantly helps in the data collection efforts. Hence, it will help if TMC operators can avoid moving camera views on the corridor for non-incident-related purposes during video data collection periods. The Georgia Tech team will provide a schedule to the TMC indicating when the I-85 cameras will be used for data collection. The Georgia Tech team will also call 511 each morning and afternoon that data are being collected to remind the operators about the data collection effort.

Procedures for Moving Camera Views

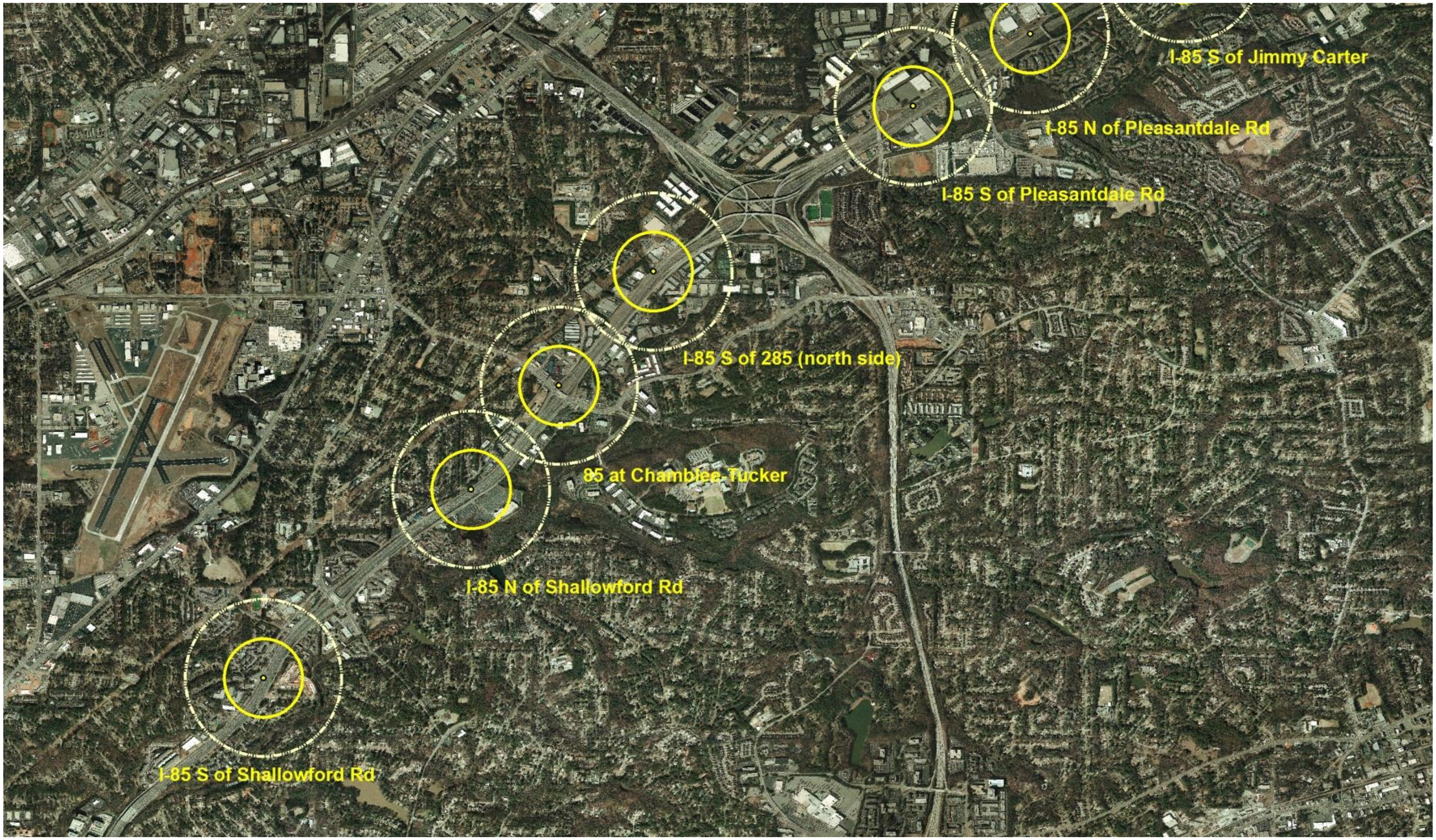
Georgia Tech staff will periodically monitor the camera views to determine when a camera has been moved from its baseline data collection position. If a camera has been moved by a TMC employee during the recording period, the camera view ***will not be*** automatically or immediately repositioned by Georgia Tech staff.

GT staff will first look for any obvious cause of the camera movement by studying the field of view and looking for an incident or an adverse traffic condition. Under no circumstances will cameras be moved if adverse traffic conditions are being monitored or an incident is active. Once an incident ends, GT staff members will wait at least 10 minutes prior to repositioning the camera back to its baseline view. Even if no incident or adverse traffic conditions are present in the camera view, the research group will wait 10 minutes before moving the camera back to its original baseline position in case the TMC operator was looking at some other condition. If after GT staff reposition the camera, the camera is again repositioned by TMC staff with no obvious incident in the field of view, GT staff will leave the camera in its current position and will call 511 to ask whether the TMC staff still need that camera view or whether the view can be returned to the baseline position for data collection.

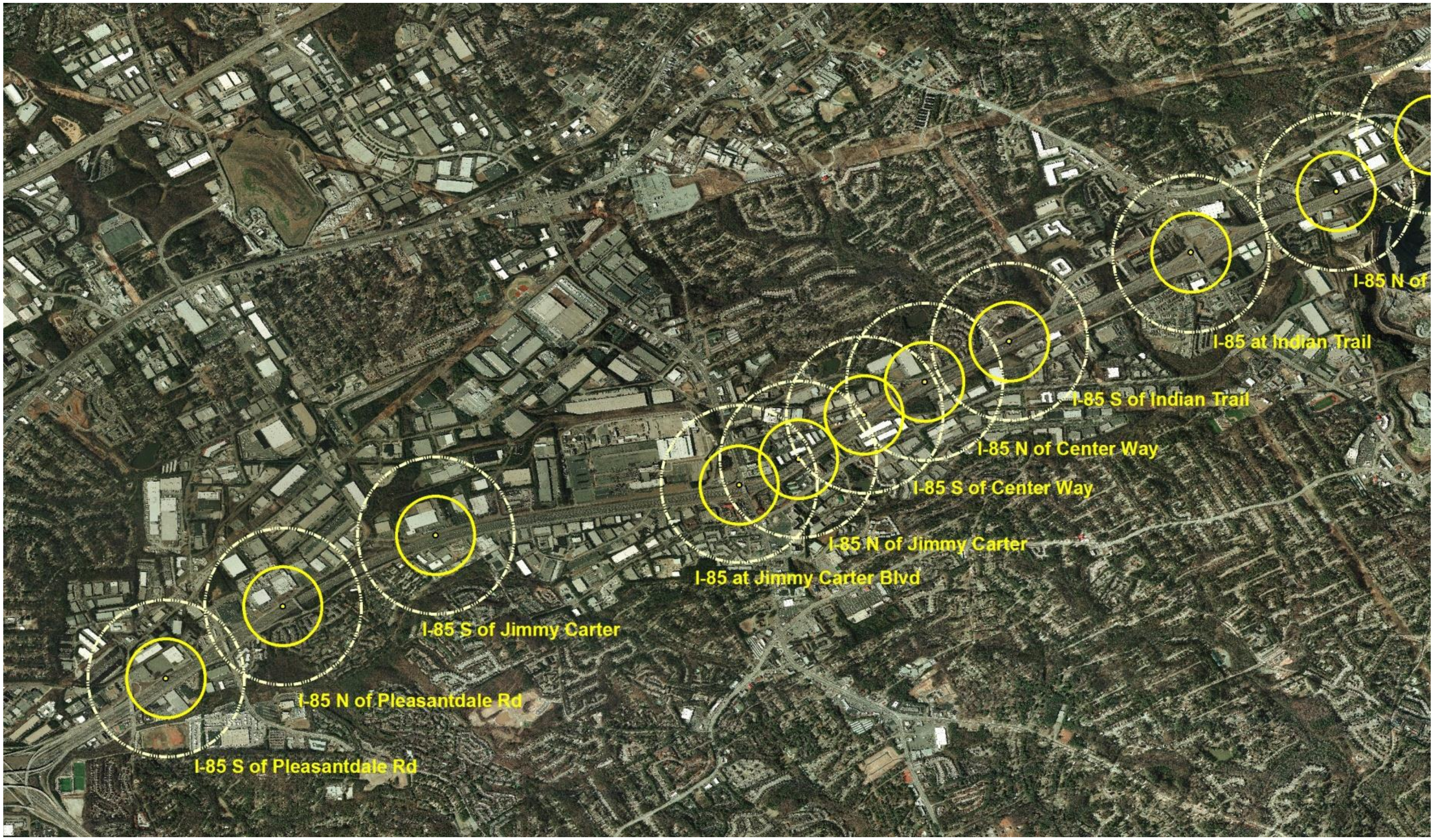
In summary, GT staff will ***not*** *move camera views when:*

- The camera is monitoring an incident or adverse traffic condition
- Ten minutes after an incident or adverse traffic conditions has ended
- Ten minutes after a camera has been moved by a TMC operator

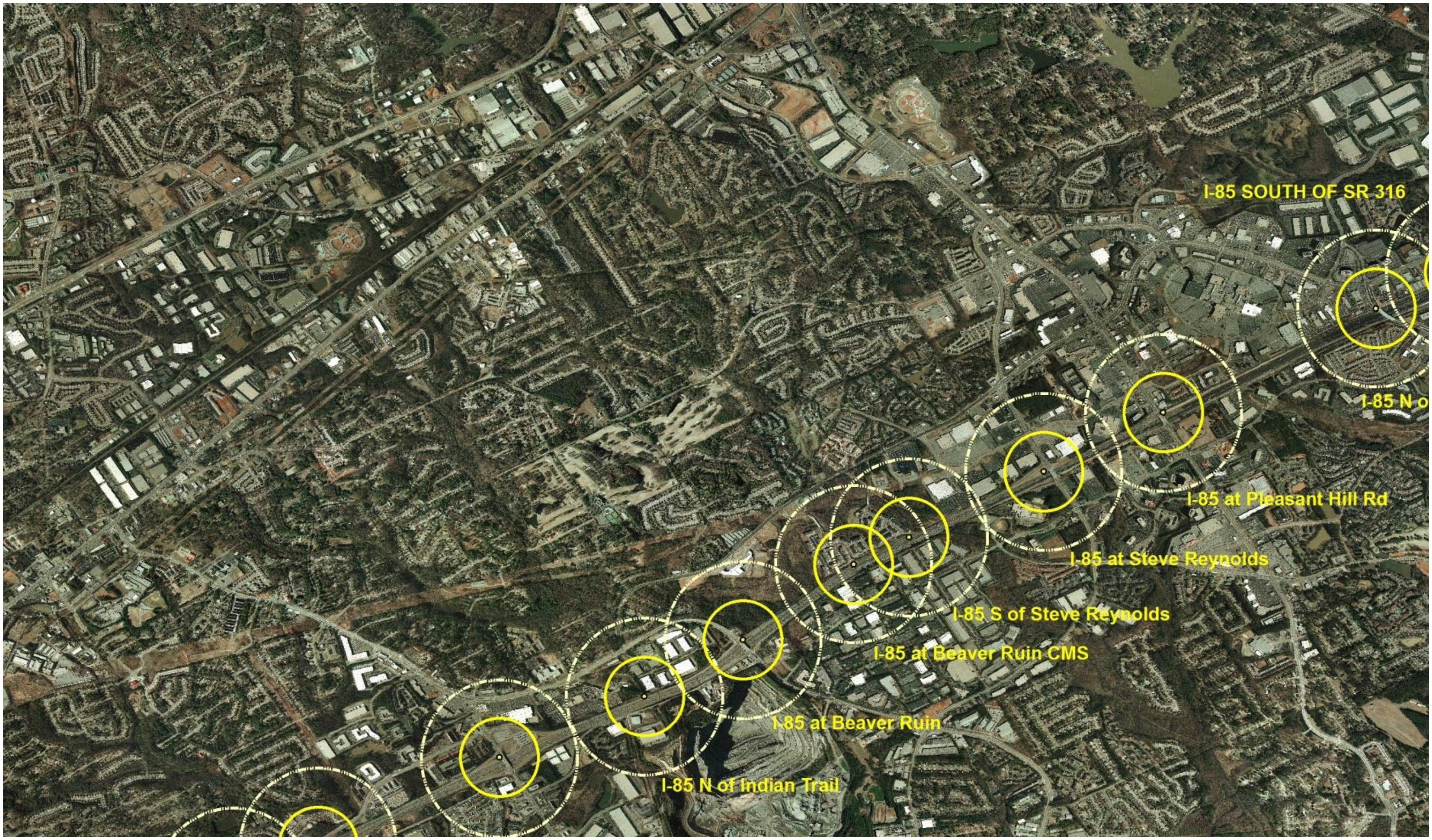
APPENDIX C: I-85 CAMERA COVERAGE (Shallowford to Pleasantdale) (Toth, 2012)



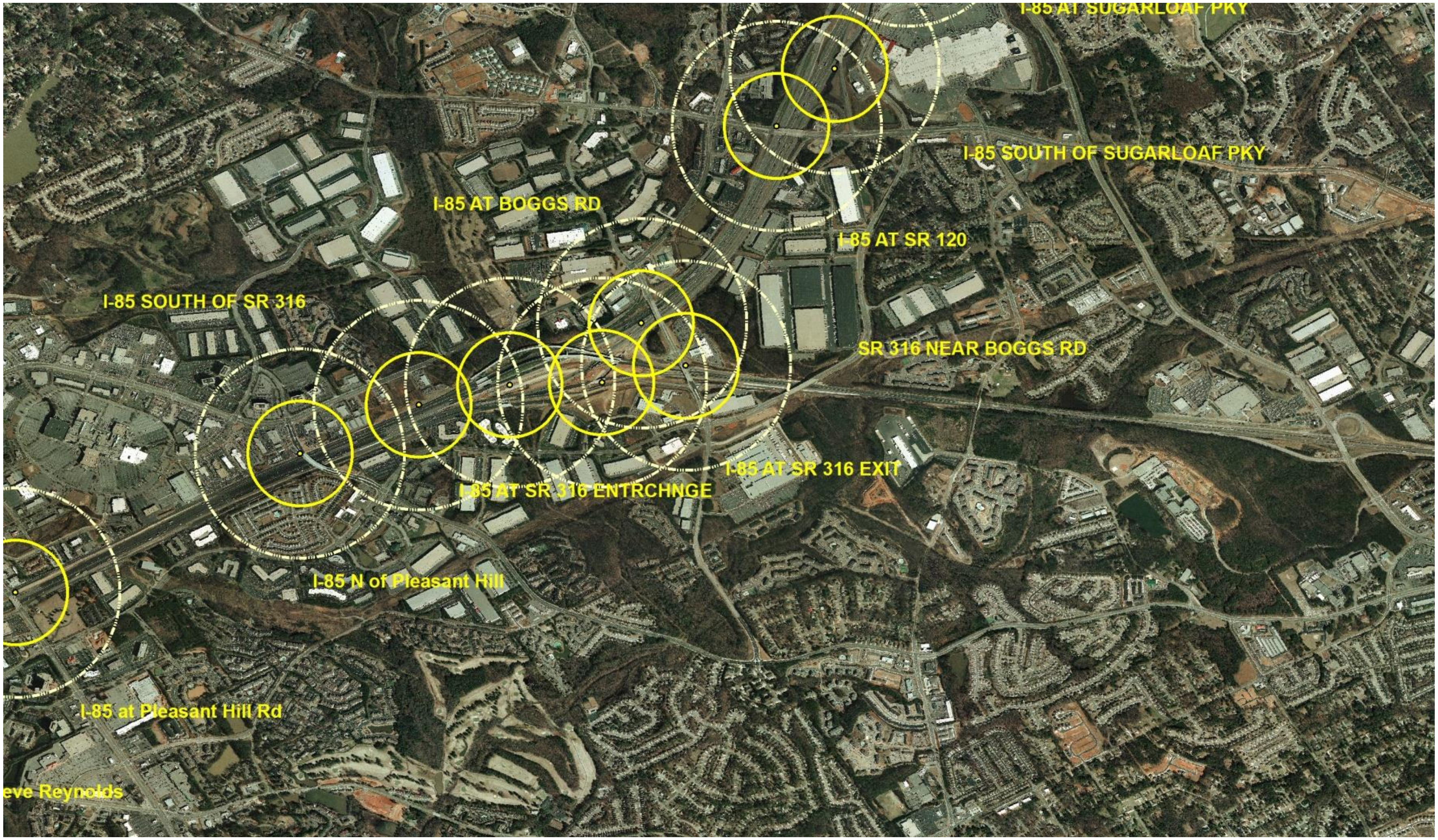
APPENDIX C: I-85 CAMERA COVERAGE (Pleasantdale to Indian Trail) (Toth, 2012)



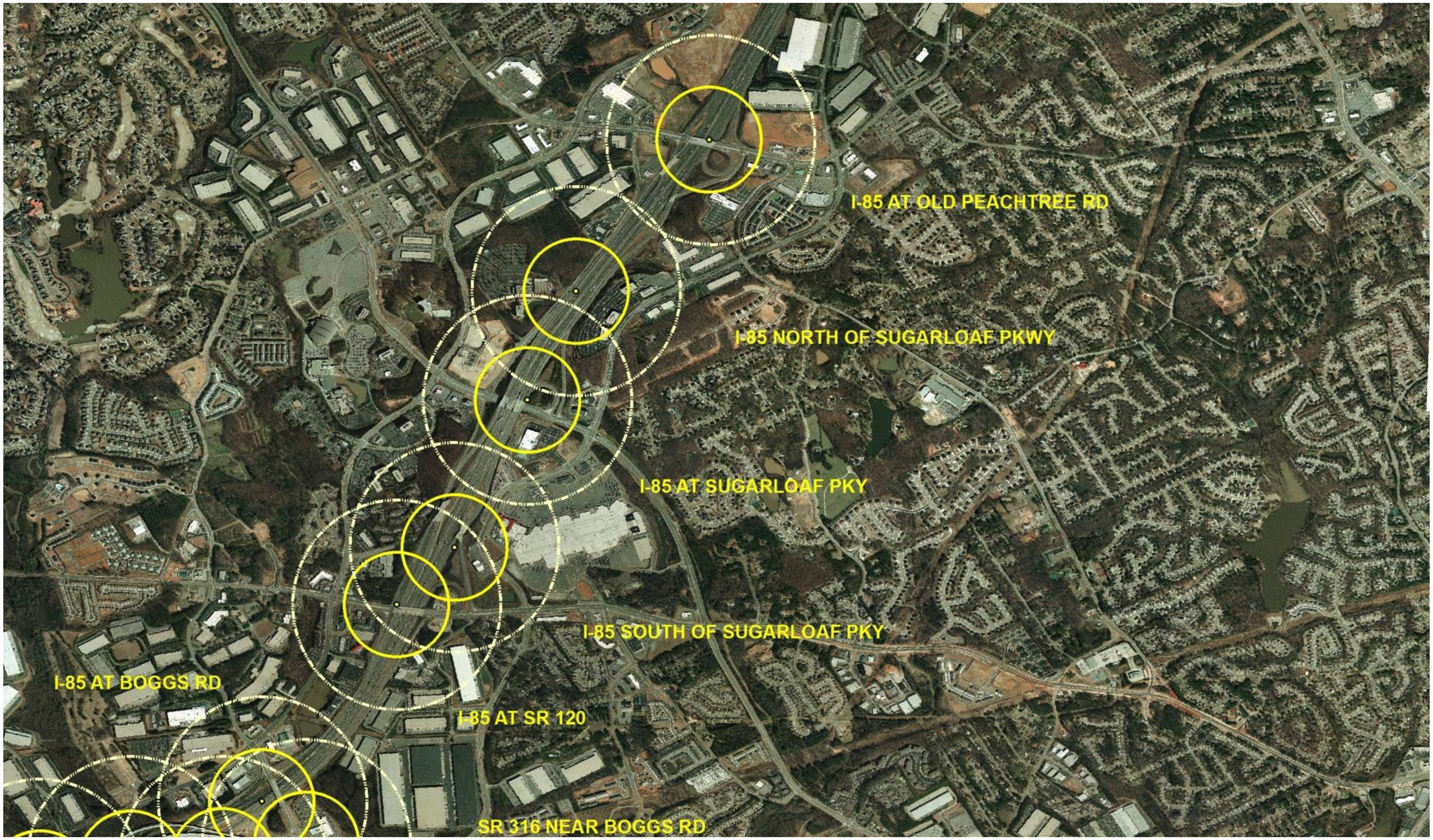
APPENDIX C: I-85 CAMERA COVERAGE (Indian Trail to Pleasant Hill) (Toth, 2012)



APPENDIX C: I-85 CAMERA COVERAGE **(Pleasant Hill to Sugarloaf) (Toth, 2012)**



APPENDIX C: I-85 CAMERA COVERAGE (Sugarloaf to Old Peachtree) (Toth, 2012)



APPENDIX D: SCREENSHOTS OF CAMERA VIEWS USED DURING RECORDING (Toth, 2012)

1. TMC Camera 46: I4

2. TMC Camera 84: I4

3. TMC Camera 87: I1

4. TMC Camera 101: L1, L3

5. TMC Camera 102: L1, L3

6. TMC Camera 104: I2

7. TMC Camera 104: I5

8. TMC Camera 106: L2, L4

9. TMC Camera 110: E1

10. TMC Camera 124: I3

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