GEORGIA DOT RESEARCH PROJECT 14-43

FINAL REPORT

OPERATIONAL EVALUATION OF DO NOT BLOCK THE BOX CAMPAIGNS IN GEORGIA

OFFICE OF PERFORMANCE-BASED
MANAGEMENT AND RESEARCH

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GDOT Research Project No. RP 14-43

Final Report

OPERATIONAL EVALUATION OF DO NOT BLOCK THE BOX CAMPAIGNS IN GEORGIA

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16. Abstract

The overarching objective of this research is to provide the Georgia Department of Transportation (GDOT) and the Perimeter Community Improvement District (PCID) with an evaluation of the operational performance impacts of implementing a "Do Not Block the Box" (DBTB) campaign at selected signalized intersections. For the studied sites, the likelihood, or propensity, of a vehicle to block was measured both before and after the DBTB treatment installation. Several blocking behavior characteristics were seen throughout the analysis. First, the change in propensity with the installation of the DBTB treatment was inconsistent, witnessing both increasing and decreasing blocking rates. However, regardless of an increase or decrease in blocking rate, the aggregated observed propensities at the studied intersections were consistently high in both the before and after treatment conditions. The lowest observed aggregate propensity to block was 55%, with all other time periods above 60%, and with half of the observed periods having a propensity to block of 70%. In addition, there was significant variability in day-to-day blocking opportunities. While the current treatment as a standalone measure did not meaningfully impact blocking behavior, there is significant value in continuing to seek reductions in blocking behavior. Based on the study findings and field observations during the data collection, several recommendations are offered in this report.

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EXECUTIVE SUMMARY

Traffic congestion is often an unfortunate reality. As such, it is necessary to manage congestion, minimizing its impacts. In congestion, when a vehicle enters an intersection that has insufficient space to exit on the opposite side due to downstream traffic spillback, it often leads to the obstruction of vehicle and pedestrian movement on conflicting approaches. The effect of "blocking the box" can propagate to nearby intersections and, in extreme cases, lead to gridlock. Along with negative traffic impacts such as capacity reductions and increased travel times, blocking the box creates potentially unsafe vehicle and pedestrian movement. A "Do Not-Block-The-Box" (DBTB) treatment seeks to reduce the likelihood of drivers entering an intersection when there is insufficient space to exit, and thus reduce blocking occurrences. DBTB treatments are typically low cost, representing a traffic management alternative accessible to most transportation agencies. This report presents a study that explored the performance of DBTB treatments installed in the greater Atlanta area.

For the studied sites, the likelihood, or propensity, of a vehicle to block was measured both before and after the DBTB treatment installation. Several blocking behavior characteristics were seen throughout the analysis. First, the change in propensity with the installation of the DBTB treatment was inconsistent, witnessing both increasing and decreasing blocking rates. However, regardless of an increase or decrease in blocking rate, the aggregated observed propensities at the studied intersections were consistently high in both the before and after treatment conditions. The lowest observed aggregate propensity to block was 55%, with all other time periods above 60%, and with half of the observed periods having a propensity to block of 70%. In addition, there was significant variability in day-to-day blocking opportunities. That is, at the same intersection, within the same week, peak periods where opportunities to block were rare or non-existent were observed, as well as peak periods with significant blocking opportunities. *Given these findings it may not be concluded that the installed treatments reliably impacted blocking behavior*. In addition, where sites did show improvements, the blocking rate remained high, often well in excess of 50%.

There are potential biases in this study. The first is that the sites were not randomly selected, but instead were identified as high blocking sites by system managers. These sites may represent the worst-case scenarios and those most difficult to address. In addition, the after data collection at several sites occurred during the I-85 bridge closure. It is not known if the potential rerouting or other driver responses to that incident may have influenced the observed driver behavior. Finally, several sites utilized police officer control during the highest demand periods. If the police were not present, these time periods may have experienced different blocking behavior than the time periods included in the evaluation. However, even given these potential biases, there still remains a failure of the DBTB treatment to address blocking under these conditions.

While not measured at these sites, it is important to highlight that a reduction in blocking may result in significant operational improvements. To explore potential performance impacts of blocking, a microscopic simulation model of blocking behavior was developed. The simulation reflects the propensity of a vehicle entering the intersection box when a blocking opportunity exists and the resulting blocking of traffic, should a vehicle “block the box.” This model allowed for the exploration of the relationship of blocking behavior to vehicle delay and intersection capacity. It showed that the impact of blocking can be significant, potentially resulting in gridlock. However, the simulation also was able to demonstrate that DBTB treatments can significantly improve traffic flow even without achieving zero blocking. From this it may be postulated that many of the intersections that were included in this study could significantly benefit if blocking could be reduced. While the treatments in the current field study did not demonstrate the blocking rate reductions necessary for meaningful operational benefits, the simulation study does highlight the importance for continuing to seek a solution to the DBTB challenge.

While the current treatment as a standalone measure did not meaningfully impact blocking behavior, there is significant value in continuing to seek reductions in blocking behavior. Thus, based on the study findings and field observations during the data collection, several recommendations are offered.

1) **Signal timing to reduce blocking opportunities.** The first strategy to address blocking should be, where possible, the elimination of the potential for blocking utilizing congested period signal timing that reduces blocking opportunities. Blocking opportunities occur where the flow of vehicles into an intersection exceeds the intersection capacity, often reflected as spillback into upstream intersections. Where practical, upstream signal timing should be set to limit downstream vehicle arrivals to that of the downstream intersection processing capacity. While this may result in lower upstream performance, avoiding the gridlock within the network resulting from spillback and blocking should be prioritized. The development of such signal timings will typically require the use

of advanced simulation tools applied at the corridor level over time periods greater than the typical peak-hour analysis. While this represents a significant investment in timing plan development, the potential benefits are substantial.

2) **Reduction or elimination of free-flow turn movements during congested periods.** One key observation at several sites is related to the impact of free-flow turn movements on intersection operations. Under high demand conditions a free-flow movement could continuously "fill-in" available capacity on the departure lanes of an intersection approach. This would result in vehicles from a controlled movement utilizing the same departure lanes continually being unable to proceed when they receive a green indication. It is reasonable to hypothesize that this increases the driver frustration and aggressiveness from the controlled movement, resulting in additional blocking, as this was seen as their only opportunity to proceed through the intersection.

3) **Limit candidate intersections.** While blocking the box occurs when a vehicle stops within the box, in a practical sense many of the observed "blocks" had minimal or no observed impacts on intersection capacity. This could occur for two reasons. The first is that the size of the intersection allowed conflicting vehicles to easily maneuver around the blocking vehicle(s). The second is that the blocking and blocked vehicles used the same intersection departure lanes. In such an instance, while blocking occurs there is no intersection capacity impact. In both situations, as drivers see minimal to no benefit of the treatment this may increase the likelihood of disregarding the treatment.

4) **Public education.** A public education program on the benefits of not blocking the box may help to decrease the propensity to block and reinforce the need to follow DBTB treatments.
5) **Enforcement.** Along with public education, there is likely a need for enforcement. For the given study, none of the intersection DBTB treatments were enforced through citations to drivers that blocked the box. The effectiveness of enforcement in improving the DBTB treatment performance should be explored. This should include different enforcement program durations (i.e., intermittent vs. continual), warnings vs. citations, automated vs. manual citations, etc.
6) **Additional Treatment.** Additional treatments should be developed and tested (e.g., flashing DBTB signs that are indicated only when vehicles are detected stopped in intersection departure lanes).

Finally, the most probable means to successfully address intersection blocking is the development of a DBTB overarching program. Such a program would combine the above recommendations into a comprehensive strategy, developing training directed at identifying factors contributing to blocking at specific intersections, developing a signal timing plan guidance addressing blocking, designing DBTB signals and striping, and implementing widespread education, etc.

Chapter 1: INTRODUCTION

When a vehicle enters an intersection that has insufficient space to exit on the opposite side due to downstream traffic spillback, it often leads to obstruction of vehicle and pedestrian movement on conflicting approaches. The effect of "blocking the box" can propagate to nearby intersections and, in extreme cases, lead to gridlock. Along with a negative impact on traffic, such as capacity loss and increased travel times, it also increases the potential for unsafe vehicle and pedestrian movement (1, 2).

There are several measures that are used to help prevent gridlock, including retiming signals, promoting other modes of transportation, increasing capacity of the intersection by redesigning the geometry, and installing box junctions. Box junctions, also known as "Do Not Block the Box" (DBTB) campaigns, have proven to be an economical traffic management alternative in several countries around the world, including the United States. The primary advantage of a successful DBTB campaign is that the intersection itself remains clear, even if traffic is spilling back from a downstream intersection. By preventing this downstream spillback from blocking movements from other conflicting directions, those movements with unconstrained receiving lanes should not experience any unnecessary congestion and thus avoid gridlock and the associated negative economic and traffic operations impacts.

1.1 Background

In 1964, the first box junction was installed in London and was generally seen as a successful traffic management measure (3). This idea soon spread to different countries having ties to the United Kingdom, including Ireland, Australia, and New Zealand. Later, other European and Asian countries also adopted this traffic control method. In the U.S., the first box junction was applied by the New York City Department of Transportation in 1971, where it was shown to improve traffic operations. By the 1980s, DBTB had become popular in the City of New York (4). Subsequently, the District of Columbia and the Cities of Boston and Miami aggressively adopted DBTB campaigns (3, 5, 6). The success of the DBTB campaigns in Miami and Boston can be attributed, at least in part, to extensive public/private partnerships. Recently (April 2015), a new DBTB campaign was adopted by the City of Austin, Texas (7).

These DBTB campaigns endeavor to control traffic operations by placing several signs before the intersection and at the intersection, and painting a “boundary box” on the pavement within the intersection, consistent with the standards of the MUTCD (8). Under the DBTB rules, if a vehicle is inside the box when the movement on the opposing approach has the right-of-way, it is under violation and is potentially subject to a traffic ticket, thereby creating an incentive to keep the intersection clear and reduce blocking of the opposing movements. The operational benefits of this approach are dependent upon several factors, including the location and size of the intersection, and the right-turn traffic movement policy.

1.2 Project Objectives

The overarching objective of this research is to provide the Georgia Department of Transportation (GDOT) and the Perimeter Community Improvement District (PCID) with an evaluation of the operational performance impacts of implementing a DBTB campaign at selected signalized intersections. The study also determines how variations in conditions among these intersections impact the effectiveness of DBTB. Collectively, these results are expected to aid decision-making regarding future DBTB implementations in Georgia.

The key sub-objectives of the project may be summarized as follows:

- Provide a review of the existing studies on "Do Not Block the Box" or "box junction" enforcement laws, and operational performance analysis
- Develop a data analysis plan to identify and quantify the factors that influence the effectiveness of DBTB at the selected intersections
- Extract and post-process the relevant data consistent with the above plan
- Perform a before–after analysis of the selected intersections undergoing DBTB implementation to evaluate differences in operational performance
- Prepare a final report and make recommendations

The remainder of this report provides additional DBTB background, the data collection and analysis methodology (Chapter 2), findings based on field data (Chapter 3), and conclusions and recommendations (Chapter 4). A literature review chapter is not included in the report to avoid repetition of previous documentation. This project represents a continuation of GDOT project RP 13-16: Enhanced Role of Activity Center Transportation Organizations in Regional Mobility. A review of previous DBTB efforts is found in that document. In addition, a detailed review of DBTB is available in the TRB paper, "Analysis of Vehicle Blocking Behavior on Intersection Performance," in Appendix A.

Chapter 2: DATA EXTRACTION AND ANALYSIS METHODOLOGY

2.1 Introduction

A vehicle entering an intersection without sufficient space to exit on the opposite side during that vehicle's phase is referred to as "blocking the box." Blocking often results in obstruction of pedestrians and other vehicles. If unchecked, intersection blocking may escalate to gridlock. For this study (with the exception of one intersection to be discussed in Chapter 3), a blocking event is considered to occur when a vehicle enters the intersection box, is not able to exit during its given phase, and obstructs conflicting phases with the right-of-way (green indication). Blocking reduces the effective green time and capacity of the obstructed movement. In this document, an approach lane that is blocked is referred to as the *blocked lane* and the approach lane from which the blocking vehicle enters the intersection is referred to as the *block-source lane*.

To study the operational impact of "Do Not Block the Box" treatments, intersection video recordings were taken during peak and adjacent off-peak demand conditions, before and after implementation of DBTB signing and marking. Data were extracted from the videos to facilitate the DBTB data analysis process. DBTB field data analysis primarily included measuring the propensity to block, i.e. the likelihood of an individual to enter an intersection when insufficient space exists to exit. Field data were used also to calibrate a VISSIM model, in which the impact on traffic characteristics, such as delay and capacity of vehicles' propensity to block, was studied in the simulation environment. This chapter discusses the data collection process, and the propensity-to-block estimation methodology.

Chapter 3 then presents the findings based on the field data collection and Chapter 4 presents the VISSIM findings.

This chapter is divided further into three sections. *Section 2.2: Video Data Collection Process* discusses the data collection equipment, video recordings parameters, and data collection challenges. *Section 2.3: Video Data Extraction Software* discusses the software developed to assist in the video data extraction process, which was named the "Georgia Tech Multi Video Player" (GT-MVP). Finally, *Section 2.4: Methodology to Estimate Propensity to Block* presents a detailed description of the steps involved to estimate the propensity to block at an intersection.

2.2 Video Data Collection Process

In this section, the videos recorded at intersections prior to DBTB installation are referred to as *before-DBTB intersection videos,* and the videos recorded at intersections after DBTB installation are referred to as *after-DBTB intersection videos*. Not all before-DBTB intersections are included in the final after-DBTB intersection data set.

To study the impact of DBTB campaigns on blocking behavior, 7–12 hours of traffic videos for each of 4–10 days were recorded at the study intersections. Chapter 3 provides detailed lists of the intersections and the number of hours of video data collected and processed for before- and after-DBTB implementation at the study intersections. To view traffic signal indications and vehicles on the corresponding approach lanes, the video recording setup sought to capture all intersection approaches and all signal indications. To achieve this, multiple cameras (i.e., two to four) were deployed at each intersection. For five before-DBTB intersections, video data recording was outsourced to a local data collection vendor. For these intersections, the vendor recorded traffic data using four cameras, each focusing on one approach/leg of the intersection. For all the remaining before- and after-DBTB intersection recordings, several customized, easily deployable, portable video data recording platforms were constructed. Each unit consisted of: 1) one GoPro HERO4® camera, 2) one 30-foot telescoping mounting pole, 3) one transparent enclosure, 4) a pair of fan units, 5) batteries, and 6) a pole support stand. The GoPro HERO4® camera, batteries, and pair of fans were placed in the transparent enclosure. A rainproof forced-air ventilation system was fabricated for the enclosure to prevent camera overheating. A unit can typically record up to 12 continuous hours of video depending on the size of the storage card. Figure 1 shows a video data recording unit deployed at the 10^{th} Street NW and Williams Street NW intersection.

Figure 1: Video Data Recording Equipment at 10th Street NW and Williams Street NW Intersection.

The research team developed the upgraded video platform to enhance the quality of the video recordings, as reliable identification of the signal indications in the initial video proved challenging with standard definition videos in the commercially available solutions. In addition, the developed platform had a wider field of view, reducing the number of cameras needed at each intersection, which aided in reducing the data extraction effort. Figure 2 shows a comparison of image quality between video recordings captured by the standard definition camera units used by the vendor and the Georgia Tech Portable Video Data Recording Platform.

Based on file size limitations, videos recorded by the data collection vendor and by the Georgia Tech Portable Video Recording Platform were segmented into 30-minute and 15-minute video files, respectively. At the start of each data collection day using the Georgia Tech Portable Video Recording Platform, the SD card in each camera was replaced with an empty card and the previous day's batteries were replaced with charged batteries.

(a)

(b)

Figure 2: Enhancement in Video Quality at Intersection of Peachtree Dunwoody Rd. at Johnson Ferry Rd., Comparing: (a) Standard Definition Vendor Unit, and (b) Georgia Tech's Portable Video Recording Platform.

2.3 Video Data Extraction Software

This section discusses the software used to extract data from the video recordings. To estimate propensity to block, two sets of data elements were extracted: 1) blocking event data, and 2) *Block-Source Lane* vehicle categorization data. Blocking event data extraction included documenting blocking event details, such as start of blocking event timestamp, end of blocking event timestamp, *Block-Source Lane*, *Blocked Lane*, etc. *Block-Source Lane* identification reviewed all traffic on the *Block-Source Lane* to identify both the vehicles that blocked and the vehicles that chose not to block, allowing for the calculation of propensity to block. The following paragraphs provide a detailed description of the data extraction steps.

Initially, blocking event data were extracted by reviewing the video and manually entering timestamps and other data into customized Microsoft Excel spreadsheets (Figure 3). A Java-based computer software program, *VideoAnalyzer*, developed in 2014 by the School of Civil and Environmental Engineering at Georgia Tech, was used to retrieve vehicle timestamps (**Figure** 4). A detailed discussion of *VideoAnalyzer* and its application may be found in the thesis, "Traffic Management Alternatives for Business Improvement Districts" (5). However, the researchers in this study found the *VideoAnalyzer* software to contain a number of inefficiencies that hindered the ability to complete the project in a timely manner. To improve the efficiency and accuracy of the data extraction process, an additional software tool, the Georgia Tech Multi Video Player, was developed. Table 1 lists the limitations of *VideoAnalyzer* and the upgrades found in GT-MVP. A detailed discussion of GT-MVP may be found in Saroj et al., "Video Tool for Manually Extracting Complex Traffic Data," provided in Appendix C (9).

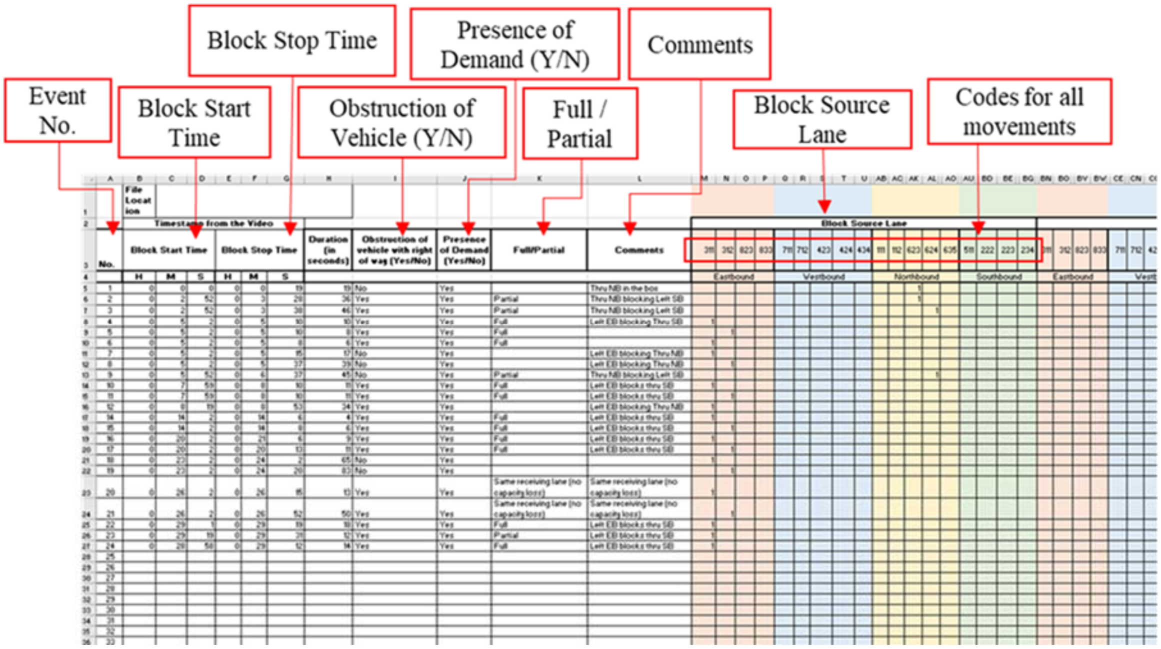


Figure 3: Snapshot of Customized Blocking Event Extraction Sheet.

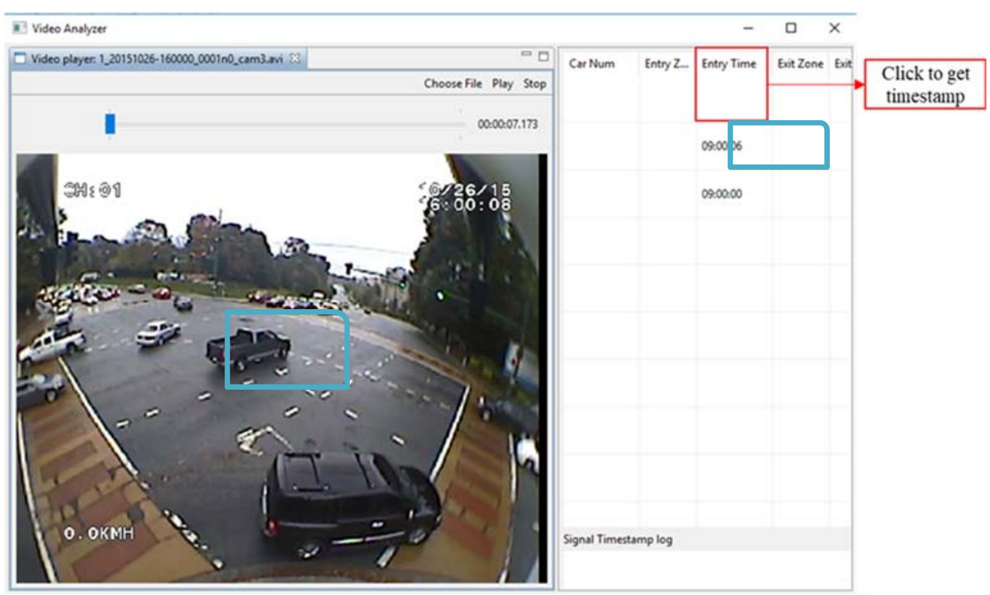


Figure 4: Example Timestamp Extraction Using *VideoAnalyzer* for Vehicle Entering the Intersection – Timestamp Taken When Vehicle in Blue Box Crosses the Crosswalk.

Table 1: Comparison of VideoAnalyzer and GT-MVP Upgrades.

Limitations of *VideoAnalyzer*	**New Video Software Upgrades – *GT-MVP***
Unable to play multiple videos in sync	Enables playing two videos in sync
No skip or forward button	Enables customized skipping forward/backward
First timestamp taken from PC internal clock, subsequent timestamps represent difference from video start.	Timestamp read from video
The GUI does not contain: • entry widgets to enter specific details • ability to clear/undo an error	Provides a customized GUI to extract data • Propensity extraction • Blocking event extraction
Requires manual entry of data into spreadsheet	Writes and reads to csv files automatically

GT-MVP contains two video player windows and one data extraction window (Figure 5). Each video player window contains a time slider (allowing the user to jump to a time in the video) and basic control buttons: Play, Pause, Play (0.5X), Play (2X), and a customizable forward/backward button. The customizable forward/backward button allows the user to choose a custom value (in seconds) to skip back or forth in the video.

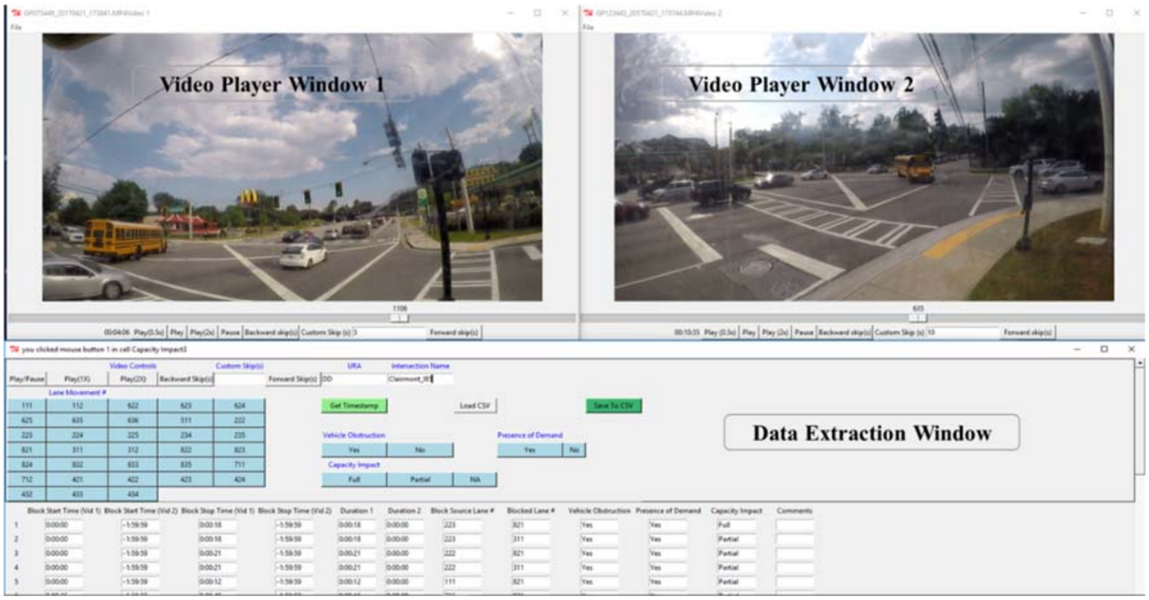
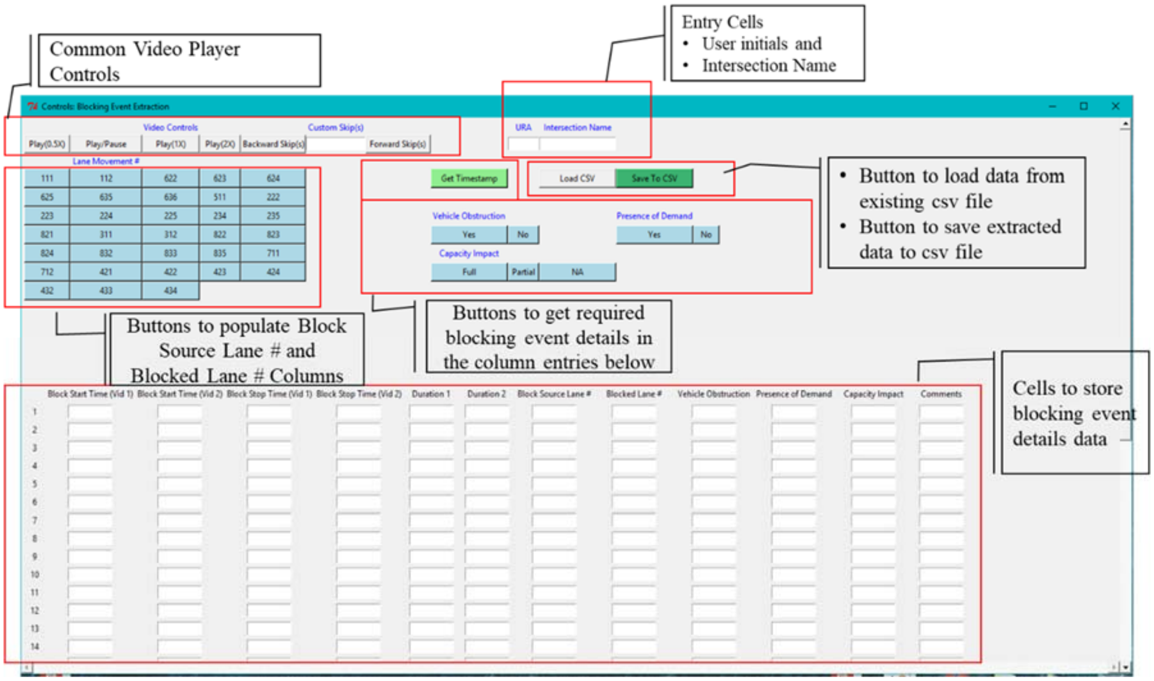


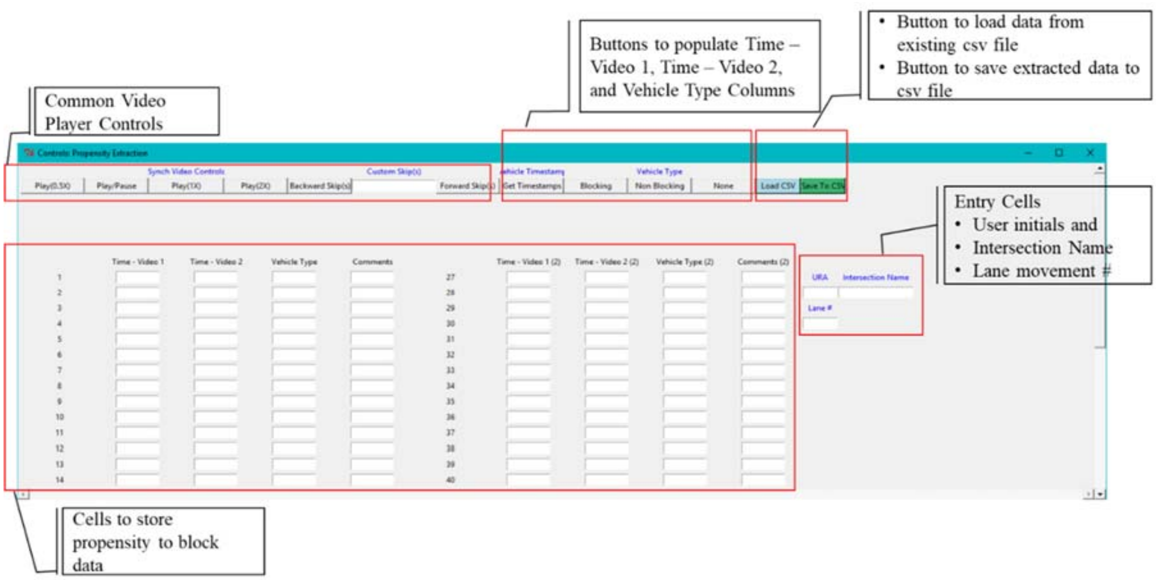
Figure 5: Screen Capture of GT-MVP Software Interface.

GT-MVP's data extraction window also contains video player control buttons: Play/Pause, Play(1X), Play(2X), customized Forward Skip and Backward Skip, and Get Timestamp. These buttons control both videos simultaneously, enabling a user to play two videos in a synchronized manner. While the *VideoAnalyzer's* timestamp button extracts the PC clock time, GT-MVP's Get Timestamp button retrieves the "time into video" timestamp (i.e., the time when the video recording started, encoded in the filename, is added to the "time into video" to obtain the correct time of day).

The graphical user interface (GUI) of the data extraction window contains an editable cell matrix to record data. GT-MVP populates these cells automatically when the user clicks the Get Timestamp button on the data extraction interface, but the cells are editable to allow for correction of errors. The cell matrix section is scrollable, similar to an Excel spreadsheet. Additionally, the Save to CSV and Load CSV buttons allow a user to save the extracted data in cell matrix to a csv file and load the data from a csv file to the cell matrix, respectively. Two different data extraction windows were designed for GT-MVP. One was customized for extracting blocking event data and the other for extracting the *Block-Source Lane* categorization data. (**Figure** 6). This software is shared for community use at http://transportation.ce.gatech.edu/publications.



(a)



(b)

Figure 6: Snapshots of (a) GT-MVP's Blocking Event Data Extraction Window (9), and (b) GT-MVP's Block-Source Lane Categorization Data Extraction Window (9).

2.4 Methodology to Estimate Propensity to Block

This section discusses the methodology to estimate propensity to block. This methodology can be divided into four steps, the first two steps extracting the blocking event data and the final two steps extracting the *Block-Source Lane* categorization data.

In step 1, Initial Review, intersection video recordings are reviewed for the presence of blocking events. Video recordings containing blocking are flagged for further processing.

In step 2, Blocking Event Extraction, blocking event details, such as blocking event start time, blocking event stop time, *Block-Source Lane*, *Blocked Lane*, and if the blocked lanes were fully or partially blocked, are extracted from the video recordings flagged in step 1.

In step 3, a detailed *Block-Source Lane* categorization data collection plan is determined for each intersection included in step 2. As collection of all potential data exceeded project resources, the research team selected a subset of days, times, and lanes for the propensity to block data extraction (i.e., *Block-Source-Lan*e categorization) based on the extracted blocking event details from step 2. For each intersection, for the days and lanes selected, the full peak period would be included in the *Block-Source Lane* categorization data extraction to ensure capture of instances when a vehicle chose not to block when a blocking opportunity existed.

In step 4, a vehicle on the *Block-Source Lane* was categorized as a) a blocking vehicle, if it entered the intersection resulting in a block; or b) a non-blocking vehicle, if the vehicle *had the opportunity to block* and did not enter the intersection, but instead waited for the next cycle to avoid blocking. The ratio of blocking vehicles to the number of vehicles with an opportunity to block (i.e., number of blocking vehicles + number of non-blocking vehicles) was estimated. This ratio is the estimated propensity to block for the corresponding *Block-Source Lane* for the study intersection. Figure 7 shows an overview of this four-step process. A detailed discussion of each step is presented in the following subsections.

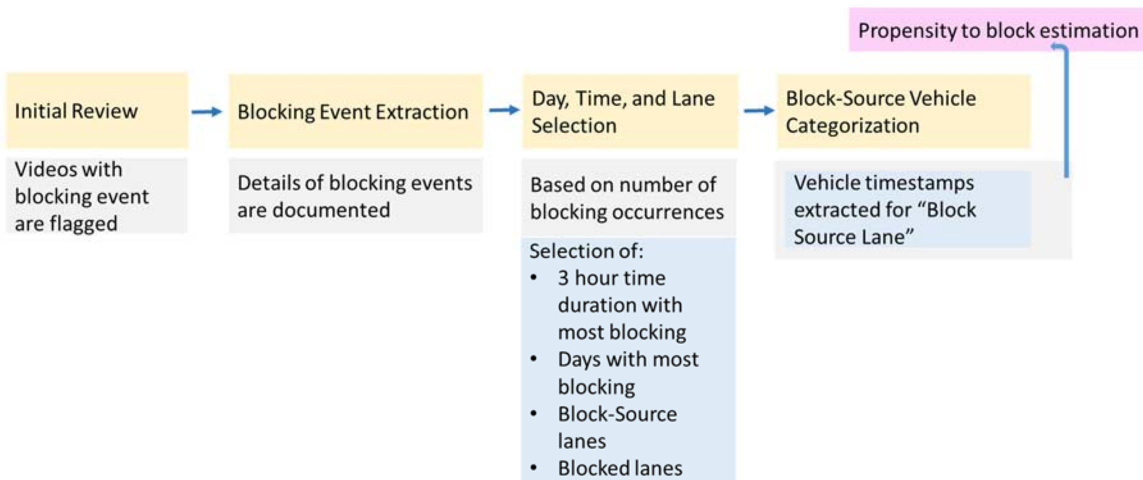


Figure 7: Flow Chart of Methodology Used to Estimate Propensity to Block.

2.4.1 Step 1. Initial Review

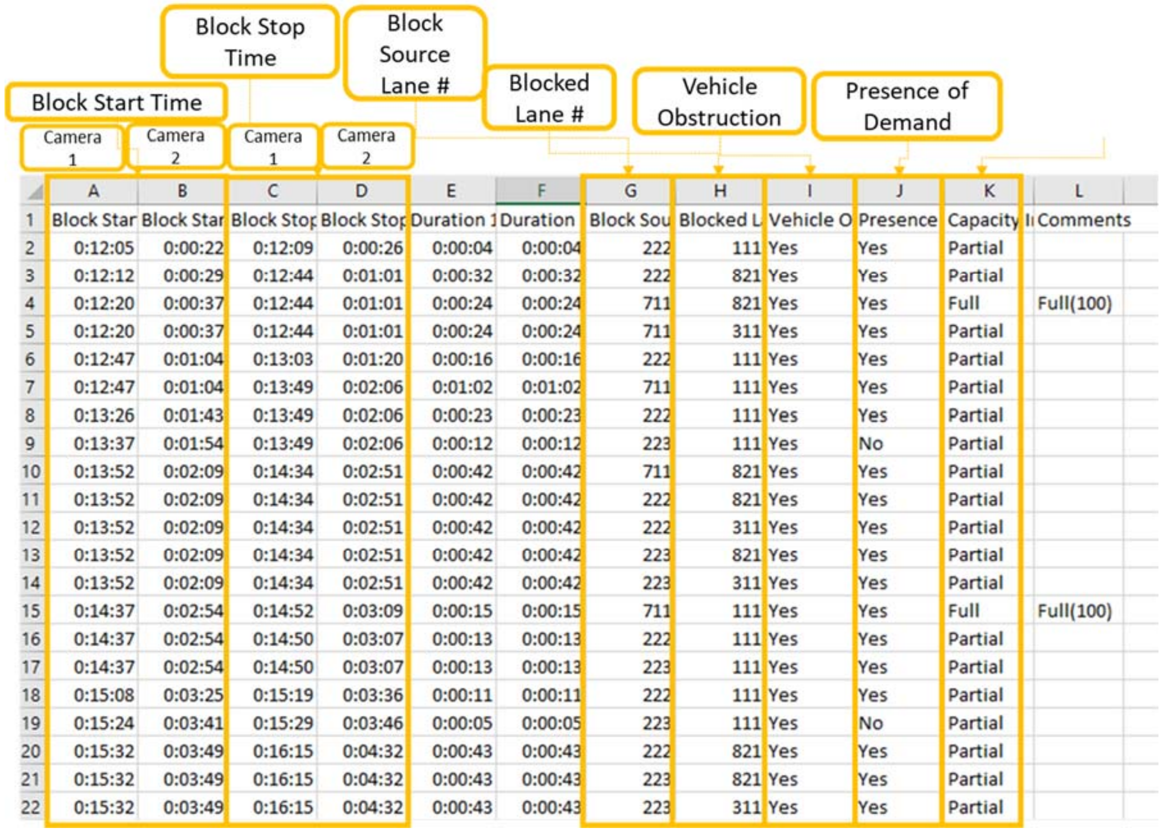
As a first step, a review of the video recordings was undertaken to check for the presence of blocking events. Video recordings of the peak period for each intersection were reviewed first. If no blocking (or significant congestion) was seen on an intersection's peak period video recordings, the remainder of the video recordings for that day were not reviewed. If blocking was noted during the peak period, the video recording review was expanded beyond the peak until the video recordings did not contain blocking or all video recordings had been checked. The videos that were found to have blocking events were flagged, as shown in Figure 8. The data for the step 2 analysis were extracted from these videos.

Video I	Intersection Name	Date of vide	Camera Num	Folder numb	FileNumbe	Who worked on initial review?	Initial Review done?	Comments	Blocking events found? (Refer to next colum
1	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	15	150007	Apurv and Lizzy	Yes		No
2	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	15	153000	Apurv and Lizzy	Yes		No
3	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	16	160000	Apurv and Lizzy	Yes		No
4	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	16	163000	Apurv and Lizzy	Yes		No
5	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	17	170000	Apurv and Lizzy	Yes		No
6	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	17	173000	Apurv and Lizzy	Yes		No
7	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	18	180000	Apurv and Lizzy	Yes		No
8	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	18	183000	Apurv and Lizzy	Yes		No
9	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	19	190000	Apurv and Lizzy	Yes		No
10	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	19	193000	Apurv and Lizzy	Yes		No
11	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	20	200000	Apurv and Lizzy	Yes		No
12	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	20	203000	Apurv and Lizzy	Yes		No
13	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	21	210000	Apurv and Lizzy	Yes		No
14	ParkPl(NS)_PerimeterSummitPkway(EW)	10/23/2015	001	21	213000	Apurv and Lizzy	Yes		No

Figure 8: Snapshot of the Spreadsheet Used to Record Flagged Videos in the Initial Review Process.

2.4.2 Step 2. Blocking Event Data Extraction

In this step, the details of blocking events observed in step 1 were extracted using the GT-MVP software. As discussed earlier, for this study, a blocking event occurs when a vehicle enters and remains in the intersection through a phase change, thus blocking a green indication on an opposing movement. In this analysis, presence of a vehicle on the blocked approach is not necessary for the block to be recorded. The blocking events were observed in videos from multiple views of the intersection to collect the necessary data. Figure 9 shows a snapshot of a blocking event extraction sheet.



	A	B	C	D	E	F	G	H	I	J	K	L
1	Block Star	Block Star	Block Stop	Block Stop	Duration 1	Duration	Block Sou	Blocked L	Vehicle O	Presence	Capacity I	Comments
2	0:12:05	0:00:22	0:12:09	0:00:26	0:00:04	0:00:04	222	111	Yes	Yes	Partial	
3	0:12:12	0:00:29	0:12:44	0:01:01	0:00:32	0:00:32	222	821	Yes	Yes	Partial	
4	0:12:20	0:00:37	0:12:44	0:01:01	0:00:24	0:00:24	711	821	Yes	Yes	Full	Full(100)
5	0:12:20	0:00:37	0:12:44	0:01:01	0:00:24	0:00:24	711	311	Yes	Yes	Partial	
6	0:12:47	0:01:04	0:13:03	0:01:20	0:00:16	0:00:16	222	111	Yes	Yes	Partial	
7	0:12:47	0:01:04	0:13:49	0:02:06	0:01:02	0:01:02	711	111	Yes	Yes	Partial	
8	0:13:26	0:01:43	0:13:49	0:02:06	0:00:23	0:00:23	222	111	Yes	Yes	Partial	
9	0:13:37	0:01:54	0:13:49	0:02:06	0:00:12	0:00:12	223	111	Yes	No	Partial	
10	0:13:52	0:02:09	0:14:34	0:02:51	0:00:42	0:00:42	711	821	Yes	Yes	Partial	
11	0:13:52	0:02:09	0:14:34	0:02:51	0:00:42	0:00:42	222	821	Yes	Yes	Partial	
12	0:13:52	0:02:09	0:14:34	0:02:51	0:00:42	0:00:42	222	311	Yes	Yes	Partial	
13	0:13:52	0:02:09	0:14:34	0:02:51	0:00:42	0:00:42	223	821	Yes	Yes	Partial	
14	0:13:52	0:02:09	0:14:34	0:02:51	0:00:42	0:00:42	223	311	Yes	Yes	Partial	
15	0:14:37	0:02:54	0:14:52	0:03:09	0:00:15	0:00:15	711	111	Yes	Yes	Full	Full(100)
16	0:14:37	0:02:54	0:14:50	0:03:07	0:00:13	0:00:13	222	111	Yes	Yes	Partial	
17	0:14:37	0:02:54	0:14:50	0:03:07	0:00:13	0:00:13	223	111	Yes	Yes	Partial	
18	0:15:08	0:03:25	0:15:19	0:03:36	0:00:11	0:00:11	222	111	Yes	Yes	Partial	
19	0:15:24	0:03:41	0:15:29	0:03:46	0:00:05	0:00:05	223	111	Yes	No	Partial	
20	0:15:32	0:03:49	0:16:15	0:04:32	0:00:43	0:00:43	222	821	Yes	Yes	Partial	
21	0:15:32	0:03:49	0:16:15	0:04:32	0:00:43	0:00:43	223	821	Yes	Yes	Partial	
22	0:15:32	0:03:49	0:16:15	0:04:32	0:00:43	0:00:43	223	311	Yes	Yes	Partial	

Figure 9: Snapshot of Blocking Event Extraction Sheet for the Intersection of Clairmont Rd. at I-85 SB, near Sam's Club, 04-17-2017 18:11 (Video 1: GP113441_20170417_181134, Video 2: GP083445_20170417_182317).

The following details for each blocking event were extracted:

- **Block Event Start Time:** The timestamp of the start of the blocking event. The timestamp from the start of the video was recorded, with the video start as time t = 0. This time was then converted to the time of day by adding the start time of the video recording.
- **Block Event Stop Time:** The timestamp of the end of the blocking event. As with block event start time, the timestamp from the end of the video was recorded, with the video start as time t = 0. This time was then converted to the time-of-day by adding the start time of the video recording.

- ***Block-Source Lane* Number and *Blocked Lane* Number:** The vehicle movements involved in the blocking event, i.e., the movement originating the blocking vehicle (*Block-Source Lane*) and the movement being blocked (*Blocked Lane*), were identified for each blocking event. For efficient data recording, all lane movements for each intersection were coded according to a three-digit number. An example of the coding for Peachtree Dunwoody Rd. at Johnson Ferry Rd. is shown in **Figure** 10. The coding schemes for each intersection analyzed can be found in Appendix B.

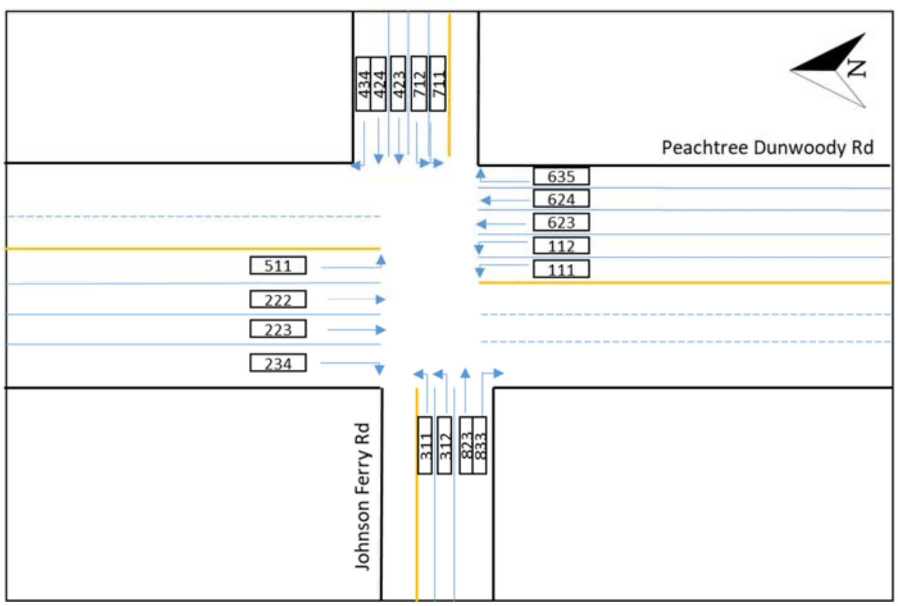


Figure 10: Lane Movement Numbers Assigned at Peachtree Dunwoody Rd. at Johnson Ferry Rd.

- **Vehicle Obstruction:** "Yes" or "No" under the "Vehicle Obstruction" column was used to indicate if a blocking vehicle impacted the regular movement of vehicles for each blocking event. Examples of "Yes" and "No" blocking events are described below:

- **Yes:** Indicates a blocking event with an obstruction of the conflicting vehicle's travel path. Figure 11 is a screen capture of a blocking event at the intersection of Peachtree Dunwoody Rd. and Abernathy Rd. that started at 16 hr. 02 min. 52 sec. The red arrow indicates the movement of vehicles from the *Block-Source Lane* (Northbound (NB) left), and the blue arrow indicates the movement of the vehicles in the *Blocked Lane* (Eastbound (EB) left). The red boxes indicate the blocking vehicles and the blue box indicates the first blocked vehicle associated with the blocking event. During the video observation, the blocking vehicles clearly obstruct the right-of-way of the blocked vehicles.

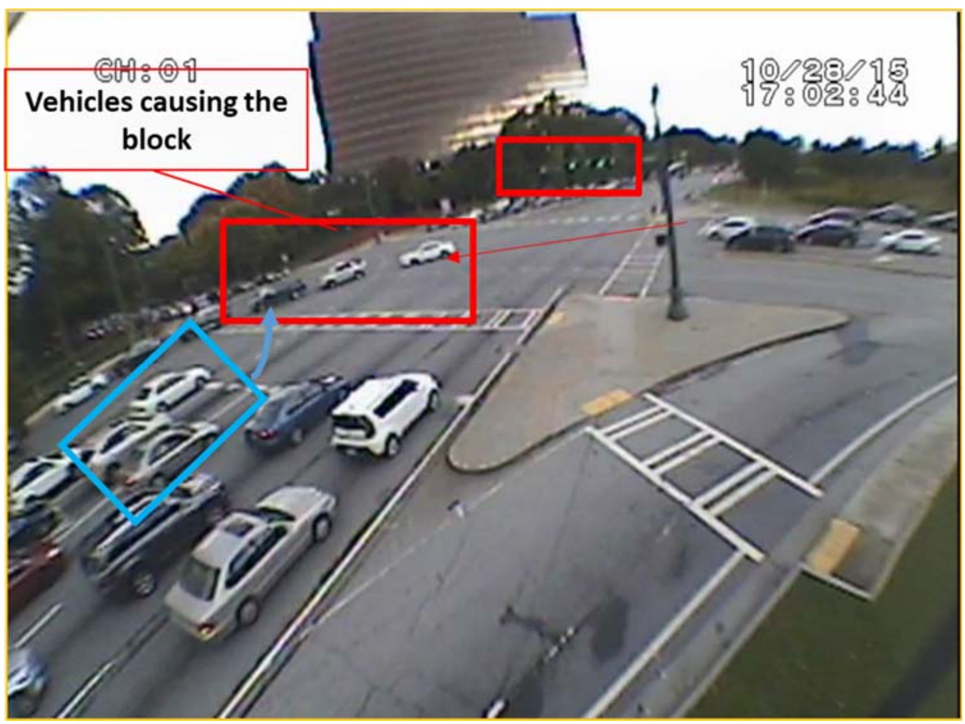


Figure 11: Vehicles in Red Blocked the Vehicles Marked in Blue (Peachtree Dunwoody Rd. at Abernathy Rd. NE, 10/28/2015, 17:02).

- **No:** Indicates a blocking event with no obstruction of the conflicting vehicle's travel path. Figure 12 provides an example of a blocking event captured in the same video as above, at the intersection of Peachtree Dunwoody Rd. and Johnson Ferry Rd. In this image the white pickup (in the red rectangle) is present in the intersection while the green indication for the Southbound (SB) left and SB through movements are active (indications are highlighted in the yellow box). However, neither the SB left nor through movement is obstructed by this blocking event. This is primarily a result of the large size of the intersection "box."

Figure 12: Example Blocking Event that Does Not Obstruct Traffic Flow (Peachtree Dunwoody Rd. at Johnson Ferry Rd., 10/26/2015, 16:00 1_20151026_160000_0001n0_cam3.avi).

- **Presence of Demand:** The presence of demand on the *Blocked Lane* was also captured under the Presence of Demand column. "Yes" indicates that demand is present and "No" indicates that no demand is present. For example, in both examples above (Figure 11 and Figure 12) the SB left turn (*Blocked Lane*) has demand during the blocking event. This is indicated with a "yes" under the Presence of Demand column for the blocking event extraction.

Figure 13 below shows a blocking event captured at the intersection of Ashford Dunwoody Rd. NE at Ravinia Dr. NE. In this example, the white vehicle (identified by the red rectangle) is blocking the crossing approach that has a green indication (signal heads marked with a smaller red rectangle). However, there is no vehicle present on the blocked lane (yellow arrow points to the blocked lane), indicating an absence of demand.

Figure 13: Blocking Event with No Presence of Demand (Ashford Dunwoody Rd. NE at Ravinia Dr. NE, 10/29/2015, 16:39).

- **Capacity Impact (Full/Partial):** Blocking events that affected capacity were further categorized as a full block or partial block.

- **Full Block:** For a full blocking event, the blocked vehicles are unable to complete their movement.
- **Partial Block:** For a partial blocking event, the blocked vehicles are hindered but are able to successfully complete the desired movement.

- **Comments:** Under the comments section, additional details about the blocking event are documented.

2.4.3 Step 3. Day, Time, and Lane Selection

In step 3, first, the blocking event details extracted for before- and after-DBTB treatment at an intersection were inspected to note a 3-hour time duration that captures most of the blocking events on all the days. Next, the days with the maximum number of blocking events with obstruction of right-of-way (i.e., capacity impact) for the selected 3-hour time duration were identified. Lastly, *Block-Source Lanes* corresponding to the blocking events observed during the selected time period on the selected days were identified. These time periods were further analyzed in step 4 to allow for a determination of propensity to block on the identified *Block-Source Lanes*. All time periods including blocks were not included in the propensity analysis due to time limitations in data extraction.

2.4.4 Step 4. *Block-Source Lane* Vehicle Categorization

In step 4, the blocking behavior of vehicles on the identified *Block-Source Lanes* for the selected days and time durations was inspected. A vehicle's choice to enter or to not enter the intersection, when presented with an opportunity to block (i.e., no space downstream to exit the intersection), was recorded. Vehicles on the *Block-Source Lane* were annotated by recording the timestamp when the vehicle crossed the stop bar to enter the intersection. A vehicle was designated to be a blocking vehicle if it entered the intersection and created a block. A vehicle was designated to be a non-blocking vehicle if it chose not to enter the intersection while having a green indication. Thus, the designation of non-blocking was based on the judgement of the vehicle driver, not the data analyst. Vehicles that entered the intersection and did not create a block were not included in the blocking or non-blocking designations. Figure 14 shows a snapshot of GT-MVP's propensity extraction module being used for the *Block-Source Lane* vehicle categorization for lane number 623 at the intersection of Peachtree Dunwoody Rd. and Johnson Ferry Rd. Figure 14 also includes a snapshot of the generated Excel spreadsheet. The vehicle categorization into 1) blocking vehicle and 2) non-blocking vehicle can be seen under the Vehicle Type column (marked in the blue rectangle).

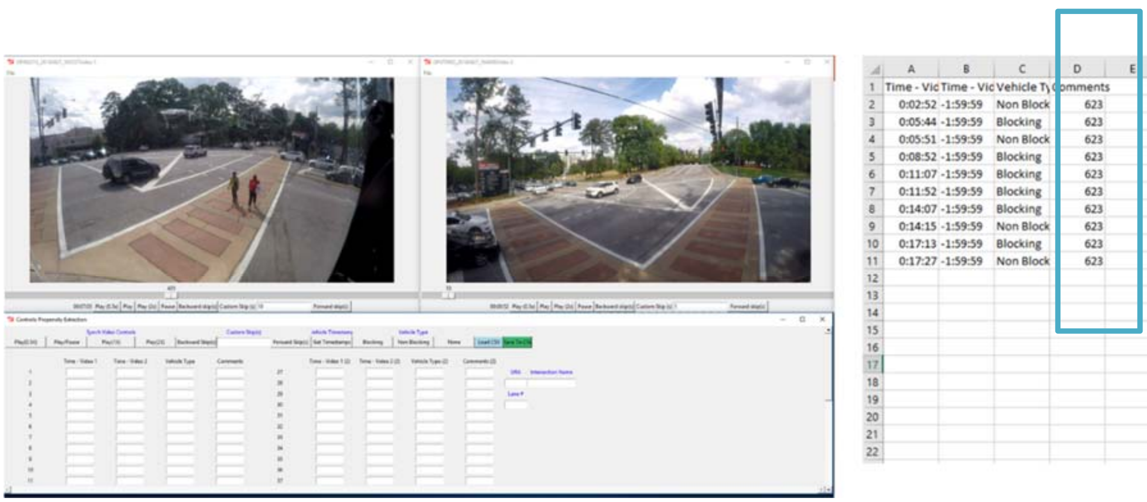


Figure 14: Snapshot: Propensity Extraction Interface of GT-MVP (Peachtree Dunwoody Rd. at Johnson Ferry Rd., 04-27-2016, 16:22 PM GP062213/GP070993) with Extracted Propensity Data Spreadsheet.

Finally, propensity to block for the intersection was estimated by determining the ratio of number of blocking vehicles to the total number of vehicles with an opportunity to block.

$$Likelihood\ to\ block = \frac{\#\ of\ blocking\ vehicles}{\#\ of\ vehicles\ with\ an\ opportunity\ to\ block}$$

Chapter 3: DATA AND FINDINGS

This study included 17 intersections in the before phase of the DBTB data collection effort. Of these, 9 intersections were included in the after study. The selection of the original 17 intersections was based on discussions with GDOT, GDOT contractors, and the PCID, identifying locations with a high likelihood of blocking. After the selection of the 17 study intersections, GDOT personnel designed the DBTB treatments for each intersection and programmed the treatment installations. Eleven of the 17 intersections were excluded from the after study due to: 1) a lack of observed blocking in the before data (six intersections), 2) the treatment not being installed in time to be included in the study (two intersections), or 3) a reduction in data extraction efforts due to project resource limitations (three intersections). Intersections included in the after study were observed to have at least several instances of blocking on at least one movement in the before data extraction. The following sections review the intersections selected, the data collection, and the findings.

3.1 Intersection Selection

The intersections in the study included a set of 5 intersections within the Perimeter Community Improvement District and 12 additional intersections on state routes throughout the Atlanta region (referred to as GDOT intersections in this report).

3.1.1 PCID Before

Data at the five PCID intersections were collected during October 2015. Intersection operations were video recorded Monday to Thursday (or Friday) for a single week, with two weeks' data collected at several intersections. For each intersection, video recordings were taken from approximately 3 PM to 9 PM, covering the PM peak and several hours before and after the peak. An external vendor completed these video recordings. Table 2 provides a list of the PCID intersections, dates, and days of video recording for the before data collection.

Table 2: PCID Before DBTB Installation: Intersections and Video Recording Dates and Days.

Intersection Name	Dates	Days
1. **Parkside PI at Perimeter Summit Pkwy.**	10/19/2015–10/23/2015 10/26/2015–10/29/2015	Mon–Fri Mon–Thu
2. **Ashford Dunwoody Rd. NE at Ravinia Dr. NE**	10/26/2015–10/29/2015	Mon–Thu
3. **Peachtree Dunwoody Rd. at Lake Hearn Dr. NE**	10/19/2015–10/23/2015 10/26/2015–10/29/2015	Mon–Fri Mon–Thu
4. **Peachtree Dunwoody Rd. at Abernathy Rd. NE**	10/26/2015–10/29/2015	Mon–Thu
5. **Peachtree Dunwoody Rd. at Johnson Ferry Rd.**	10/26/2015–10/29/2015	Mon–Thu

3.1.2 PCID After

The after study intersections were selected based on the nature of blocking events observed in the before study intersection video recordings. Of the initial five intersections, four intersections were observed to experience blocking with an impact on the capacity of the intersection. Only the Parkside Pl at Perimeter Summit Pkwy intersection had limited blocking events and was not carried forward in the after study, as the blocking observed did not impact intersection capacity. Similar to the before video recordings, the after video recordings covered the weekdays Monday to Thursday, from approximately 3 PM to 9 PM.

The after video recordings were completed by the Georgia Tech research team using the equipment discussed in Chapter 2. Table 3 shows a list of the PCID intersections, dates, and days of data collection for the after data collection.

Table 3: PCID After DBTB Installation: Intersections and Video Recording Dates and Days.

Intersection Name	Dates	Days
1. **Ashford Dunwoody Rd. NE at Ravinia Dr. NE**	04/18/2016–04/21/2016	Mon–Thu
2. **Peachtree Dunwoody Rd.at Lake Hearn Dr. NE**	04/25/2016–04/29/2016 05/06/2016	Mon–Fri Fri
3. **Peachtree Dunwoody Rd. at Abernathy Rd. NE**	04/18/2016–04/21/2016	Mon–Thu
4. **Peachtree Dunwoody Rd. at Johnson Ferry Rd.**	04/25/2016–04/29/2016	Mon–Thu

Figure 15 provides an example aerial view of Ashford Dunwoody Rd. at Ravinia Dr. NE prior to DBTB implementation. Figure 16 and Figure 17 show example image captures from the after video recordings for this intersection. An aerial image, an image from each video recording angle with and without treatment, and a sketch showing the lane numbering (as discussed in Chapter 2) for each intersection are provided in Appendix B.

Figure 15: Ashford Dunwoody Rd. NE at Ravinia Dr. NE
Source: Google® Street View.

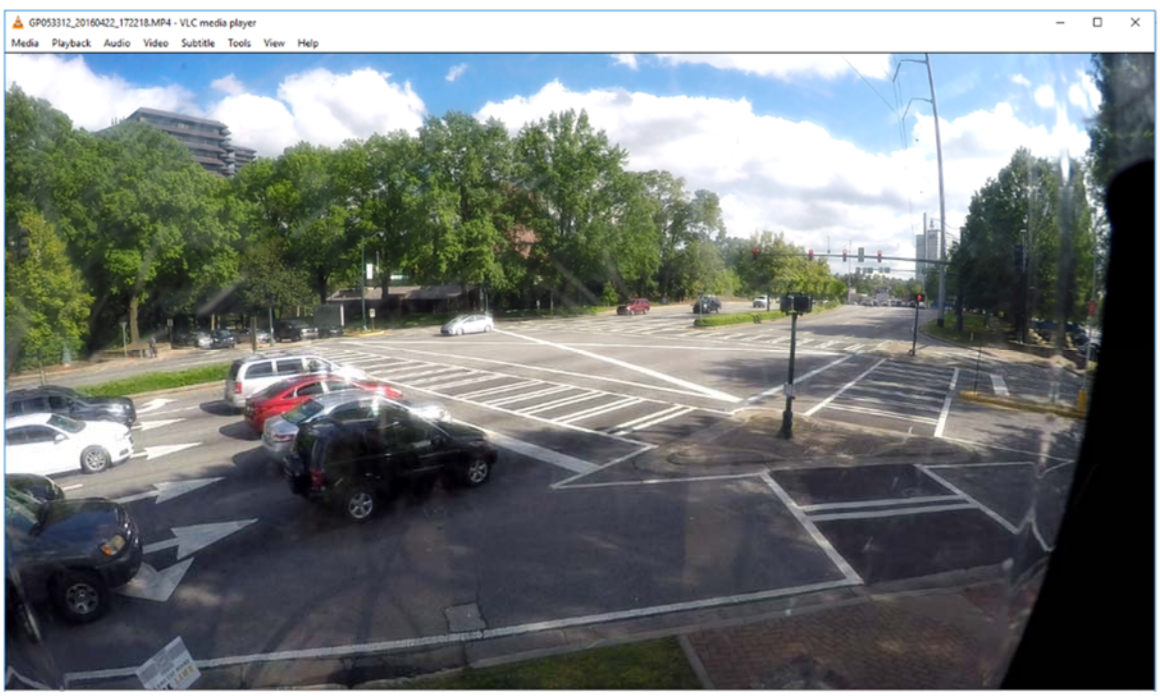


Figure 16: Ashford Dunwoody Rd. NE at Ravinia Dr. NE,
Video Screen Capture, Location 1, 04/21/2016.

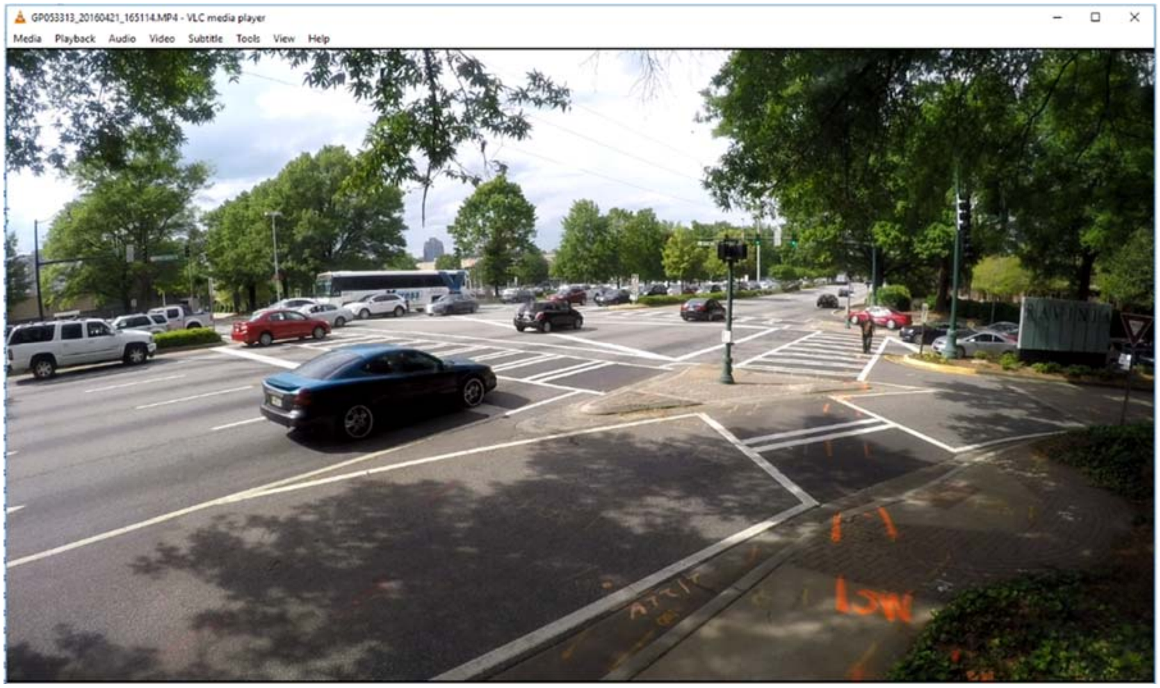


Figure 17: Ashford Dunwoody Rd. NE at Ravinia Dr. NE, Video Screen Capture, Location 2, 04/21/2016.

3.1.3 GDOT Before

Along with the PCID locations, GDOT selected 12 additional intersections for DBTB treatment. These intersections were video recorded for before DBTB installation in March and April of 2016. Video recording was completed by Georgia Tech staff, recording each intersection for at least four out of five weekdays. Table 4 lists the 12 intersections and video recording dates and days.

Table 4: Additional GDOT Before Intersections and Video Recording Dates and Days.

Intersection Name	Dates	Days
1. **Peachtree Rd. NE at Lenox Rd. NE**	03/15/2016–03/18/2016	Tue–Fri
2. **Peachtree Rd. NE at Highland Dr. NE**	03/15/2016–03/18/2016	Tue–Fri
3. **Peachtree Rd. NE at Stratford Rd. NE**	03/15/2016–03/18/2016	Tue–Fri
4. **Ponce De Leon Ave. NE at City Hall East**	03/15/2016–03/18/2016	Tue–Fri
5. **S. Cobb Dr. at Pearl St.**	03/21/2016–03/25/2016	Mon–Fri
6. **S. Cobb Dr. at Walker St.**	03/21/2016–03/25/2016	Mon–Fri
7. **W. Paces Ferry Rd. NW at I-75 SB On/Off Ramps**	03/28/2016–04/01/2016	Mon–Fri
8. **Mount Paran Rd. NW at I-75 NB Off Ramp**	03/28/2016–03/31/2016	Mon–Thu
9. **Williams St. NW at 10th St. NW**	04/05/2016–04/08/2016	Tue–Fri
10. **South Cobb Dr. at I-285 SB On/Off-Ramps**	04/04/2016–04/08/2016	Mon–Fri
11. **Clairmont Rd. at I-85 SB, near Sam's Club**	04/11/2016–04/15/2016	Mon–Fri
12. **14th St. NW at Hemphill Ave. NW**	04/11/2016–04/15/2016	Mon–Fri

3.1.4 GDOT After

As with the PCID intersections, the after study intersections were primarily selected based on the nature of blocking events observed in the before study intersection video recordings. These 12 intersections were observed and categorized in "High, Medium, and Low" levels of blocking in terms of frequency and duration of the blocking event. Due to limitations in data extraction project resources, intersections with a "Low" level of blocking were not included in the after analysis. Of the initial 12 intersections, 7 were found to have sufficient blocking in the before period to warrant inclusion in the after DBTB analysis. In this instance, insufficient blocking was defined as either few blocking instances during the peak periods or blocking with no significant capacity impact (i.e., a blocking vehicle may encroach into the intersection box but does not hinder any conflicting vehicles). Table 5 lists those intersections not included in the after analysis. Of the remaining seven intersections where blocking was observed, the intersections of South Cobb Dr. at Walker St. and South Cobb Dr. at I-285 SB On/Off Ramps were not included, as the DBTB treatment had not yet been installed at the time of the after data video recording. Similar to the before video recordings, the after video recordings occurred during weekdays, starting approximately from 2–4 PM until 10 PM. The after video recordings were completed by the Georgia Tech research team. A list of the GDOT intersections, dates, and days of data collection are given in Table 6 for the after data collection.

Table 5: Intersections Dropped from the Study.

Intersection Name
Peachtree Rd. NE at Lenox Rd. NE
Peachtree Rd. NE at Highland Dr. NE
Ponce De Leon Ave. NE at City Hall East
S. Cobb Dr. at Pearl St.
Mount Paran Rd. NW & I-75 NB Off Ramp

Table 6: Additional GDOT After Intersections and Video Recording Dates and Days.

Intersection Name	Dates	Days
1. **Peachtree Rd. NE at Stratford Rd. NE**	03/29/2017–03/31/2017, 04/19/2017–04/20/2017, 04/25/2017	Tue–Fri
2. **W. Paces Ferry Rd. NW at I-75 SB On/Off-Ramps**	04/12/2017–04/13/2017, 04/17/2017–04/18/2017, 4/27/2017	Mon–Thu
3. **Williams St. NW at 10th St. NW**	04/25/2017–05/27/2017, 05/01/2017, 05/03/2017, 05/08/2017	Mon–Thu
4. **Clairmont Rd. at I-85 SB, near Sam's Club**	03/29/2017–03/31/2017, 04/12/2017–04/13/2017, 04/17/2017–04/18/2017, 04/21/2017	Mon–Fri
5. **14th St. NW at Hemphill Ave. NW**	04/20/2017, 05/01/2017, 05/03/2017, 05/08/2017–05/09/2017	Mon–Thu

Of the five intersections in Table 6, data extraction and analysis are included in the findings for the intersections of West Paces Ferry Rd. NW at I-75 SB On/Off Ramps and Clairmont Rd. at I-85 SB, near Sam's Club. The remaining three intersections are not included in the final results due to the project's budget limitations. However, a visual review of the intersection videos indicates findings likely similar to the other seven intersections fully reduced for this study. An aerial image, an image from each video recording angle with (where applicable) and without treatment, and a sketch showing the lane numbering for each intersection may be found in Appendix B.

3.2 Intersection Results

As discussed in section 2.4, propensity analysis was undertaken at intersections with at least a minimum threshold of blocking events in the before data. For selected intersections, on the days of interest, data were extracted for a 3-hour period, unless otherwise noted. The 3-hour range was selected to encompass any observed blocking. The same 3-hour window was utilized in the before and after data collection. Extracting data over the full 3-hour block typically included video with no blocking. However, it was critical to obtaining an accurate propensity estimate to include the full 3-hour period as instances of vehicles choosing not to block may be present during these no-block present videos. The intersections and monitored lanes included in the final propensity analysis are indicated in Table 7 below. For each intersection, data were collected for 3 days in both the before and after period, with an additional fourth day at the intersections of Peachtree Dunwoody Rd. at Abernathy Rd. NE and Peachtree Dunwoody Rd. at Johnson Ferry Rd. All lanes that experienced blocking on any of the days either before or after were included in the analysis with the exception that in both Peachtree Dunwoody Rd. at Abernathy Rd. NE and Peachtree Dunwoody Rd. at Johnson Ferry Rd. a lane with a single block over the entire time period was not included in order to reduce data extraction efforts. Appendix B contains the lane configuration map and numbering key for each intersection. A discussion of each intersection's results is presented in the following sections.

Table 7: Final Propensity Analysis Intersections and Lanes.

Intersection Name	Lanes Selected
1. **Ashford Dunwoody Rd. NE at Ravinia Dr. NE**	222, 223, 224, 225, 711, 712
2. **Peachtree Dunwoody Rd. at Lake Hearn Dr. NE**	311, 623, 511, 711, 222
3. **Peachtree Dunwoody Rd. at Abernathy Rd. NE**	311, 111, 112, 312
4. **Peachtree Dunwoody Rd. at Johnson Ferry Rd.**	311, 312, 623, 624
5. **W. Paces Ferry Rd. NW at I-75 SB On/Off-Ramps**	622, 711, 712, 623, 222, 223, 511
6. **Clairmont Rd. at I-85 SB, near Sam's Club**	111, 222, 223, 224, 711, 831

3.2.1 Ashford Dunwoody Rd. NE at Ravinia Dr. NE

For the Ashford Dunwoody Rd. NE and Ravinia Dr. NE intersection, 4 hours of propensity data were extracted from the before video recordings, 2 hours on 10/26/2105, 1 hour on 10/27/2015, and 1 hour on 10/28/2015. Three-hour periods were not extracted for these days as police were providing traffic control during all other high-volume periods with the potential for blocking. For the after study, 9 hours of data were extracted from the video recordings over 3 days, from 4:30–7:30 PM each day. Table 8 provides the number of hours of data extracted for each day, total number of blocking opportunities, total number of observed blocking vehicles, total number of observed non-blocking vehicles, and blocking propensity. The analysis is provided for each day of observation and overall before and after.

Table 8: Ashford Dunwoody Rd. NE at Ravinia Dr. NE.

Before	**10/26/2015 (Mon*)**	**10/27/2015 (Tue*)**	**10/28/2015 (Thu*)**	**Total**
Hours of Study	2	1	1	4
Total # Opportunities	23	1	4	28
Total # Blocking	19	0	1	20
Total # Non-Blocking	4	1	3	8
Propensity	0.83	0.00	0.25	0.71

After	**04/18/2016 (Mon)**	**04/19/2016 (Tue)**	**04/21/2016 (Thu)**	
Hours of Study	3	3	3	9
Total # Opportunities	10	154	140	304
Total # Blocking	5	79	100	184
Total # Non-Blocking	5	75	38	118
Propensity	0.50	0.51	0.71	0.61
** Police present*				

In the before analysis, the highest observed propensity to block was 0.83, on Monday (10/26/2015), whereas the lowest observed propensity was 0.0 on Tuesday (10/27/2015), although only a single opportunity to block was observed, thus the value lacks significance. Aggregating overall blocking and non-blocking opportunities during the before data collection, a propensity to block of 0.71 was observed. That is, 71% of drivers chose to block when presented with a blocking opportunity. In the after DBTB implementation, the highest observed propensity to block during a 3-hour period was 0.71, on Thursday (04/21/2016), whereas the lowest observed propensity to block was 0.50, on Monday (04/18/2016). The aggregate after propensity to block was 0.61, or 61%, which was 10% lower than the before period.

This intersection had several characteristics in blocking behavior that will be seen throughout the analysis. First, even though a decrease in propensity to block was observed, the after blocking rate remained high, with a higher likelihood that a vehicle would choose to block than to not block. Also, there was significant variability in day-to-day blocking opportunities. Within the same week there would be peak periods where the opportunity to block was rare or non-existent, while on other days significant (hundreds) of blocking opportunities were observed. Traffic counts were conducted on the video data to explore a potential relationship between intersection counts and blocking. However, no meaningful relationship was found, as blocking is a function of spillback emanating from downstream intersections or system congestion. The researchers were not able to collect meaningful data on the overall system demands, as for any given day only one or two intersections were under observation. However, Appendix A, discussed in Section 3.4, presents simulated findings based on propensity to block that demonstrate the impact of system demand.

3.2.2 Peachtree Dunwoody Rd. at Lake Hearn Dr. NE

For the Peachtree Dunwoody Rd. at Lake Hearn Dr. intersection, 9 hours of propensity data were extracted from the before video and 6.5 hours of propensity data were extracted from the after video. Similar to the Ashford Dunwoody Rd. NE at Ravinia Dr. intersection, the after data were limited to under 3 hours in two peak periods due to the presence of traffic control police officers at the intersection. Videos during periods when a traffic control police officer was present, was not used for data extraction. All video extraction was between the hours of 3:30 PM and 6:30 PM. Table 9 provides the number of hours of data extracted for each day, total number of blocking opportunities, total number of observed blocking vehicles, total number of observed non-blocking vehicles, and blocking propensity. The analysis is provided for each day of observation and overall before and after.

Table 9: Peachtree Dunwoody Rd. at Lake Hearn Dr. NE.

Before	**10/22/2015 (Thu)**	**10/26/2015 (Mon)**	**10/29/2015 (Thu)**	**Total**
Hours of Study	3	3	3	9
Total # Opportunities	67	40	7	114
Total # Blocking	47	30	0	77
Total # Non-Blocking	20	10	7	37
Propensity	0.70	0.75	0	0.68

After	**04/26/2016 (Tue*)**	**04/28/2016 (Thu)**	**05/06/2016 (Mon*)**	
Hours of Study	1.5	3	2	6.5
Total # Opportunities	2	30	12	44
Total # Blocking	2	26	11	39
Total # Non-Blocking	0	4	1	5
Propensity	1	0.87	0.92	0.89
** Police present*				

The highest observed before study propensity to block was 0.75, on Monday (10/26/2015), whereas the lowest propensity of 0.0 was observed on Thursday (10/29/2015), although the total opportunities were limited in that instance to seven opportunities. The highest observed after propensity to block was 1.0 on Tuesday (04/26/2016), again of limited significance as there were only two blocking opportunities, and the lowest was 0.87 on Thursday (04/28/2016). Aggregating overall blocking and non-blocking opportunities during the before and after data collection, propensities to block of 0.68 and 0.89 were observed. Unlike the Ashford Dunwoody Rd. NE at Ravinia Dr. NE, in this instance, the propensity to block increased. However, similar to the Ashford

Dunwoody Rd. NE at Ravinia Dr. NE, both the before and after propensity rates were high, with drivers in both cases more likely to block than not block. And again, from day to day, significant variations were seen in the likelihood to block.

3.2.3 Peachtree Dunwoody Rd. at Abernathy Rd. NE

For the Peachtree Dunwoody Rd. and Abernathy Rd. NE intersection, 8 hours of propensity data were extracted from the before video, and 4 hours of propensity data were extracted from the after video. Again, times for extraction were limited by the presence of traffic police. The 3-hour before–after study period was 4:00–7:00 PM. The highest observed before study propensity to block was 0.93 on Thursday (10/29/2015), whereas the lowest propensity of 0.75 was observed on Tuesday (10/27/2015), although the total opportunities were limited in that instance to four opportunities. For this intersection, the limited availability of after data due to the presence of traffic police resulted in inconclusive findings, with only 12 opportunities to block observed over the 4-day period. However, as with the previous two intersections, it is again seen in the before data that propensity rates were high, with drivers consistently more likely to block than not block.

Table 10 provides the number of hours of data extracted for each day, total number of blocking opportunities, total number of observed blocking vehicles, total number of observed non-blocking vehicles, and blocking propensity. The analysis is provided for each day of observation and overall before and after.

The highest observed before study propensity to block was 0.93 on Thursday (10/29/2015), whereas the lowest propensity of 0.75 was observed on Tuesday (10/27/2015), although the total opportunities were limited in that instance to four opportunities. For this intersection, the limited availability of after data due to the presence of traffic police resulted in inconclusive findings, with only 12 opportunities to block observed over the 4-day period. However, as with the previous two intersections, it is again seen in the before data that propensity rates were high, with drivers consistently more likely to block than not block.

Table 10: Peachtree Dunwoody Rd. at Abernathy Rd. NE.

Before	**10/26/2015 (Mon*)**	**10/27/2015 (Tue*)**	**10/28/2015 (Wed*)**	**10/29/2015 (Thu*)**	**Total**
Hours of Study	2.5	2	1.5	2	8
Total # Opportunities	62	4	19	45	130
Total # Blocking	51	3	16	42	112
Total # Non-Blocking	11	1	3	3	18
Propensity	0.82	0.75	0.84	0.93	0.86

After	**04/18/2016 (Mon*)**	**04/19/2016 (Tue*)**	**04/20/2016 (Wed*)**	**04/21/2016 (Thu*)**	
Hours of Study	1	1	1	1	4
Total # Opportunities	3	8	1	0	12
Total # Blocking	0	0	1	0	1
Total # Non-Blocking	3	8	0	0	11
Propensity	0	0	1.0	NA	Insufficient Data

** Police present – Data insufficient to conclude*

3.2.4 Peachtree Dunwoody Rd. at Johnson Ferry Rd.

For the Peachtree Dunwoody Rd. and Johnson Ferry Rd. intersection, 10.5 hours of propensity data were extracted from the before video and 8.75 hours of propensity data were extracted from the after video. Again, times for extraction were limited by the presence of traffic police. The 3-hour before–after study period was 3:00–6:00 PM. Table 11 provides the number of hours of data extracted for each day, total number of blocking opportunities, total number of observed blocking vehicles, total number of observed non-blocking vehicles, and blocking propensity. The analysis is provided for each day of observation and overall before and after.

Table 11: Peachtree Dunwoody Rd. at Johnson Ferry Rd.

Before	**10/26/2015 (Mon*)**	**10/27/2015 (Tue)**	**10/28/2015 (Wed)**	**10/29/2015 (Thu*)**	**Total**
Hours of Study	2	3	3	2.5	10.5
Total # Opportunities	187	1	0	31	219
Total # Blocking	161	1	0	20	182
Total # Non-Blocking	26	0	0	11	37
Propensity	0.86	0.00	NA	0.65	0.83

After	**04/25/2016 (Mon)**	**04/26/2016 (Tue)**	**04/27/2016 (Wed*)**	**04/28/2016 (Thu)**	
Hours of Study	1.5	2	2.25	3	8.75
Total # Opportunities	0	0	84	59	143
Total # Blocking	0	0	50	39	89
Total # Non-Blocking	0	0	34	20	54
Propensity	NA	NA	0.60	0.66	0.62
** Police present*					

The highest observed before study propensity to block was 0.86, on Monday (10/26/2015), whereas the lowest propensity of 0.0 was observed on Tuesday (10/27/2015), although again the total opportunities were limited in this instance to 1 opportunity. The highest observed after propensity to block was 0.66 on Thursday (04/28/2016) and the lowest was 0.60 on Wednesday (04/27/2016). Aggregating overall blocking and non-blocking opportunities during the before and after data collection, propensities to block of 0.83 and 0.62 were observed, a 21% decrease in propensity. However, similar to the previous intersections, both the before and after propensity rates were high, with drivers in both cases more likely to block than not block. And again, from day to day, significant variations were seen in the likelihood to block.

3.2.5 W. Paces Ferry Rd. NW at I-75 SB On/Off Ramps

For the West Paces Ferry Rd. NW and I-75 SB On/Off Ramps intersection, 9 hours of propensity data were extracted from both the before and after videos. The 3-hour before–after study period was 4:00–7:00 PM. Table 12 provides the number of hours of data extracted for each day, total number of blocking opportunities, total number of observed blocking vehicles, total number of observed non-blocking vehicles, and blocking propensity. The analysis is provided for each day of observation and overall before and after.

Table 12: W. Paces Ferry Rd. NW at I-75 SB On/Off Ramps.

Before	03/29/2016 (Tue)	03/30/2016 (Wed)	04/01/2016 (Fri)	Total
Hours of Study	3	3	3	9
Total # Opportunities	34	46	5	85
Total # Blocking	18	26	3	47
Total # Non-Blocking	16	20	2	38
Propensity	0.53	0.57	0.60	0.55

After	04/17/2017 (Mon)	04/18/2017 (Tue)	04/27/2017 (Thu)	
Hours of Study	3	3	3	9
Total # Opportunities	4	8	21	33
Total # Blocking	3	5	14	22
Total # Non-Blocking	1	3	7	11
Propensity	0.75	0.63	0.67	0.67

The highest observed before study propensity to block was 0.60, on Friday (04/01/2016), whereas the lowest propensity of 0.53 was observed on Tuesday (03/29/2016). The highest observed after propensity to block was 0.75 on Monday (04/17/2017) and the lowest was 0.63 on Tuesday (04/18/2017), again with a low sample size. Aggregating overall blocking and non-blocking opportunities during the before and after data collection, propensities to block of 0.55 and 0.67 were observed, a 12% increase in propensity. Again, similar to the previous intersections, both the before and after propensity rates were high, with drivers in both cases more likely to block than not block. And again, from day to day, significant variations were seen in the likelihood to block.

3.2.6 Clairmont Rd. at I-85 SB, near Sam's Club

For the Clairmont Rd. and I-85 SB, near Sam's Club, intersection, 9 hours of propensity data were extracted from both the before and after videos. The 3-hour before–after study period was 4:00–7:00 PM. Table 13 provides the number of hours of data extracted for each day, total number of blocking opportunities, total number of observed blocking vehicles, total number of observed non-blocking vehicles, and blocking propensity. The analysis is provided for each day of observation and overall before and after.

There is a significant difference between the Clairmont Rd. and I-85 SB, near Sam's Club intersection propensity data and that of the other intersections. The previous intersections all utilized the blocking definition as presented in Chapter 2. However, for this intersection a vehicle was counted as blocking if it entered the intersection and was unable to immediately exit. Thus, a vehicle that entered the box, stopped, and then was able to exit the box prior to its phase changing was considered to have blocked. In the prior definition, to be considered blocking, a vehicle was required to be in the intersection box when a conflicting movement received its phase change. Similarly, any vehicle that stopped at the stop bar and did not enter the intersection, for any period of time, was counted as not blocking, even if later during the phase indication the vehicle entered the intersection creating a block. In this instance, such vehicle behavior would be counted as both not blocking and blocking.

This broader blocking definition was selected to explore whether the blocking definitions chosen significantly influenced results. Also, this definition captures blocking of permissive movements that is not captured by the previous definition.

Table 13: Clairmont at I-85 SB, near Sam's Club.

Before	**04/11/2016 (Mon)**	**04/12/2016 (Tue)**	**04/15/2016 (Fri)**	**Total**
Hours of Study	3	3	3	9
Total # Opportunities	230	416	381	1027
Total # Blocking	159	314	278	751

Total # Non-Blocking	71	102	103	276
Propensity	0.69	0.75	0.73	0.73

After	**04/17/2017 (Mon)**	**04/18/2017 (Tue)**	**04/21/2017 (Fri)**	
Hours of Study	3	3	3	9
Total # Opportunities	361	217	510	1088
Total # Blocking	326	191	382	899
Total # Non-Blocking	35	26	128	189
Propensity	0.90	0.88	0.75	0.83

While the number of blocking opportunities under this broader definition is significantly greater, the overall propensity rates are similar to those of the previous intersections, ranging from 0.69 to 0.90. Aggregating overall blocking and non-blocking opportunities during the before and after data collection, propensities to block of 0.73 and 0.83 were observed, a 10% increase in propensity. Again, these results were in line with the previous observations. And once again, in both the before and after data, propensity rates were high, with drivers in both cases more likely to block than not block. However, a reduction in the day-to-day variation was seen.

3.3 Field Result Summary

Table 14 summarizes the overall results of the propensity analysis for all intersections.

Table 14: Results Summary for All Intersections.

Intersection Name		Total # Hours	Total # of Opportu-nity	Total # of Blocking	Total # of Non-Blocking	Prope-nsity
1. **Ashford Dunwoody Rd. NE at Ravinia Dr. NE**	Before	4	28	20	8	0.71
	After	9	304	184	118	0.61
2. **Peachtree Dunwoody Rd. at Lake Hearn Dr. NE**	Before	9	114	77	37	0.68
	After	6.5	44	39	5	0.89
3. **Peachtree Dunwoody Rd. at Abernathy Rd. NE**	Before	8	130	112	18	0.86
	After	4	12	1	11	Insuffi-cient data
4. **Peachtree Dunwoody Rd. at Johnson Ferry Rd.**	Before	10.5	219	182	37	0.83
	After	8.75	143	89	54	0.62
5. **W. Paces Ferry Rd. NW at I-75 SB On/Off Ramps**	Before	9	85	47	38	0.55
	After	9	33	22	11	0.67
6. **Clairmont Rd. at I-85 SB, near Sam's Club**	Before	9	1027	751	276	0.73
	After	9	1088	899	189	0.83

Several characteristics in blocking behavior are evident throughout the analysis. First, the change in propensity between before and after conditions was inconsistent, witnessing both increasing and decreasing propensity. However, regardless of an increase or decrease in blocking rate, the aggregated observed propensities were consistently high in both the before and after conditions. The lowest observed aggregate propensity to block was 55% with all other time periods above 60%, and half of the time periods observed had a propensity to block of 70%. In addition, there was significant variability in day-to-day blocking opportunities. At the same intersection, within the same week there would be peak periods where the opportunity to block was rare or non-existent, while on other days significant blocking opportunities were observed.

3.4 Simulation Study

As previously discussed, it was not possible to collect operation metrics such as travel time and delay at the intersections. To understand the operational impact of DBTB treatments, a microscopic simulation model of a signalized four-leg intersection that has downstream bottlenecks on its major street was developed. The simulation reflects the propensity of a vehicle entering the intersection box when a blocking opportunity exists and the resulting blocking of traffic should a vehicle "block the box." This study explores the relationship of this blocking behavior to vehicle delay and reduced capacity. Appendix C provides a detailed discussion of the simulation study methodology and findings; thus, only the key insights are provided in the following discussion.

From the delay and capacity reduction results of the simulation study, it is seen that the impact of blocking can be significant, reaching complete gridlock on intersection approaches. However, the results demonstrate that a DBTB treatment can significantly improve flow even without achieving the goal of zero blocking. This is particularly true where blocking propensity is reduced from the mid-range (40% to 60%) to under 20%. From this it may be postulated that many of the intersections that were included in this study could potentially receive a significant benefit if blocking could be reduced to significantly lower rates. While the treatments in the current field study did not demonstrate rate reductions to the level necessary in the simulation study for meaningful operational benefits, the simulation study does highlight the importance for continuing to seek a solution to the DBTB challenge.

Chapter 4: CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

Traffic congestion is often an unfortunate reality. As such, it is necessary to manage congestion, minimizing its impacts. In congestion, when a vehicle enters an intersection that has insufficient space to exit on the opposite side due to downstream traffic spillback, it often leads to the obstruction of vehicle and pedestrian movement on conflicting approaches. The effect of "blocking the box" can propagate to nearby intersections and, in extreme cases, lead to gridlock. Along with negative traffic impacts, such as capacity reductions and increased travel times, blocking the box creates potentially unsafe vehicle and pedestrian movement. A "Do Not Block the Box" treatment seeks to reduce the likelihood of drivers entering an intersection when there is insufficient space to exit, and thus reduce blocking occurrences. DBTB treatments are typically low cost, representing a traffic management alternative accessible to most transportation agencies. This report presented a study that explored the performance of DBTB treatments installed in the greater Atlanta, Georgia, area.

For the studied sites, the likelihood, or propensity, of a vehicle to block was measured both before and after the DBTB treatment installation. Several blocking behavior characteristics were observed throughout the analysis. First, the change in propensity with the installation of the DBTB treatment was inconsistent, witnessing both increasing and decreasing blocking rates. However, regardless of an increase or decrease in blocking rate, the aggregated observed propensities at the studied intersections were consistently high in both the before and after treatment conditions. The lowest observed aggregate propensity to block was 55%, with all other time periods above 60%, and half of the observed periods with a propensity to block of 70%. In addition, there was significant variability in day-to-day blocking opportunities. That is, at the same intersection, within the same week, peak periods where opportunities to block were rare or non-existent were observed, as well as peak periods with significant blocking opportunities. *Given these findings, it may not be concluded that the installed treatments reliably impacted blocking behavior*. In addition, where sites did show improvements, the blocking rate remained high, often well in excess of 50%.

There are potential biases in this study. The first is that the sites were not randomly selected; rather, they were identified as high blocking sites by system managers. These sites may represent the worst-case scenarios and the most difficult to address. In addition, the after data collection at several sites occurred during the I-85 bridge closure. It is not known if the potential rerouting or other driver responses to this incident may have influenced the observed driver behavior. Finally, several sites utilized police officer control during the highest demand periods. If the police were not present, these time periods may have experienced different blocking behavior than the time periods included in the evaluation. However, even given these potential biases, there still remains a failure of the DBTB treatment to address blocking under these conditions.

While not measured at these sites, it is important to highlight that a reduction in blocking may result in significant operational improvements. To explore potential performance impacts of blocking, a microscopic simulation model of blocking behavior was developed. The simulation reflects the propensity of a vehicle entering the intersection box when a blocking opportunity exists and the resulting blocking of traffic, should a vehicle "block the box." This model allowed for the exploration of the relationship of blocking behavior to vehicle delay and intersection capacity. The results showed that the impact of blocking can be significant, potentially resulting in gridlock. However, the simulation also was able to demonstrate that DBTB treatments can significantly improve traffic flow even without achieving zero blocking. From this it may be postulated that many of the intersections that were included in this study could significantly benefit if blocking could be reduced. While the treatments in the current field study did not demonstrate the blocking rate reductions necessary for meaningful operational benefits, the simulation study does highlight the importance for continuing to seek a solution to the DBTB challenge.

4.2 Recommendations

Vehicle blocking can significantly impact traffic operations. While the current treatment as a standalone measure did not meaningfully impact blocking behavior, there is significant value in continuing to seek reductions in blocking behavior. Thus, based on the study findings and field observations during the data collection, several recommendations are offered.

1) **Signal timing to reduce blocking opportunities.** The first strategy to address blocking should be, where possible, the elimination of the potential for blocking utilizing congested-period signal timing that reduces blocking opportunities. Blocking opportunities occur where the flow of vehicles into an intersection exceeds the intersection capacity, often reflected as spillback into upstream

intersections. Where practical, upstream signal timing should be set to limit downstream vehicle arrivals to that of the downstream intersection processing capacity. While this may result in lower upstream performance, avoiding the gridlock within the network resulting from spillback and blocking should be prioritized. The development of such signal timings will typically require the use of advanced simulation tools applied at the corridor level over time periods greater than the typical peak-hour analysis. While this represents a significant investment in timing plan development, the potential benefits are substantial.

2) **Reduction or elimination of free-flow turn movements during congested periods.** One key observation at several sites is related to the impact of free-flow turn movements on intersection operations. Under high-demand conditions, a free-flow movement could continuously "fill-in" available capacity on the departure lanes of an intersection approach. This would result in vehicles from a controlled movement utilizing the same departure lanes continually being unable to proceed when they receive a green indication. It is reasonable to hypothesize that this increases the driver frustration and aggressiveness from the controlled movement, resulting in additional blocking, as they saw that as the only opportunity to proceed through the intersection.

3) **Limit candidate intersections.** While blocking the box occurs when a vehicle stops within the box, in a practical sense many of the observed "blocks" had minimal or no observed impacts on intersection capacity. This could occur for two reasons. The first is that the size of the intersection proper allowed conflicting vehicles to easily maneuver around the blocking vehicle(s). The second is that the

blocking and blocked vehicles used the same intersection departure lanes. In such an instance, while blocking occurred, there was no intersection capacity impact. In both situations, as drivers saw minimal-to-no benefit of the treatment, this may have increased the likelihood of disregarding the treatment.

4) **Public education.** A public education program on the benefits of not blocking the box may help to decrease the propensity to block and reinforce the need to follow DBTB treatments.
5) **Enforcement.** Along with public education, there is likely a need for enforcement. For the given study, none of the intersection DBTB treatments were enforced through citations to drivers that blocked the box. The effectiveness of enforcement in improving the DBTB treatment performance should be explored. This should include different enforcement program durations (i.e., intermittent vs continual), warnings vs. citations, automated vs. manual citations, etc.
6) **Additional treatment.** Additional treatments should be developed and tested, for instance, flashing DBTB signs that are indicated only when vehicles are detected stopped in intersection departure lanes.

Finally, the most probable means to successfully address intersection blocking is the development of a DBTB overarching program. Such a program would combine the above recommendations into a comprehensive strategy, developing training directed at identifying factors contributing to blocking at specific intersections, developing signal timing plan guidance addressing blocking, applying DBTB signal and striping design, implementing wide-spread education, etc.

Chapter 5: REFERENCES

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Appendix A ANALYSIS OF VEHICLE BLOCKING BEHAVIOR ON INTERSECTION PERFORMANCE

LIST OF TABLES

LIST OF FIGURES

A.1 Abstract

While some congestion may be inevitable, it is critical that congestion not escalate due to gridlock. As such, “Do Not Block the Box” (DBTB) treatments represent a potential low cost, traffic operations mitigation measure aimed at minimizing gridlock in congested intersection networks. A vehicle is considered to “Block the Box” when it enters the intersection with no space to exit due to the traffic spillback downstream. While the use of a DBTB treatment as a control strategy has been adopted by many cities in the U.S., there is a lack of literature on its effectiveness. This research explores the performance of DBTB treatments by quantifying the impact of vehicle blocking behavior on intersection performance. For this, a microscopic simulation model of a signalized four-leg intersection that has downstream bottlenecks on its major street was developed. The simulation reflects the likelihood of a vehicle entering the intersection box when a blocking opportunity exists and the resulting blocking of traffic should a vehicle “block the box.” This study explores the relationship of this blocking behavior to vehicle delay and reduced capacity. From the delay and capacity-reduction results, it is seen that the impact of blocking can be significant, reaching complete gridlock on intersection approaches. Ultimately, the goal of a DBTB treatment is to reduce the number of blocking events to zero. However, from the result of this study it is seen that a DBTB treatment can significantly improve flow even without achieving the goal of zero blocking.

Keywords: Do Not Block the Box, Public Information, Gridlock, Traffic Enforcement, Traffic Simulation

A.2 Introduction

Traffic congestion negatively impacts quality of life, hampers business activities, and adds to harmful vehicular emissions (1). In 2013 alone, traffic congestion cost the U.S. an estimated $124B, a value that is projected to increase 50% by 2030 (2). While some congestion may be inevitable, it is critical that congestion not escalate due to gridlock. As such, "Do Not Block Intersection" or "Do Not Block the Box" treatments represent a potential low cost, traffic operations mitigation measure aimed at minimizing gridlock in congested intersection networks. DBTB treatments have been successfully implemented in several parts of the world and represent a traffic management alternative available to federal, state, and local transportation agencies and groups (3). This paper explores the potential impact of DBTB treatments at congested signalized intersections.

"Blocking the box" occurs when a vehicle with right-of-way (e.g., a green indication at a signalized intersection) enters the intersection with insufficient space to exit on the opposite side due to downstream traffic spillback. This vehicle must then stop within the intersection proper, or "box," potentially obstructing the movement of pedestrians and vehicles with right-of-way on conflicting approaches. For instance, blocking a permitted turn movement during the current phase or blocking cross-street traffic if the vehicle remains trapped in the intersection after the current phase terminates. The compounding of multiple blocking events on a congested network can lead to gridlock situations and excessive delays (3). A DBTB treatment seeks to reduce the likelihood of drivers entering an intersection when there is insufficient space to exit the box, and thus reduce blocking occurrences and the potential for gridlock.

A.3 Background

Characteristics of gridlock and strategies to control it has long been a topic of interest to researchers (4, 5, 6, 7, 8). It is been shown that avoiding growth of small localized gridlock can prevent a network-level gridlock ("jam" state) (9). However, there is lack of detailed study on DBTB treatments performance and efficiency (3). One of the few studies identified considered the DBTB treatment implemented by the Boston Transportation Department in partnership with the Medical Academic and Scientific Community Organization (MASCO) and the Boston Police Department. This study observed a 50% decrease in intersection blocking and it reported a reduction of 22% to 64% in number of citations after enforcing DBTB treatments (3, 10). A number of additional studies have also reported on citations and warnings related to DBTB enforcement (3, 11, 12, 13, 14); however, while the number of blocking events could be quantified by tracking citations the driver time savings due to this DBTB and enforcement must be estimated through other means.

While studies on DBTB operations are limited, the history of using DBTB treatments to avert gridlock dates back to at least 1964, with success of the first recorded DBTB treatment, installed in London, England. In the 1970s, the first U.S. DBTB treatments were installed in New York. Since those first installments, DBTB programs have increased in popularity as a gridlock mitigation measure (3, 15). As of today, DBTB has been adopted in many U.S. cities, including Boston, Miami, Austin, San Francisco, Atlanta, etc.

Installing DBTB at an intersection is a simple and low-cost process. It consists of implementing a striping treatment adhering to the standards in the Manual on Uniform Traffic Control Devices (MUTCD), as shown in Figure A-1. In addition, signs stating "Do

Not Block Intersection" or "Do Not Block the Box" are installed near the intersection. This striping treatment visually warns the driver to avoid queueing within the intersection box. The cost of installing a DBTB treatment involves cost of painting the pavement markings and installing the signs and typically ranges from $1000 to $2000 with a comparable 20-year maintenance cost. A significant share of DBTB program cost goes to enforcement, which is done either through parking attendants, police, or automated gridlock cameras (3). For instance, within the StreetSafe initiative launched in 2013, the Washington D.C. Metropolitan Police Department (MPD) installed gridlock cameras at 20 intersections (16).

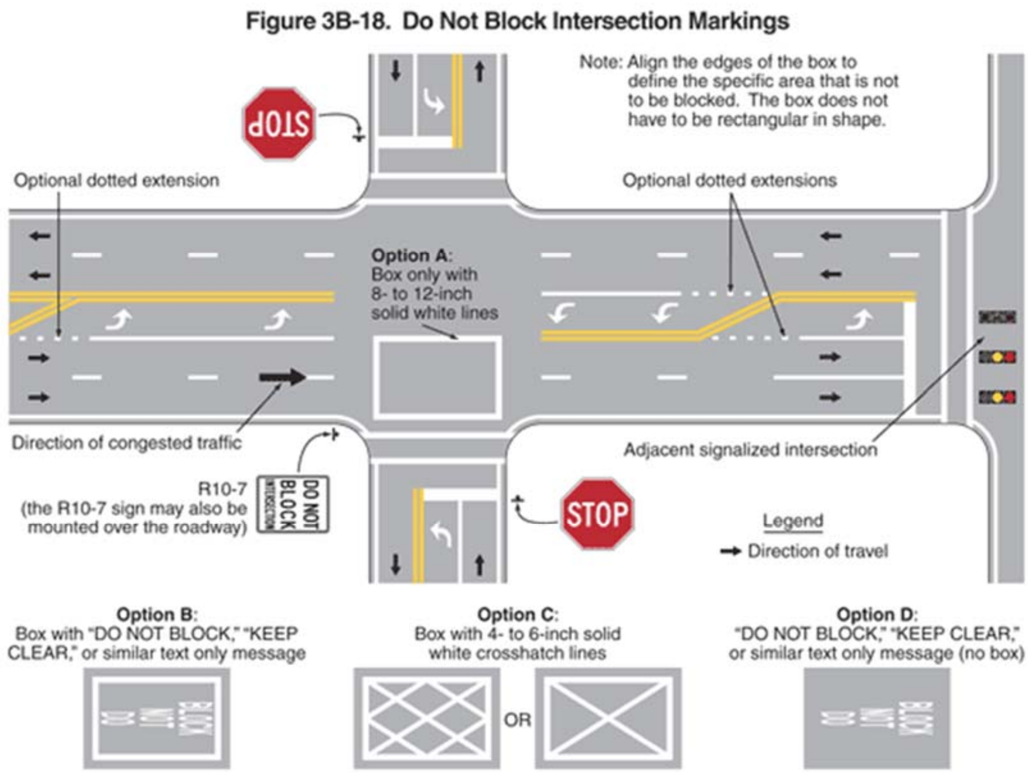


Figure A-1: MUTCD "Do Not Block Intersection" Markings (3, 17).

Drivers' adherence to DBTB regulations is crucial for the success of DBTB treatments. U.S. traffic codes that enable issuing citations to block-the-box violators, generally fall into three categories: 1) obstructing, 2) stopping, and 3) sign laws. The obstructing laws prohibit a driver from entering an intersection that has insufficient space to exit, regardless of the traffic control signal indication. The stopping laws prohibit a vehicle from standing, stopping, or parking within an intersection, unless necessary either to avoid conflict or comply with the directions of a police officer or traffic control device. Lastly, in some states, the sign laws reinforce the stopping laws, restricting the driver from stopping at posted locations (3). While most jurisdictions consider blocking-the-box as a moving violation, some cities (e.g., New York) classify it as non-moving to enable both police officers and parking attendants to issue citations thus greatly increasing the number of people that may enforce DBTB (3, 18). Table A-1 summarizes presence of DBTB laws in state traffic codes.

Table A-1: Summary of Blocking Laws for Every State, Including the District of Columbia (3, 19).

State	Obstructing Law	Stopping Law	Sign Law
Alabama, California, Colorado, Georgia, Hawaii, Minnesota, North Dakota, Ohio, Pennsylvania, Washington	✓	✓	✓
Delaware, District of Columbia, Florida, Idaho, Michigan, Nevada, New York, Oregon, South Carolina	✓	✓	
Arizona, Arkansas, Illinois, Kansas, Louisiana, Maryland, Mississippi, Nebraska, New Hampshire, New Mexico, Oklahoma, Rhode Island, South Dakota, Tennessee, Texas, Vermont, West Virginia, Wyoming		✓	✓
Alaska, Missouri, New Jersey, North Carolina, Utah, Virginia	✓		
Montana		✓	
Connecticut, Indiana, Iowa, Kentucky, Maine, Massachusetts, Wisconsin	-	-	-

A.4 Methodology

A traffic simulation model consisting of a signalized four-leg intersection, a six-lane major arterial crossing a four-lane minor street, developed in VISSIM®, was employed to investigate DBTB. To generate blocking opportunities at the intersection, downstream bottlenecks are placed on the major arterial, creating spillback (i.e., queuing) through the intersection box. Major street vehicles may follow either blocking (i.e., will enter the intersection box when the exit is blocked by a queue) or non-blocking (i.e., will not enter an intersection if a block would result) behavior. The selected behavior is determined randomly according to a user defined *blocking likelihood*, i.e., the likelihood that a vehicle will exhibit blocking behavior. For instance, a *blocking likelihood* of "zero" precludes any vehicle from entering the intersection if the entry would cause a block to occur, while a *blocking likelihood* of "one" indicates that all vehicles will enter the intersection without concern for the potential to create a block. This modeling approach allows for the exploration of the sensitivity of intersection operations to different levels of *blocking likelihood* and to the impact of a reduced likelihood due to a DBTB treatment. Implementation of this methodology is described in the remainder of this section.

A.4.1 PTV VISSIM® Traffic Simulation Software

The traffic simulation used in this research was implemented in PTV-VISSIM 5.2® a commercially available microscopic transportation simulation package. In this model, traffic flow is based on the Wiedemann's car-following models and rule-based algorithms for lateral vehicle movement (20, 21). This effort required use of the VISSIM COM (component object model) interface that allows access to the object model hierarchy, with network elements such as vehicles, links, vehicle inputs, etc. (22).

A.4.2 Network Layout

The simulation model is shown schematically in Figure A-2: . The left image is a snapshot of the network and the right image is a sketch of the signal layout. Signal A controls the traffic movement at the Major Street and Minor Street intersection. Signals B and C are placed on the major street, downstream of the intersection, to function as traffic bottlenecks.

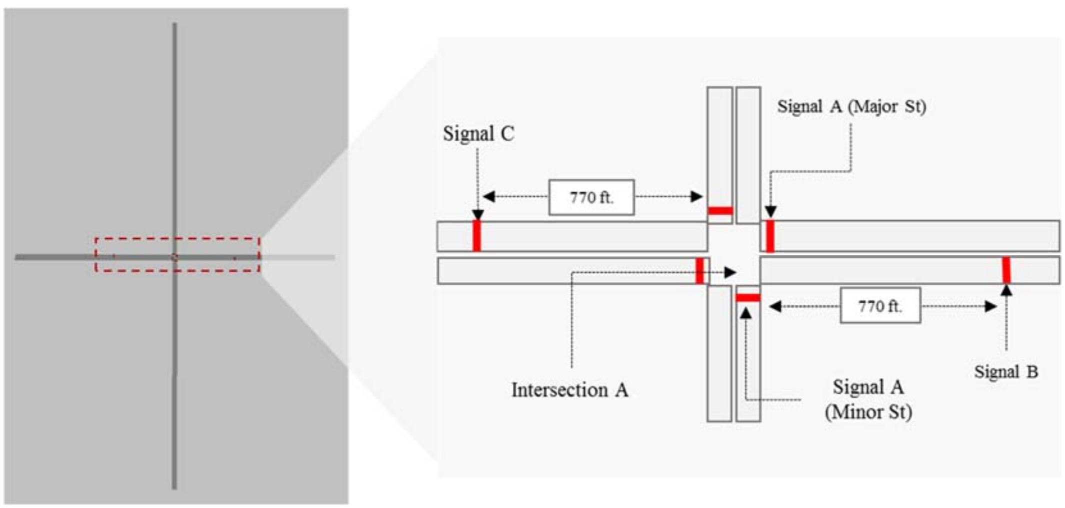


Figure A-2: Schematic Diagram of the Network Developed in the Simulation Model.

A.4.3 Implementing Blocking Behavior

To simulate a blocking incident a vehicle must enter the intersection when a blocking opportunity exists. That is, traffic spillback (i.e., queuing) from a downstream bottleneck must reach the subject intersection, leaving insufficient space for a vehicle that enters the intersection box to exit. To generate the spillback in this study, fixed-time signal phase lengths were chosen such that the Signal B (or Signal C) hourly capacity is less than that of the upstream Signal A approach. Thus, as the mainline flow increased the capacity of

Signal B (or Signal C) would be exceeded prior to that of Signal A, allowing for the development of a queue between Signal B (or Signal C) and Intersection A.

At several intersections in Atlanta it was observed that not all drivers choose to enter an intersection box when that action could result in blocking. Thus, it is also necessary that the simulation reflects the likelihood of a vehicle entering the intersection box when a blocking opportunity exists. For this effort, this is referred to as the blocking likelihood. To implement blocking likelihood in VISSIM, dynamic assignment of the Vehicle Type attribute of the Vehicle Object is utilized in coordination with Priority Rules.

A.4.4 Dynamic Assignment of Vehicle Type

Three different vehicle types are defined:

- *Vehicle Type 1* – This vehicle has the default characteristics. All vehicles enter the simulation as a type 1 vehicle.
- *Vehicle Type 2 – Vehicle type 1* with driver behavior to enter an intersection box irrespective of space availability to exit the box. That is, a vehicle that can create a blocking event.
- *Vehicle Type 3 – Vehicle type 1* with driver behavior that will not enter the intersection when insufficient space exists at the box exit. That is, a vehicle that will not create a blocking event.

To implement dynamic assignment of *vehicle type* according to the *blocking likelihood* each major street approach of the DBTB intersection is divided into two sections: 1) the decision-zone, i.e., the area where vehicles are assigned as *vehicle type 2* or *vehicle type 3*; and 2) the box zone, i.e., the area including the intersection proper and one vehicle length downstream. The schematic representation of the sections is shown in Figure A-3: .

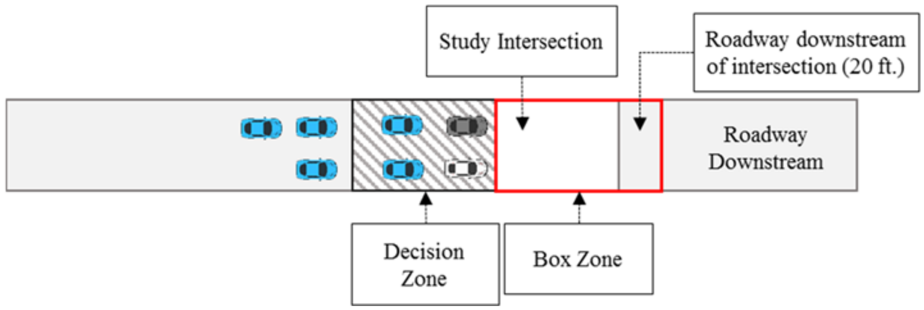


Figure A-3: Roadway Sections of the Network on Major Street Approaches to Implement DBTB.

Dynamic assignment of the *vehicle type* is implemented in VB.Net using the VISSIM COM interface. The first step is to determine if the potential for blocking exists. This step acts only as a filter, eliminating the need to dynamically assign *vehicle type* when blocking is not possible. While elimination of this filter would not alter the simulation results, it serves to reduce internal calculations required to assign *vehicle type* and significantly enhance the execution speed of the simulation. In the current implementation, a vehicle speed of 15 mph in the box zone was used for this filter.

In the second step of the dynamic assignment process, applied only when the potential for blocking has been indicated, COM is used to identify vehicles within the decision zone using the *approach link number* and *vehicle coordinate* attributes. The vehicle closest to the stop line in the decision-zone is assigned as the lead vehicle. The lead vehicle is then assigned as *vehicle type 2* with a probability of *blocking likelihood*; otherwise, the lead vehicle is assigned as *vehicle type 3*. Those vehicles in decision zone upstream of the leading vehicle are then designated as following vehicles and assigned the same vehicle type as the lead vehicle. The *vehicle type* assignments for the lead and following vehicles is undertaken on a lane-by-lane basis. The assignment of the following vehicle behavior to that of the lead vehicle is based on observation of blocking behavior in Atlanta, Georgia. It was observed that when a vehicle made a decision to block, several vehicles behind that vehicle (i.e., following vehicles) also had a very high tendency to enter the intersection. Future efforts will seek to formalize the relationship between the lead vehicle *blocking likelihood* and the subsequent following vehicles *blocking likelihood*.

A.4.5 Implementing Blocking Rules

VISSIM priority rules are used to enable the conditional stopping necessary to implement the desired blocking and non-blocking behavior based on the assigned *vehicle type*. Priority rules are based on the headway and gap conditions of a vehicle at specified location and are specific to a *vehicle type*. Two elements are required to implement a priority rule in VISSIM: 1) a stop line, and 2) one or more conflict markers associated with the stop line. In this implementation, the stop line of the priority rule is placed at the stop bar of the major street approach, with the conflict marker placed one vehicle length downstream of the intersection box. Figure A-4 shows this framework in the model. The minimum headway, defined as the length of the conflict area, is set to extend from the conflict marker to the approach stop bar (yellow area in Figure A-4:). The minimum gap, defined as the time until a conflicting vehicle reaches the conflict marker, is set to two seconds. Thus, if a vehicle is within the area between the stop bar and the conflict marker or within two seconds of the conflict marker, the priority rule will be active and an adhering *vehicle type* will not enter the intersection box. Finally, the priority rule was conditioned on the speed of the subject vehicle type, with approximately 18 mph for the priority rule to apply. In this implementation, only *vehicle type 3* adheres to the priority rule. Thus, *vehicle type*

3 will exhibit non-blocking behavior, while *vehicle type 2* will enter an intersection box when the possibility of creating a block exists.

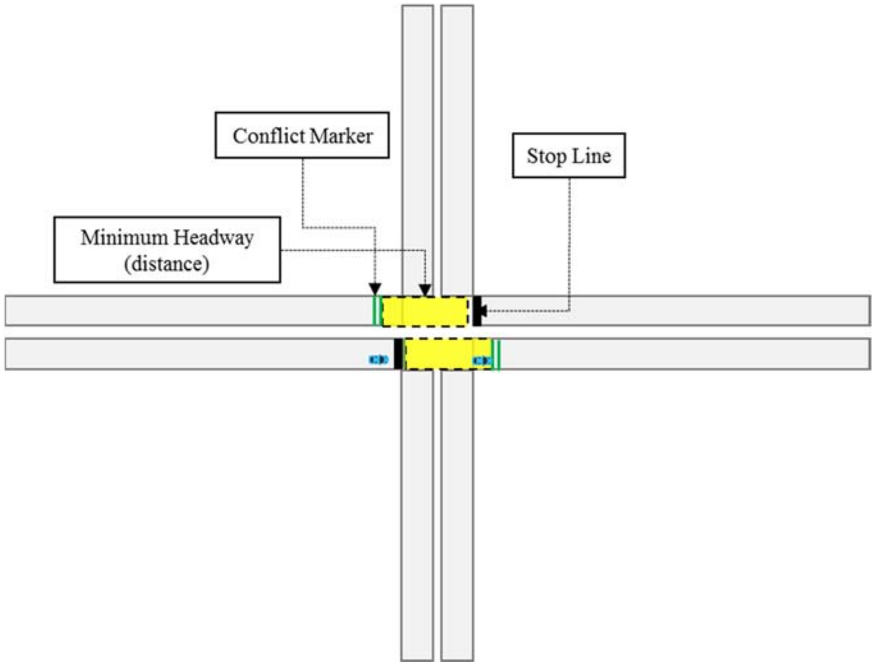


Figure A-4: Operation of the Priority Rule to Incorporate the Non-blocking Behavior for Vehicle Type 3.

Figure A-5: is a snapshot of the simulation with a *blocking likelihood* of 60%. The image shows *vehicle type* indicated by color. A change in vehicle type associated with the dynamic assignment of vehicles of *vehicle type 1* is seen on every lane of the major street. For example, considering Eastbound traffic, the yellow colored EB vehicles of *vehicle type 1* change to *vehicle type 2* or *vehicle type 3* in the decision zone. Furthermore, vehicles of *vehicle type 2* on the two leftmost lanes of EB approach block the vehicles on the NB approach while the vehicles of *vehicle type 3* on the rightmost lane exhibit non-blocking behavior and remain out of the box.

Vehicle Colors As per Vehicle Type
EB *Vehicle Type 1* – Yellow
WB *Vehicle Type 1* – Red
NB *Vehicle Type 1* – Blue
SB *Vehicle Type 1* – Green

Lead *Vehicle Type 2* – Purple
Lead *Vehicle Type 3* – Orange
Follower *Vehicle Type 2* – Black
Follower *Vehicle Type 3* – White

Figure A-5: Simulation Run Snapshot (60% Blocking Likelihood) Showing Dynamic Assignment of Vehicle Type with Change in Vehicle Color.

Figure A-6: displays the flowchart of the simulation COM logic for the dynamic assignment of *vehicle type*. This logic is implemented in VB.NET and executed each simulation time step, for each Major Street approach lane.

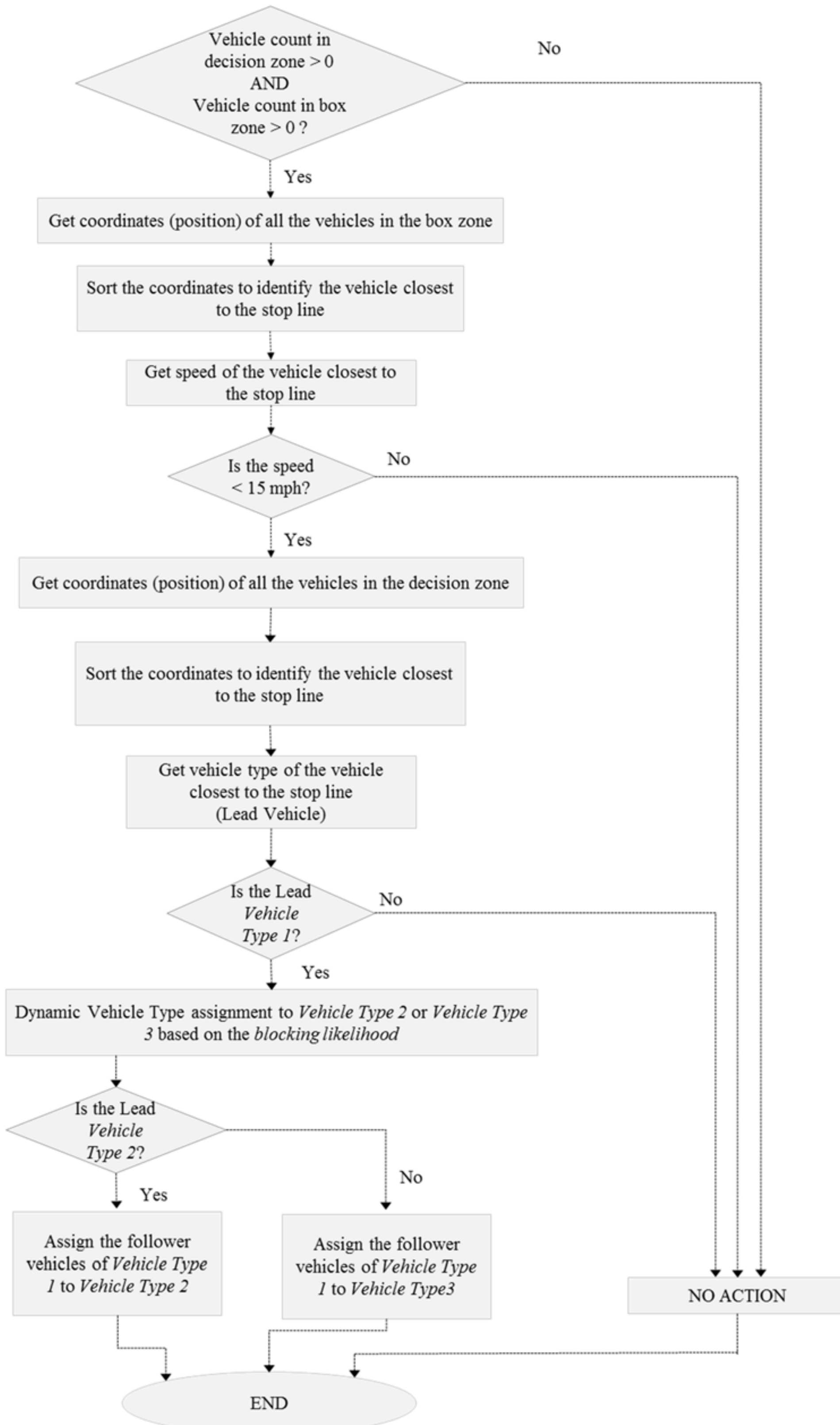


Figure A-6: Logic Flowchart of the DBTB Dynamic Assignment of Vehicle Type.

A.5 Experimental Design

The base simulation scenario consisted of a 3-hour simulation allowing for the collection of performance metrics during major street near-capacity conditions, overcapacity conditions, where blocking could occur, and a recovery period. To accomplish this the first-hour major street traffic demand was set just below the capacity of the downstream Signals B and C, the second-hour traffic demand was set over the capacity of Signals B and C while under the capacity of the Intersection A major street approaches, and the third hour major street traffic demand was set under the capacity of Signals B and C. The minor street had consistent traffic demand throughout the simulation run. All signals were fixed time. Signals B and C near-capacity (1900 vph) and over-capacity (2600 vph) demands were determined through iterative runs on the base network.

Simulation experiments were conducted to model the delay incurred and the reduction in the number of vehicles processed on the minor street approaches for three under-saturated traffic conditions (100, 200, and 300 vph) as well as oversaturated conditions (standing minor street approach queue throughout the simulation), under various blocking likelihoods (0%, 20%, 40%, 60%, 80%, and 100%). The reduction in the number of vehicles processed when the minor street was oversaturated also represents reduction in minor street capacity during blocking. In all scenarios, only through vehicles are modeled. Ten replicate trials were conducted for each traffic demand with blocking likelihood combination.

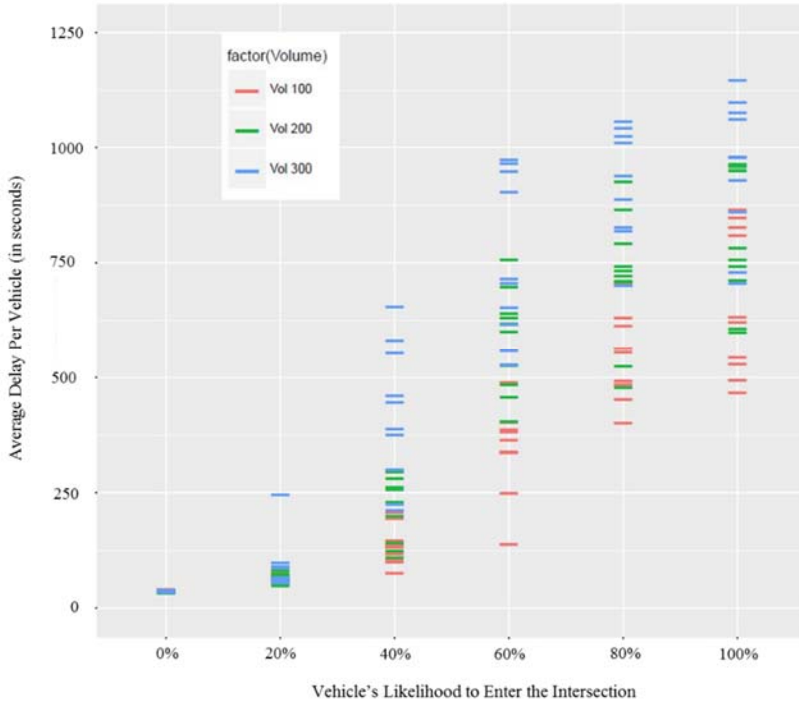
A.6 Results

The focus of the simulation results is on the minor street vehicles, since the given scenarios' blocking has minimal impact on the major street performance. As there are no turning movements a major street vehicle choosing not to block does not compete for space with minor street vehicles turning onto the major street. While the addition of turning movements will allow for the capture of additional interactions, it is not expected to change the overall observed trends.

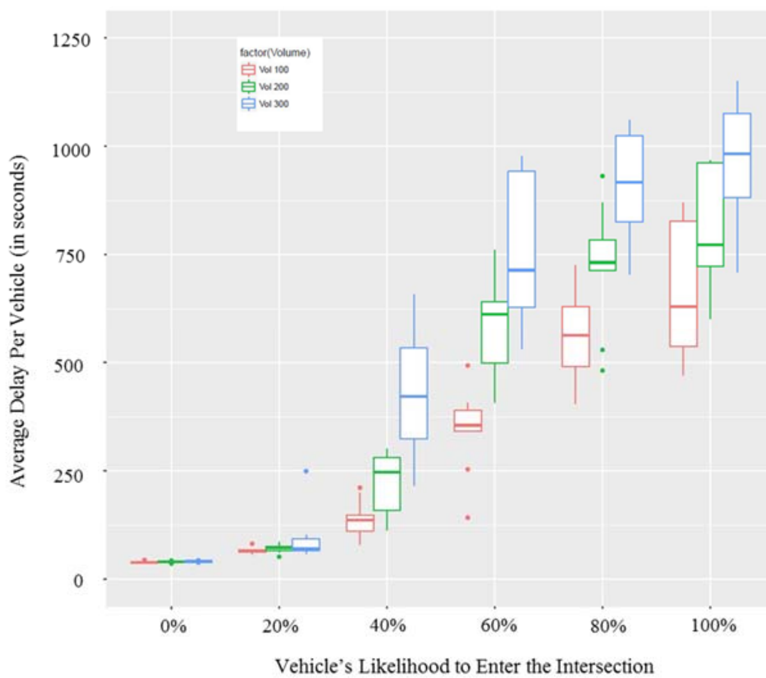
A.6.1 Delay

Figure A-7: (a) and Figure A-7: (b) show the scatterplot and box plots, respectively, for the average delay (sec/veh) over the 3-hour run, obtained for the 100 vph, 200 vph, and 300 vph minor street volumes across *blocking likelihoods*. For this analysis, the average vehicle delay was determined for every five-minute interval and the reported average delay is the average of these intervals.

As expected, as the minor street volume increases, the delay values also increase. The *blocking likelihood* of 0% shows the expected delay for no blocking by major street vehicles. As the blocking likelihood increases the delay increases, with the most significant increases in mean delay and variability at 40% and 60%. The higher minor street volumes also have more dramatic increases in delay and variability, as seen in the box plots. These values may be conservative, as the simulation does not reflect that these increasing delays may increase minor street vehicle aggressiveness, resulting in additional blocking as minor street vehicles attempt to force their traversal of the intersection. Figure A-8: (a) and Figure A-8: (b) show the scatterplot and box plots, respectively, for the maximum 15-minute average delay (sec/veh). These delay values represent the worst case performance experienced by vehicles, with instances at the highest *blocking likelihoods* representing complete gridlock with delays approaching one hour. Although the range of average delay values obtained in Figure A-8: are more than twice that shown in Figure A-7: the basic pattern in variation across different blocking likelihood and minor street volumes remains similar.

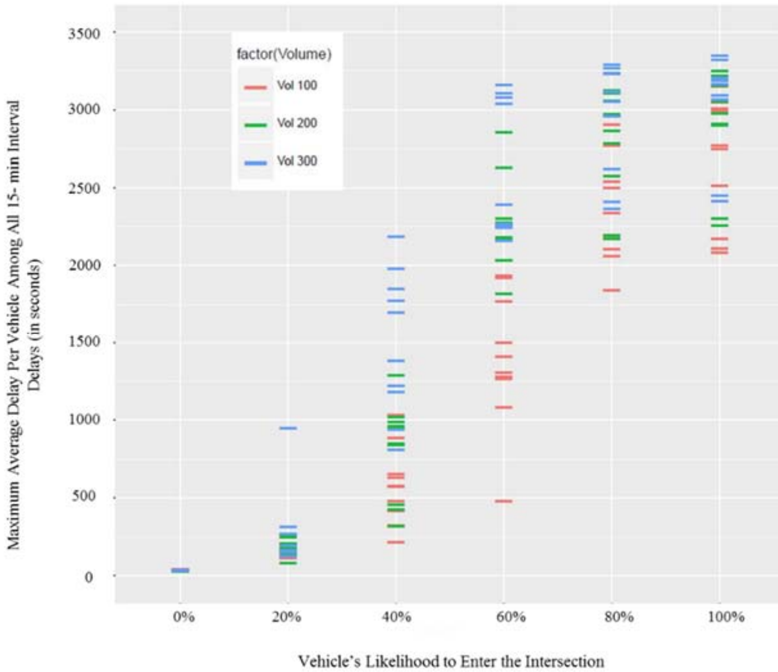


(a)

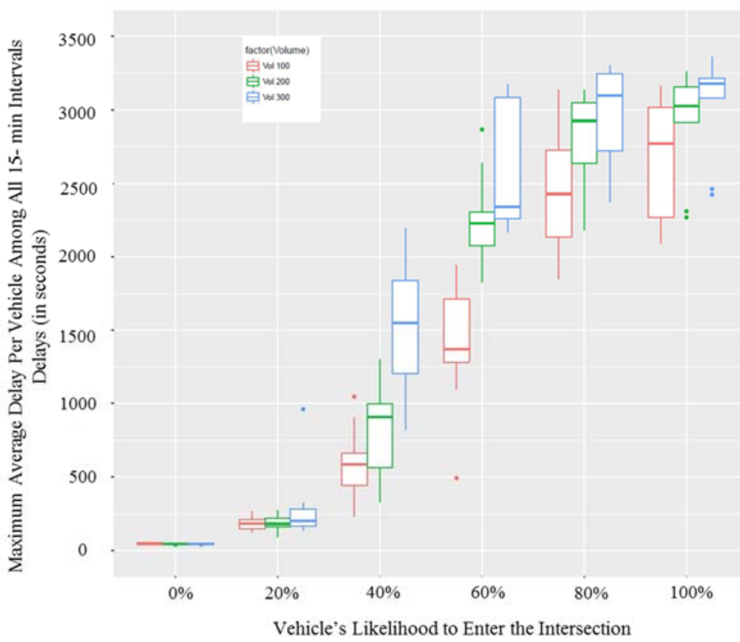


(b)

Figure A-7: (a) Scatterplot of Average Delay (sec/veh) on Minor Street Versus Blocking Likelihood, and (b) Boxplot of Average Delay (sec/veh) on Minor Street Versus Blocking Likelihood.



(a)



(b)

Figure A-8: (a) Scatterplot of Max 15-min Average Delay (sec/veh) on Minor Street Versus Blocking Likelihood, and (b) Boxplot of Maximum 15-min Average Delay on Minor Street Vehicle Versus Blocking Likelihood.

A.6.2 Minor Street Capacity Reduction

The results obtained for the oversaturated demand on the side street are shown in Figure A-9:. The scatterplot shows the reduction in minor street processed traffic due to blocking on the major street. Given the oversaturated conditions, (i.e., there was a continuous standing queue) minor street processed traffic was approximately 2400 vehicles during the 3-hour simulation run (i.e., an hourly capacity of approximately 800 veh/hr), determined as the number of minor street vehicles to traverse the intersection when no major street vehicles were blocking, i.e. *blocking likelihood* of zero. The reduction in traffic processed in Figure A-9: represents how many fewer vehicles departed the Minor Street approach during the 3-hour run, for the varying likelihoods, with nearly all reductions occurring in the second hour during blocking.

The scatterplots again indicate that the most dramatic reductions in traffic processed occur in the mid-range *blocking likelihoods* of 40% and 60%, with reductions due to blocking equivalent to 60% to 100% of an hour of capacity. Also, agreeing with the prior delay results, nearly complete gridlock is seen in the 80% and 100% *blocking likelihoods* with reductions approaching and exceeding the capacity of the entire second hour of the Major Street blocking period.

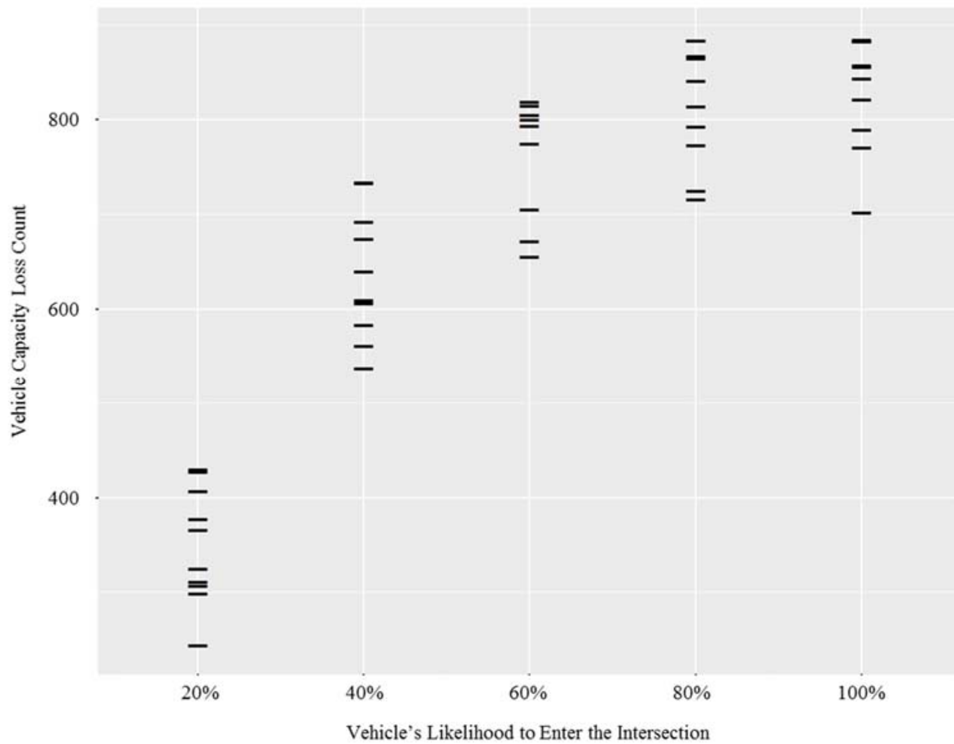


Figure A-9: Scatterplot Depicting Variability in the Minor Street Capacity Loss Across Different Levels of Blocking Likelihoods.

A.7 Conclusion

This study explores the relationship between blocking behavior, increased vehicle delay, and capacity reduction in a single intersection scenario. From the delay and capacity reduction results, it is seen that the impact of blocking can be significant, reaching complete gridlock on intersection approaches. Ultimately, the goal of a DBTB treatment is to reduce the *blocking likelihood* to zero, or nearly so. However, from the results it can be seen that a DBTB treatment can significantly improve flow even without achieving the goal of zero blocking. This is particularly true where *blocking likelihood* is reduced from the mid-range (40% to 60%) to under 20%. This also demonstrates the importance of enforcement programs. While it is not necessary that enforcement eliminate blocking altogether, they must be of sufficient frequency to limit those drivers willing to risk blocking to a low percentage of the driving population.

While the results highlight the potentially significant impact of blocking, and the improvements that could be achieved through DBTB treatments, several challenges remain in the analysis. The first is regarding model validation. Current validation is limited to observational comparisons with in-field DBTB treatments. However, ongoing data collection efforts are underway to quantify before-and-after DBTB treatment operations, allowing for further model calibration and validation. In addition, the models could be expanded to include multiple intersections (directly capturing gridlock between intersections) and turning movements to reflect potential additional interaction between the cross streets.

A.8 References

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Appendix B STUDY SITES

LIST OF TABLES

LIST OF FIGURES

Table B-1: List of Intersections.

No.	Intersection Name	Before "DBTB" Data Collection Status	Intersection Selection Result	After "DBTB" Data Collection Status	After "DBTB" Data Processing Status
1	Parkside Pl. & Perimeter Summit Pkwy.	✓	Insufficient capacity impact observed (merging cases)	Not selected for after study	NA
2	Ashford Dunwoody Rd. NE & Ravinia Dr. NE	✓	Selected for after study	✓	✓
3	Peachtree Dunwoody Rd. & Lake Hearn Dr. NE	✓	Selected for after study	✓	✓
4	Peachtree Dunwoody Rd. & Johnson Ferry Rd.	✓	Selected for after study	✓	✓
5	Peachtree Dunwoody Rd. & Abernathy Rd. NE	✓	Selected for after study	✓	✓
6	Peachtree Rd. NE & Lenox Rd. NE	✓	Insufficient capacity impact observed	Not selected for after study	NA
7	Peachtree Rd. NE & Highland Dr. NE	✓	Insufficient capacity impact observed	Not selected for after study	NA
8	Peachtree Rd. NE & Stratford Rd. NE	✓	Selected for after study	✓ (Only one camera angle recording)	NA
9	Ponce De Leon Ave. NE & City Hall East	✓	Insufficient capacity impact observed	Not selected for after study	NA
10	S. Cobb Dr. & Pearl St.	✓	Insufficient capacity impact observed	Not selected for after study	NA
11	S. Cobb Dr. & Walker St.	✓	Selected for after study	Not painted	NA
12	W. Paces Ferry Rd. NW & I-75 SB On/Off Ramps	✓	Selected for after study	✓	✓
13	Mount Paran Rd. NW at I-75 NB Off Ramp	✓	Insufficient capacity impact observed	Not selected for after study	NA
14	Williams St. NW & 10th St. NW	✓	Selected for after study	✓	Not Complete
15	South Cobb Dr. & I-285 SB On/Off Ramps	✓	Selected for after study	Not painted	NA
16	Clairmont Rd. & I-85 SB, near Sam's Club	✓	Selected for after study	✓	✓
17	14th St. NW & Hemphill Ave. NW	✓	Selected for after study	✓	Not Complete

Table B-2: Hours of Video Data Collected and Processed.

No.	Intersection Name	Days Video Data Recorded		Total Hours of Data Recorded		Total Hours of Data Initial Reviewed		Total Hours of Data Processed	
		Before	After	Before	After	Before	After	Before	After
1	Parkside Pl. & Perimeter Summit Pkwy.	9	0	67.5	NA	67.5	NA	67.5	NA
2	Ashford Dunwoody Rd. NE & Ravinia Dr. NE	4	6	30	68.75	30	30	12.5	9
3	Peachtree Dunwoody Rd. & Lake Hearn Dr. NE	9	7	67.5	82.25	67.5	30	18.5	6.5
4	Peachtree Dunwoody Rd. & Johnson Ferry Rd.	4	5	30	65.25	30	25	11	8.75
5	Peachtree Dunwoody Rd. & Abernathy Rd. NE	4	4	30	56	30	20	13.5	4
6	Peachtree Rd. NE & Lenox Rd. NE	6	0	70.5	NA	28	NA	0	NA
7	Peachtree Rd. NE & Highland Dr. NE	6	0	71.5	NA	28	NA	0	NA
8	Peachtree Rd. NE & Stratford Rd. NE	6	8	70.5	92.25	28	30	0	NA
9	Ponce De Leon Ave. at City Hall East	5	0	56	NA	23	NA	0	NA
10	S. Cobb Dr. & Pearl St.	6	0	68.25	NA	28	NA	0	NA
11	S. Cobb Dr. & Walker St.	6	0	69	NA	28	NA	0	NA
12	W. Paces Ferry Rd. NW & I-75 SB On/Off Ramps	6	9	67.5	92.5	25	30	6.75	9
13	Mount Paran Rd. NW at I-75 NB Off Ramp	6	0	68	NA	28	NA	0	NA
14	Williams St. NW & 10th St. NW	5	11	56.75	159.5	25	40	0	0
15	South Cobb Dr. & I-285 SB On/Off Ramps	6	0	61.25	NA	28	NA	0	NA
16	Clairmont Rd. & I-85 SB, near Sam's Club	6	10	66	119.25	25	35	10.5	9
17	14th St. NW & Hemphill Ave. NW	6	10	71.25	138	25	35	0	0

NA – Intersection not selected for after DBTB study. Video data not collected.
0 – Intersection dropped from study. Video data not processed.

**Figure B-1: Parkside Pl. & Perimeter Summit Pkwy.,
Source: Google® Street View.**

**Figure B-2: Parkside Pl. & Perimeter Summit Pkwy.,
Video Capture, Location 1 – 10/23/2015 (Before).**

Figure B-3: Parkside Pl. & Perimeter Summit Pkwy., Video Capture, Location 2 – 10/23/2015 (Before).

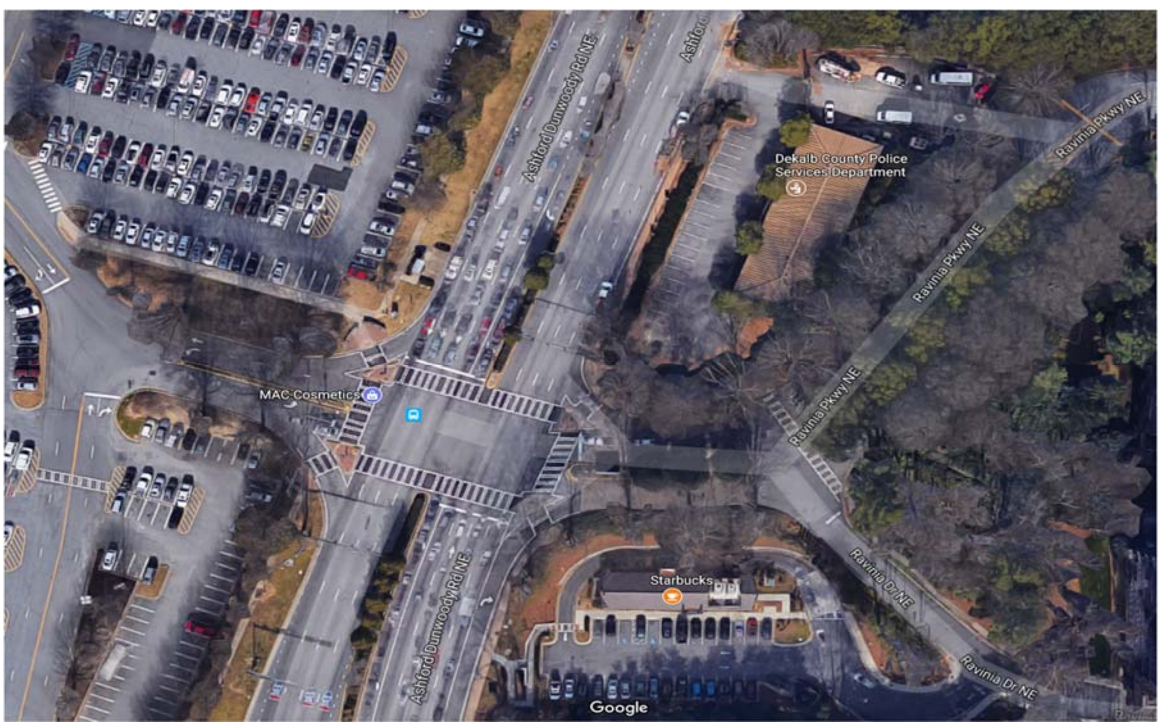

Figure B-4: Ashford Dunwoody Rd. NE & Ravinia Dr. NE, Source: Google® Street View.

Figure B-5: Ashford Dunwoody Rd. NE & Ravinia Dr. NE, Video Capture, Location 1 – 10/26/2015 (Before).

Figure B-6: Ashford Dunwoody Rd. NE & Ravinia Dr. NE, Video Capture, Location 2 – 10/26/2015 (Before).

Figure B-7: Ashford Dunwoody Rd. NE & Ravinia Dr. NE, Video Capture, Location 3 – 10/26/2015 (Before).

Figure B-8: Ashford Dunwoody Rd. NE & Ravinia Dr. NE, Video Capture, Location 4 – 10/26/2015 (Before).

Figure B-9: Ashford Dunwoody Rd. NE & Ravinia Dr. NE, Video Capture, Location 1 – 05/06/2016 (After).

Figure B-10: Ashford Dunwoody Rd. NE & Ravinia Dr. NE, Video Capture, Location 2 – 04/19/2016 (After).

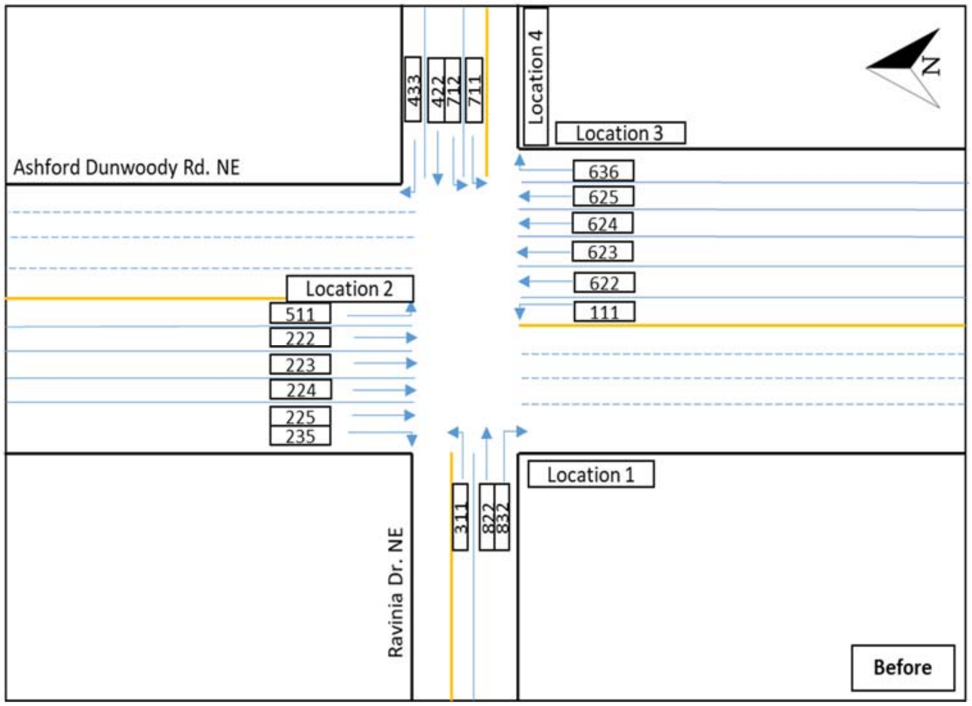

Figure B-11: Ashford Dunwoody Rd. NE & Ravinia Dr. NE, Before DBTB Lane Configuration and Camera Location.

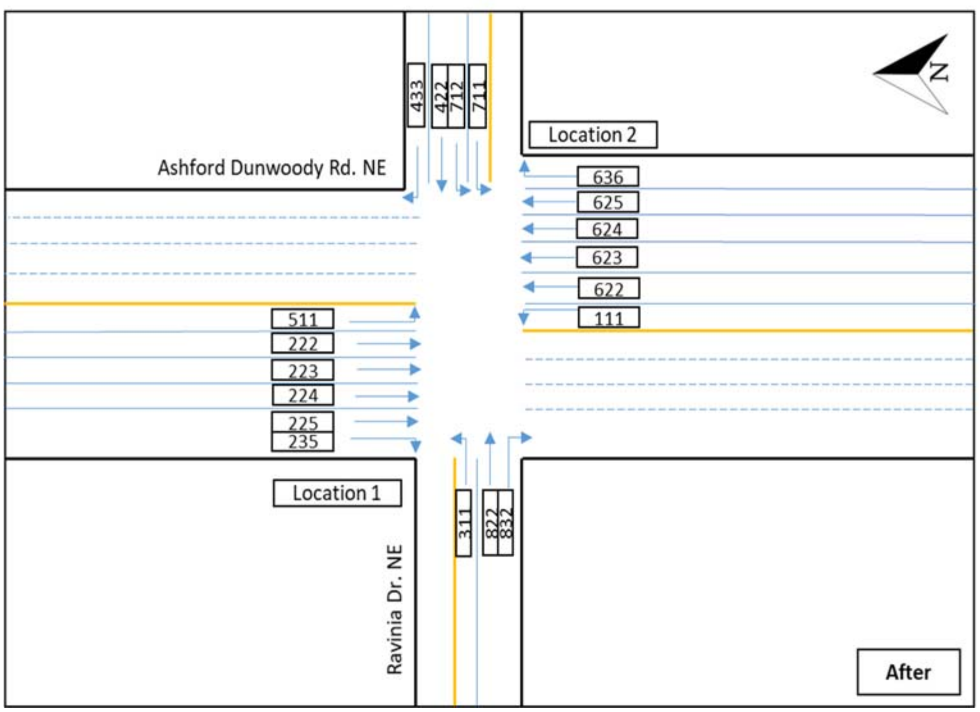

Figure B-12: Ashford Dunwoody Rd. NE & Ravinia Dr. NE, After DBTB Lane Configuration and Camera Location.

Figure B-13: Peachtree Dunwoody Rd. & Lake Hearn Dr. NE, Source: Google® Street View.

Figure B-14: Peachtree Dunwoody Rd. & Lake Hearn Dr. NE, Video Capture, Location 1 – 10/23/2015 (Before).

Figure B-15: Peachtree Dunwoody Rd. & Lake Hearn Dr. NE, Video Capture, Location 2 – 10/23/2015 (Before).

Figure B-16: Peachtree Dunwoody Rd. & Lake Hearn Dr. NE, Video Capture, Location 3 – 10/23/2015 (Before).

Figure B-17: Peachtree Dunwoody Rd. & Lake Hearn Dr. NE, Video Capture, Location 1 – 05/06/2016 (After).

Figure B-18: Peachtree Dunwoody Rd. & Lake Hearn Dr. NE, Video Capture, Location 2 – 05/06/2016 (After).

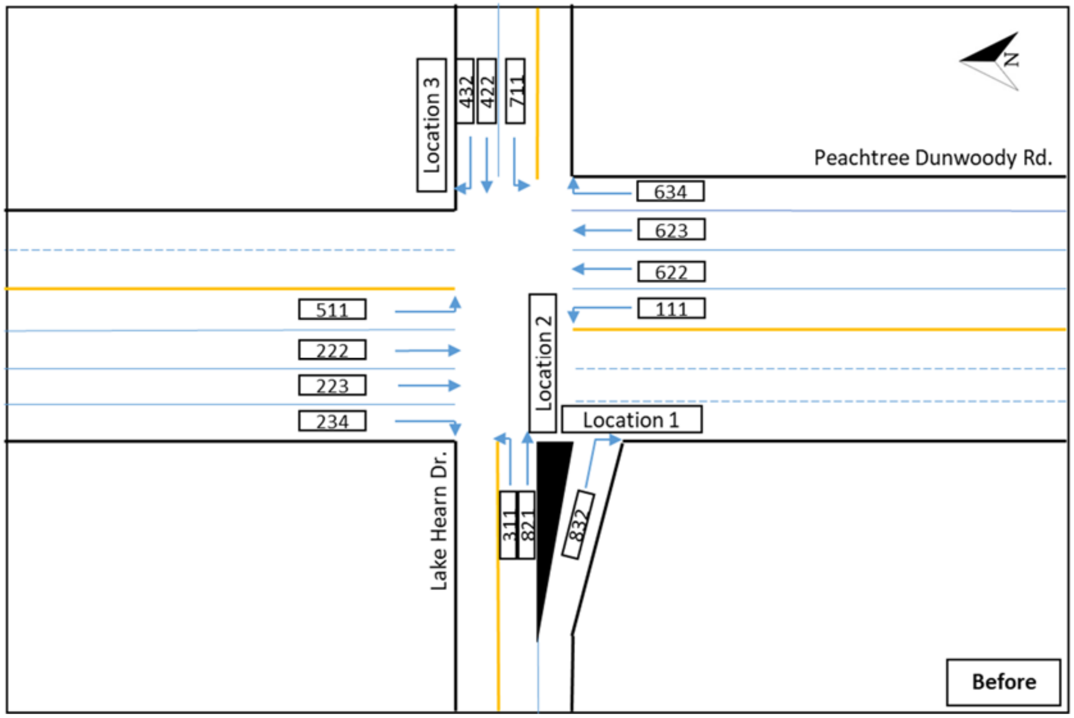

Figure B-19: Peachtree Dunwoody Rd. & Lake Hearn Dr. NE, Before Lane Configuration and Camera Location.

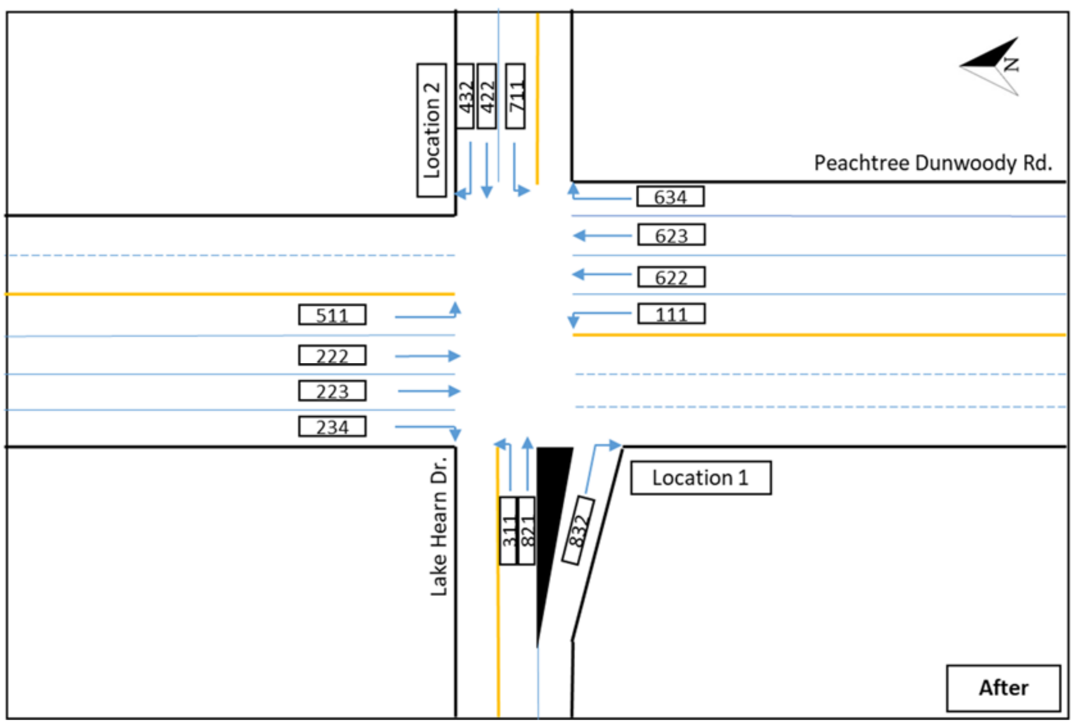

Figure B-20: Peachtree Dunwoody Rd. & Lake Hearn Dr. NE, After Lane Configuration and Camera Location.

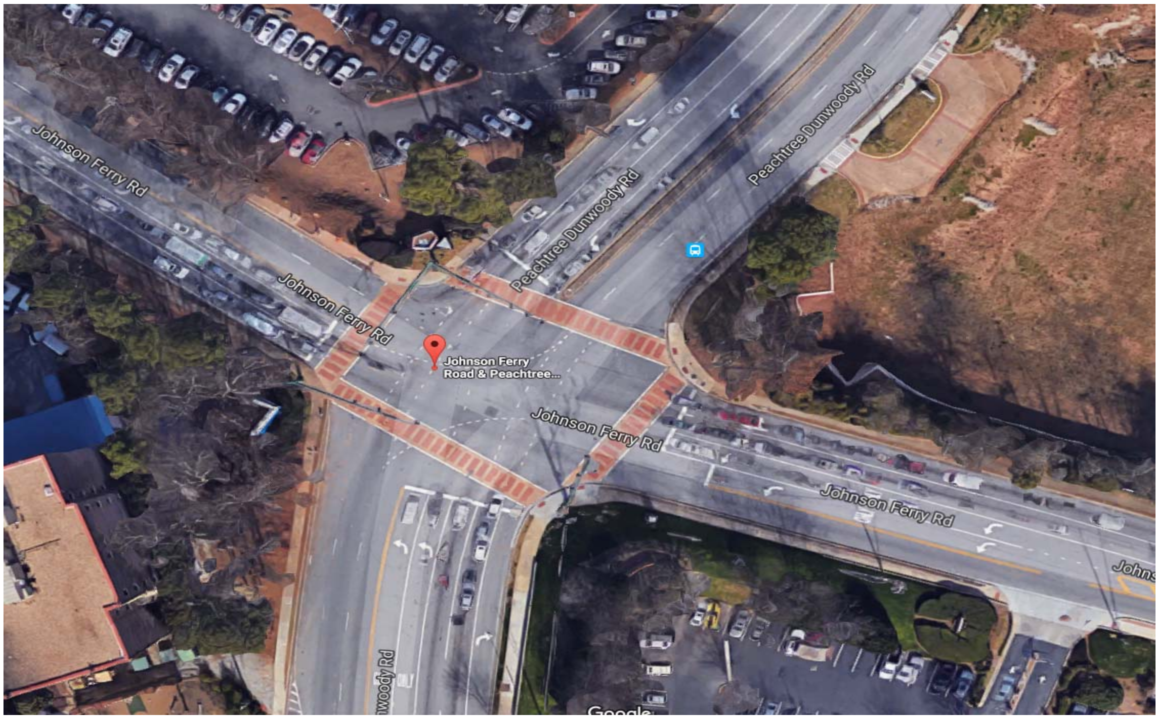

Figure B-21: Peachtree Dunwoody Rd. & Johnson Ferry Rd., Source: Google® Street View.

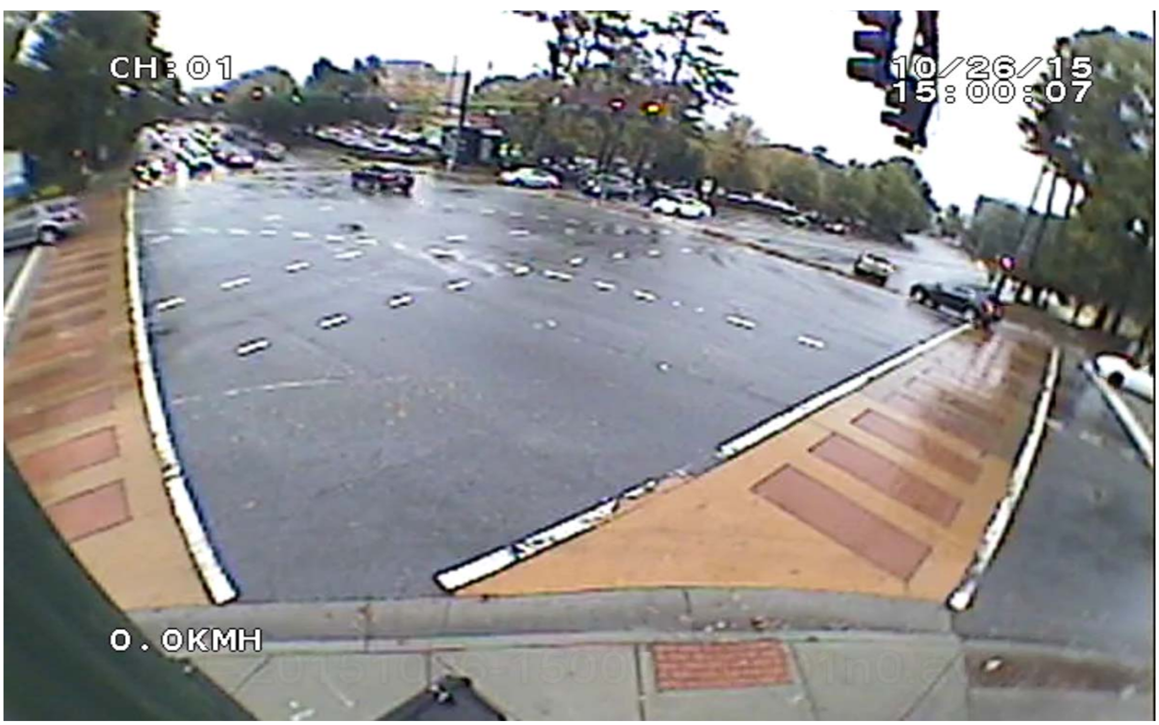

Figure B-22: Peachtree Dunwoody Rd. & Johnson Ferry Rd., Video Capture, Location 1 – 10/26/2015 (Before).

Figure B-23: Peachtree Dunwoody Rd. & Johnson Ferry Rd., Video Capture, Location 2 – 10/26/2015 (Before).

Figure B-24: Peachtree Dunwoody Rd. & Johnson Ferry Rd., Video Capture, Location 3 – 10/26/2015 (Before).

**Figure B-25: Peachtree Dunwoody Rd. & Johnson Ferry Rd.,
Video Capture, Location 4 – 10/26/2015 (Before).**

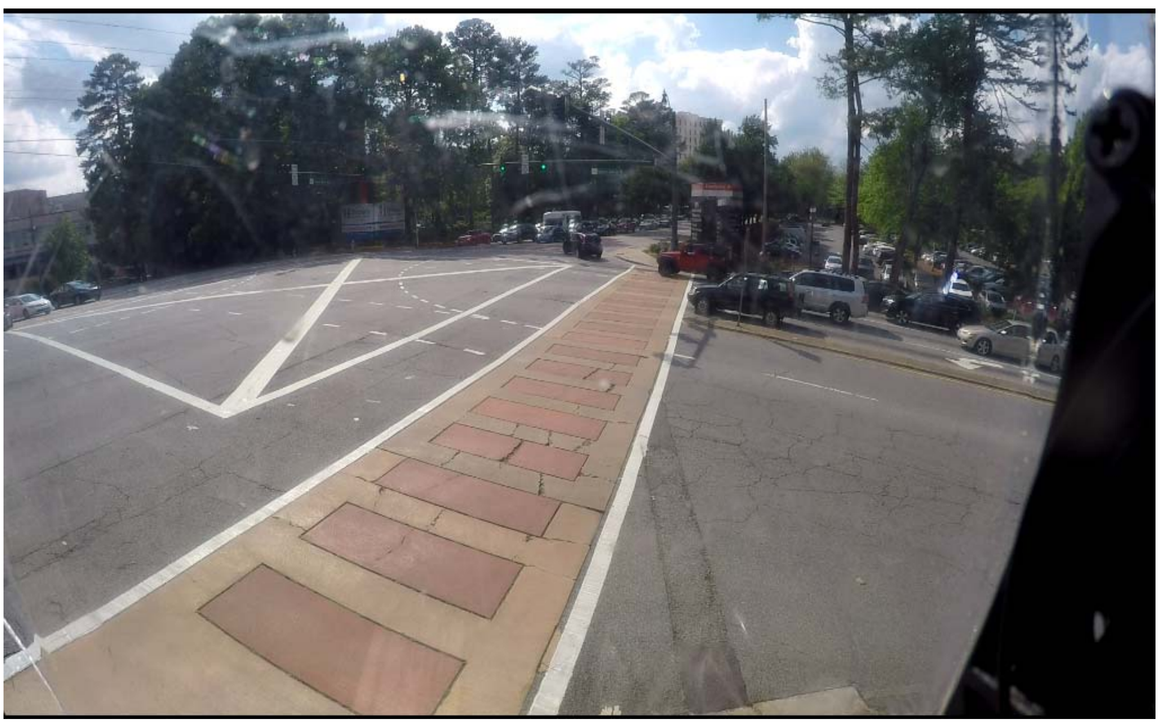

**Figure B-26: Peachtree Dunwoody Rd. & Johnson Ferry Rd.,
Video Capture, Location 1 – 04/25/2016 (After).**

Figure B-27: Peachtree Dunwoody Rd. & Johnson Ferry Rd., Video Capture, Location 2 – 04/25/2016 (After).

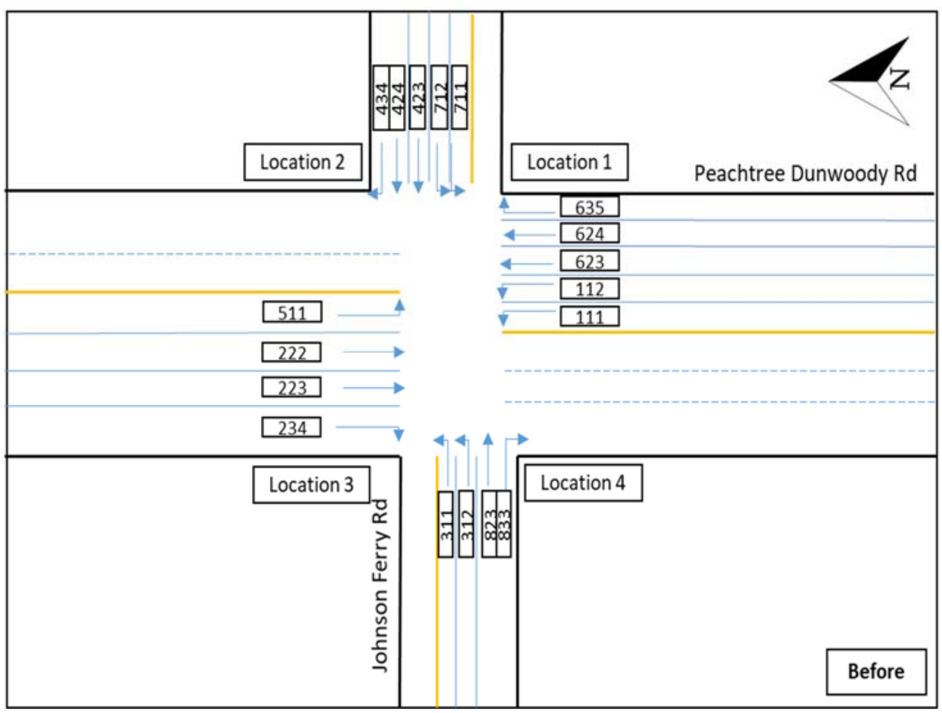

Figure B-28: Peachtree Dunwoody Rd. & Johnson Ferry Rd., Before Lane Configuration and Camera Location.

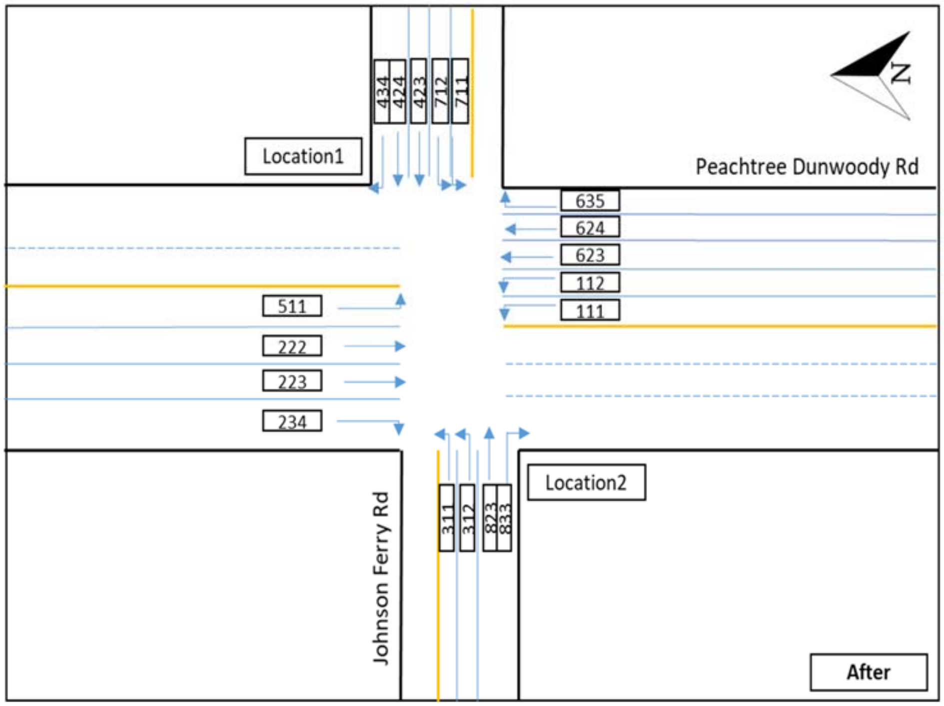

Figure B-29: Peachtree Dunwoody Rd. & Johnson Ferry Rd., After Lane Configuration and Camera Location.

Figure B-30: Peachtree Dunwoody Rd. & Abernathy Rd. NE, Source: Google® Street View.

Figure B-31: Peachtree Dunwoody Rd. & Abernathy Rd. NE, Video Capture, Location 1 – 10/28/2015 (Before).

Figure B-32: Peachtree Dunwoody Rd. & Abernathy Rd. NE, Video Capture, Location 2 – 10/28/2015 (Before).

**Figure B-33: Peachtree Dunwoody Rd. & Abernathy Rd. NE,
Video Capture, Location 3 – 10/28/2015 (Before).**

**Figure B-34: Peachtree Dunwoody Rd. & Abernathy Rd. NE,
Video Capture, Location 4 – 10/28/2015 (Before).**

Figure B-35: Peachtree Dunwoody Rd. & Abernathy Rd. NE, Video Capture, Location 1 – 04/18/2016 (After).

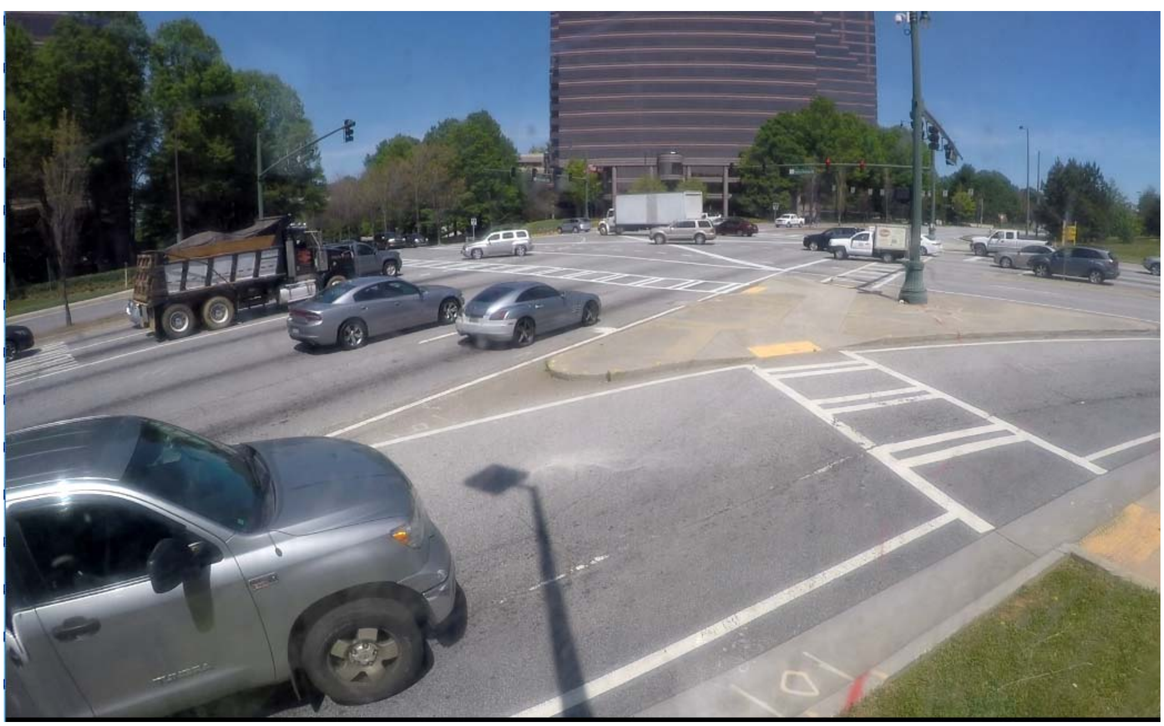

Figure B-36: Peachtree Dunwoody Rd. & Abernathy Rd. NE, Video Capture, Location 2 – 04/18/2016 (After).

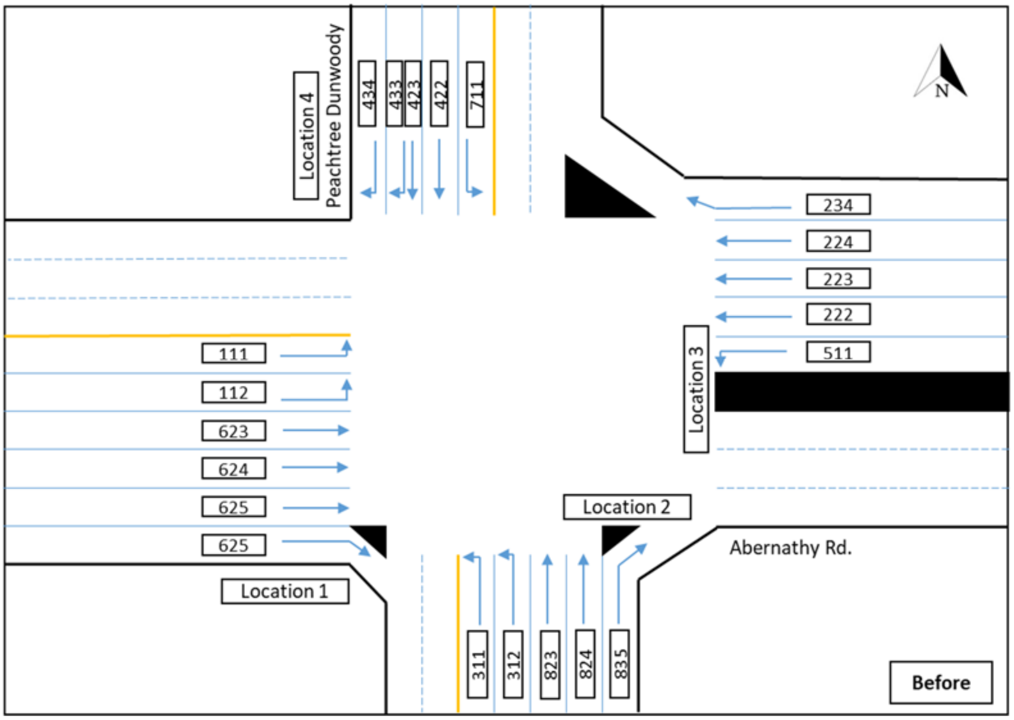

Figure B-37: Peachtree Dunwoody Rd. & Abernathy Rd. NE, Before Lane Configuration and Camera Location.

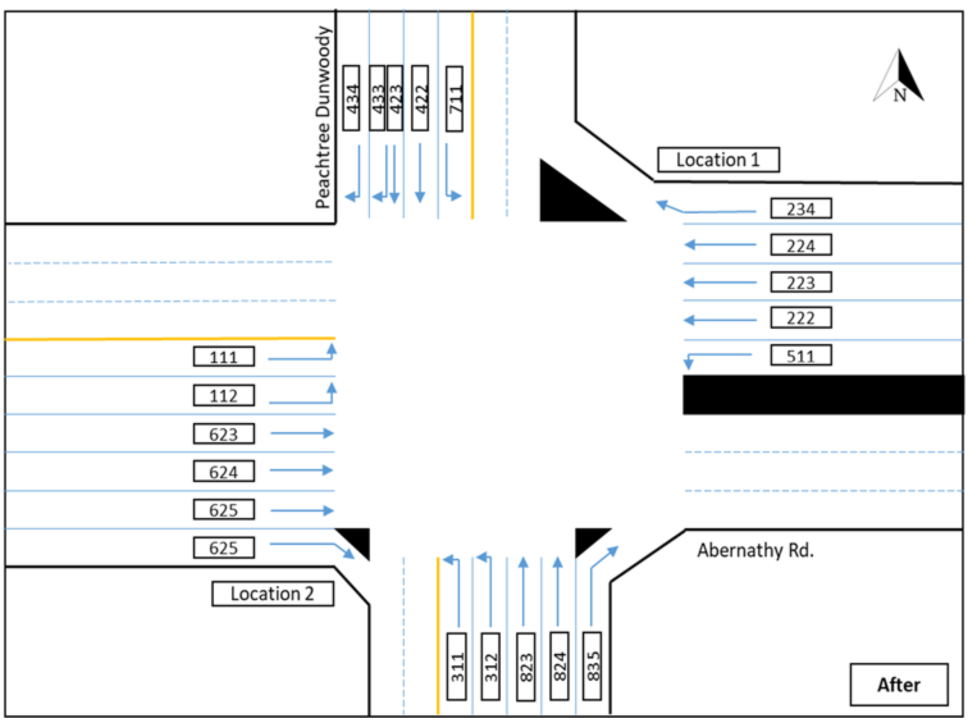

Figure B-38: Peachtree Dunwoody Rd. & Abernathy Rd. NE, After Lane Configuration and Camera Location.

**Figure B-39: Peachtree Rd. NE & Lenox Rd. NE,
Source: Google® Street View.**

**Figure B-40: Peachtree Rd. NE & Lenox Rd. NE,
Video Capture, Location 1 – 05/02/2016 (Before).**

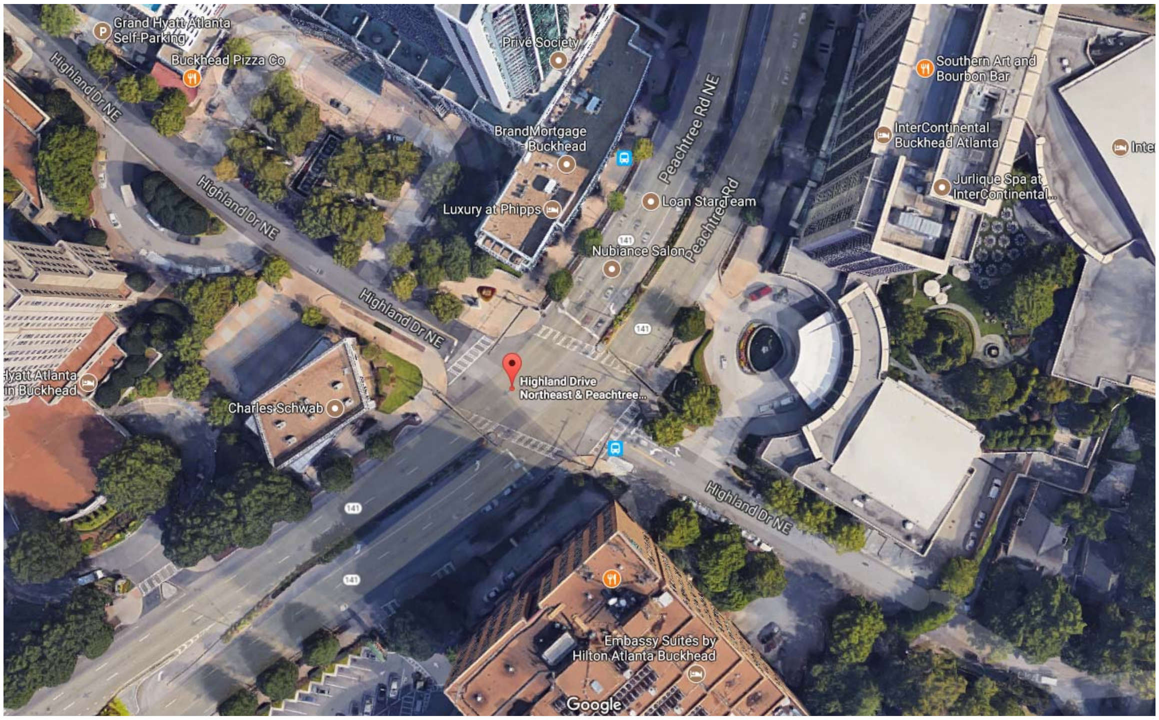

Figure B-41: Peachtree Rd. NE & Highland Dr. NE,
Source: Google® Street View.

Figure B-42: Peachtree Rd. NE & Highland Dr. NE,
Video Capture, Location 1 – 05/02/2016 (Before).

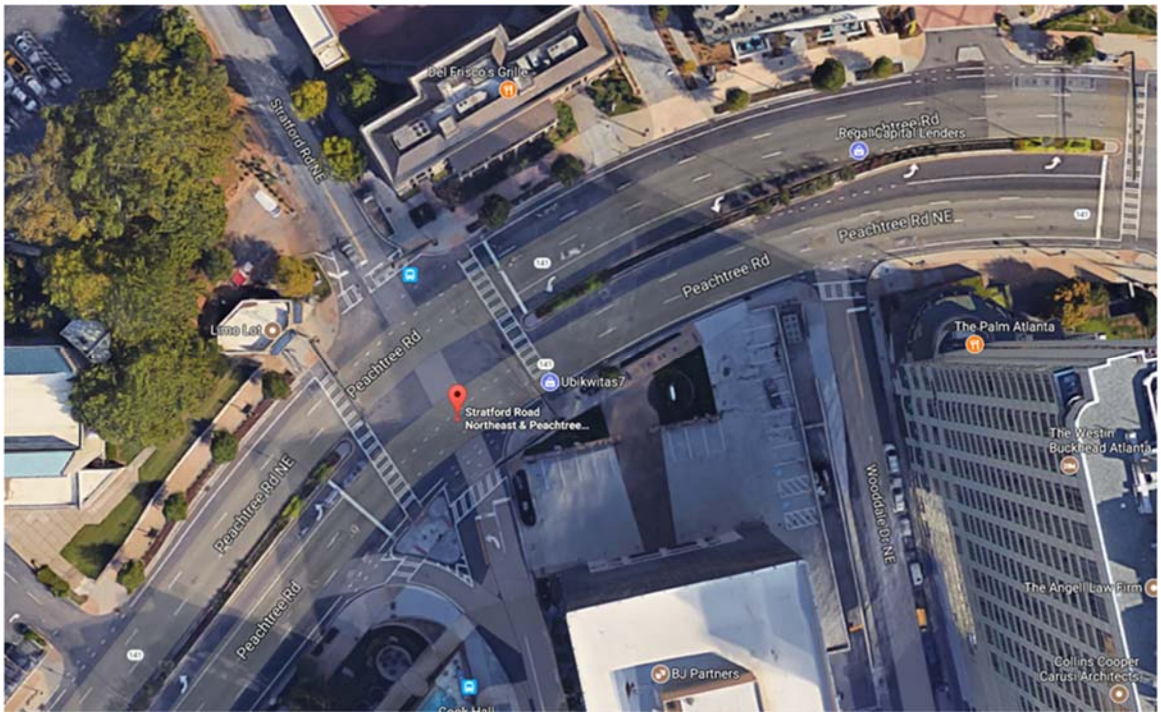

Figure B-43: Peachtree Rd. NE & Stratford Rd. NE, Source: Google® Street View.

Figure B-44: Peachtree Rd. NE & Stratford Rd. NE, Video Capture, Location 1 – 05/02/2016 (Before).

Figure B-45: Peachtree Rd. NE & Stratford Rd. NE, Video Capture, Location 1 – 04/19/2017 (After).

Figure B-46: Peachtree Rd. NE & Stratford Rd. NE, Video Capture, Location 2 – 04/19/2017 (After).

Figure B-47: Ponce De Leon Ave. at City Hall East, Source: Google® Street View.

Figure B-48: Ponce De Leon Ave. at City Hall East, Video Capture, Location 1 – 03/18/2016 (Before).

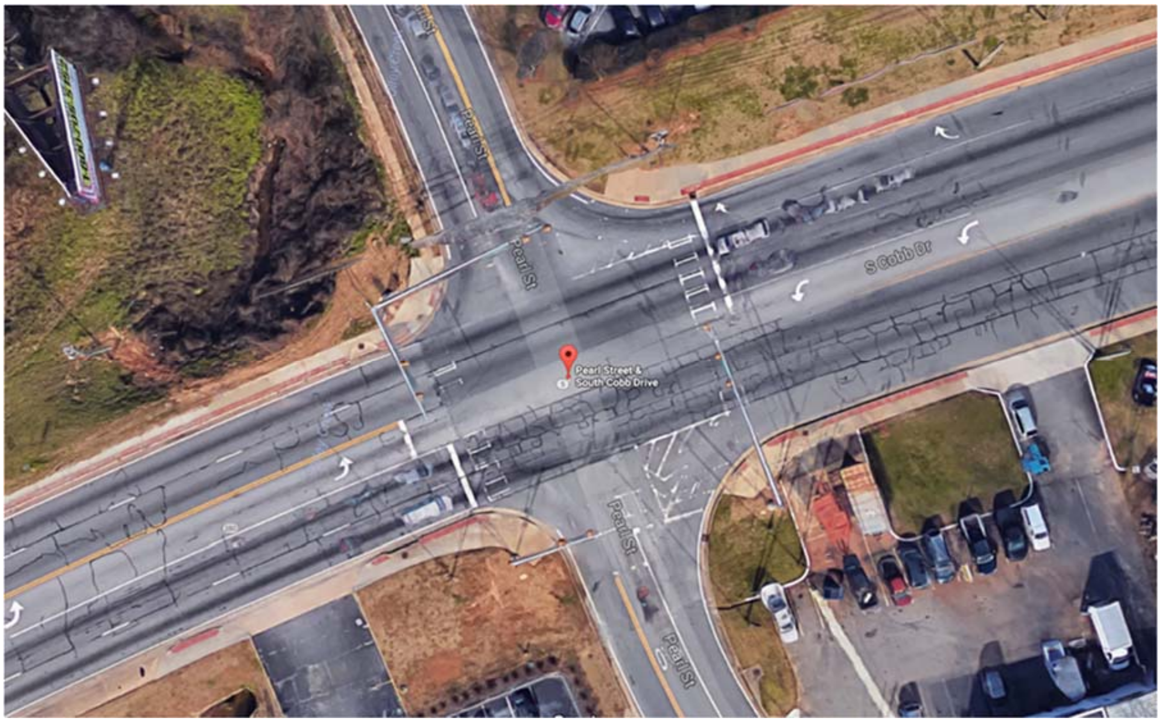

Figure B-49: S. Cobb Dr. & Pearl St.,
Source: Google® Street View.

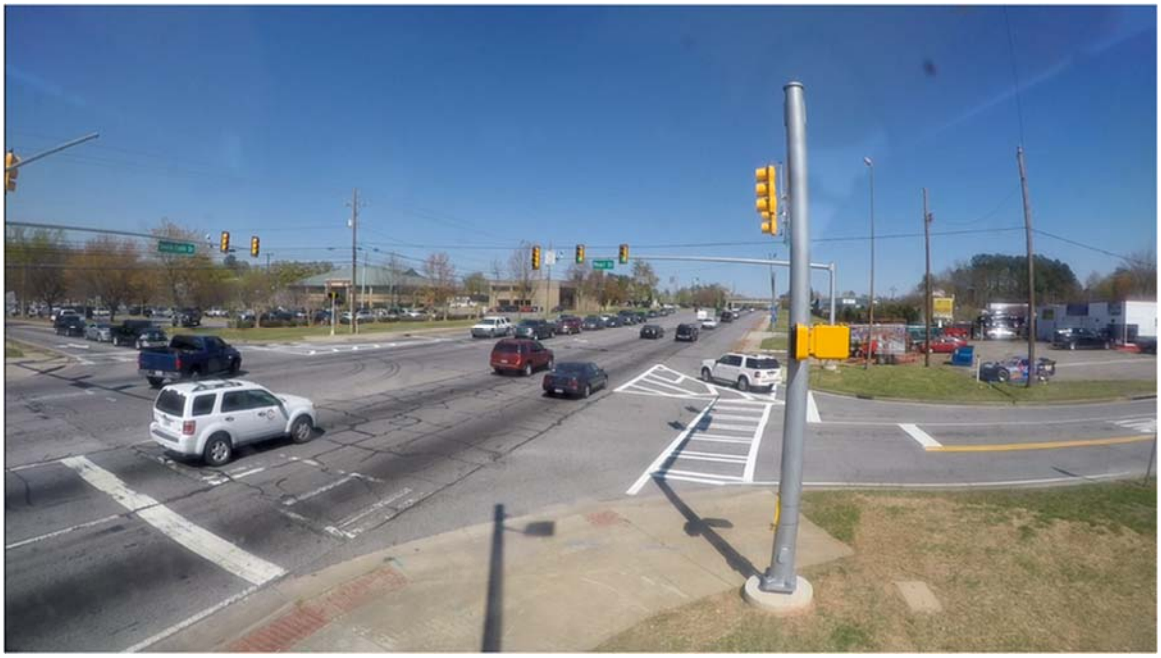

Figure B-50: S. Cobb Dr. & Pearl St.,
Video Capture, Location 1 – 03/21/2016 (Before).

**Figure B-51: S. Cobb Dr. & Pearl St.,
Video Capture, Location 2 – 03/21/2016 (Before).**

**Figure B-52: S. Cobb Dr. & Walker St.,
Source: Google® Street View.**

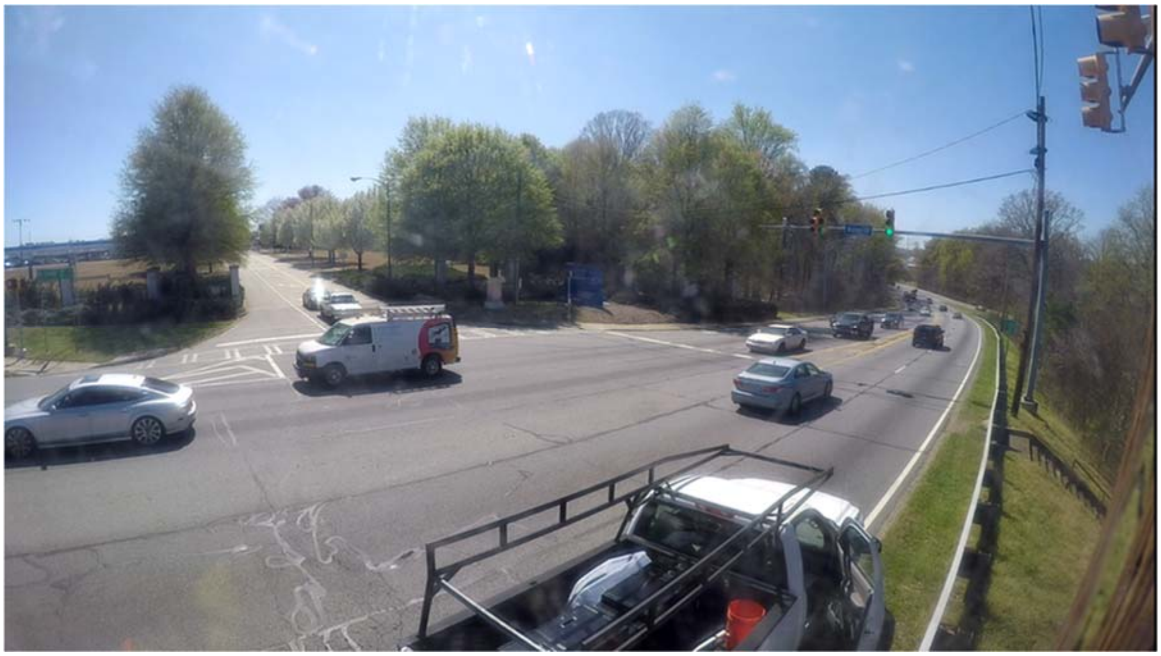

**Figure B-53: S. Cobb Dr. & Walker St.,
Video Capture, Location 1 – 03/21/2016 (Before).**

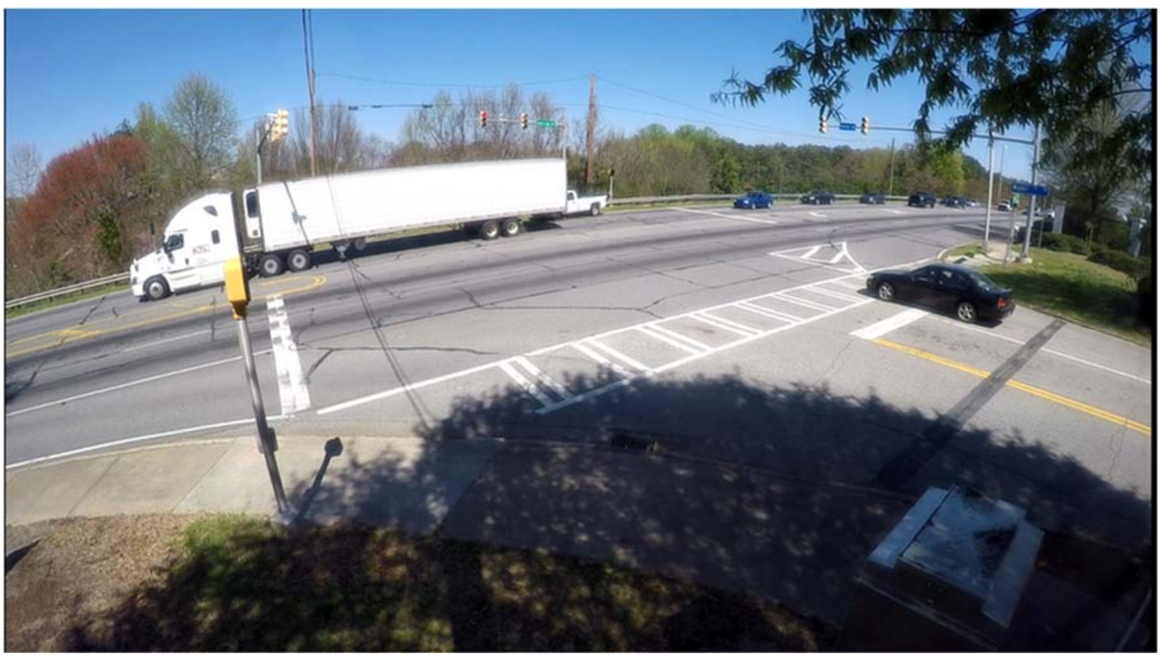

**Figure B-54: S. Cobb Dr. & Walker St.,
Video Capture, Location 2 – 03/21/2016 (Before).**

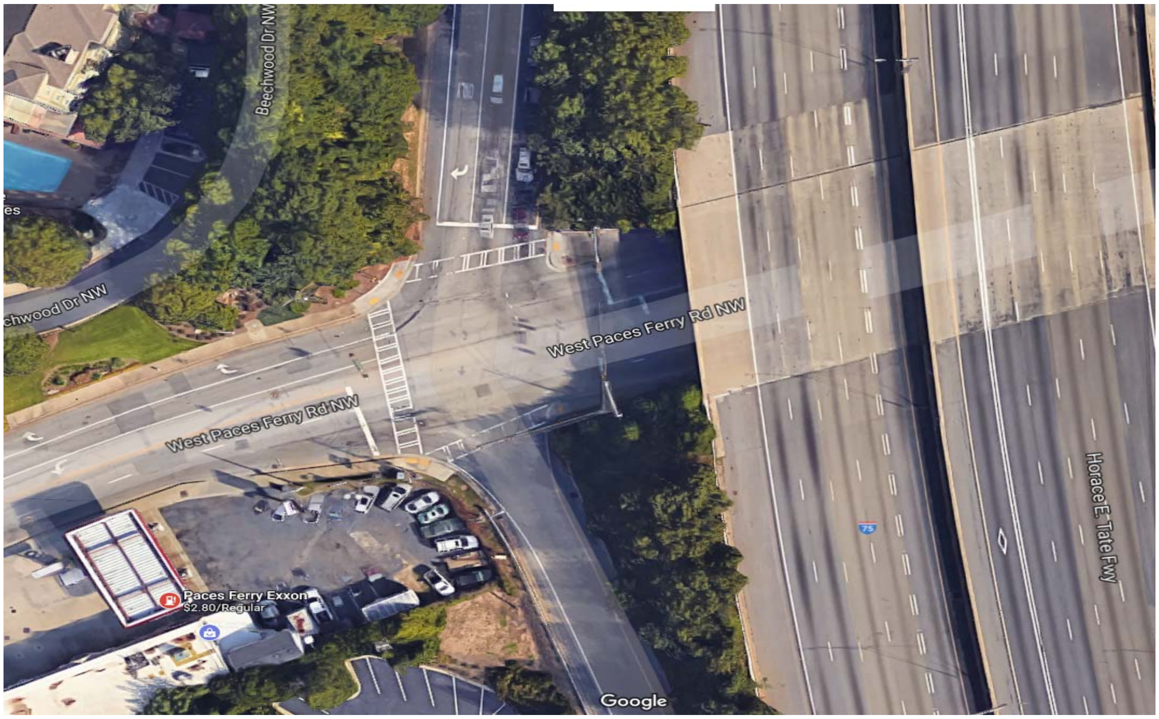

Figure B-55: W. Paces Ferry Rd. NW & I-75 SB On/Off Ramps, Source: Google® Street View.

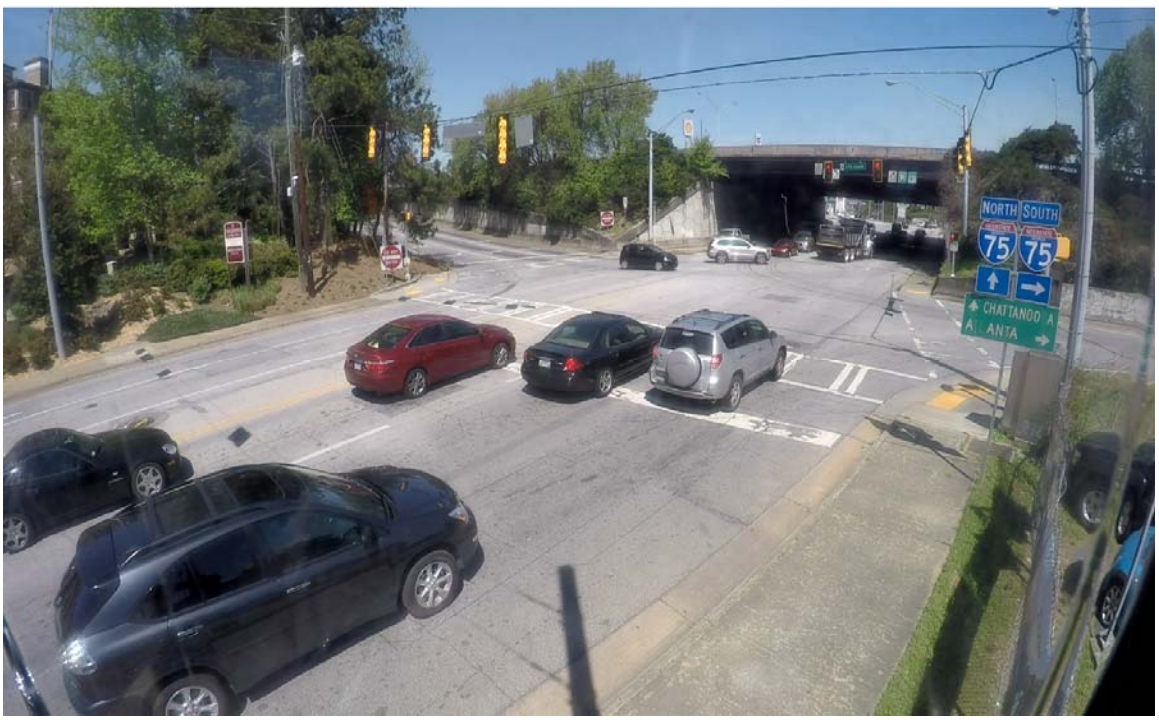

Figure B-56: W. Paces Ferry Rd. NW & I-75 SB On/Off Ramps, Video Capture, Location 1 – 03/28/2016 (Before).

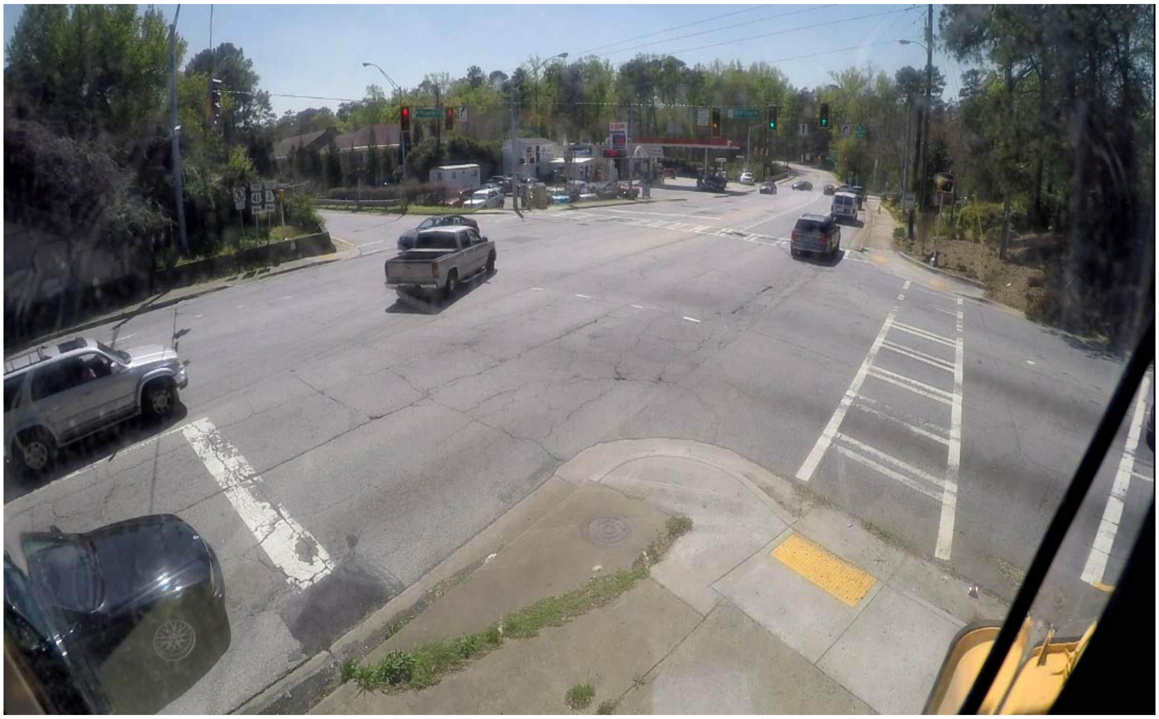

Figure B-57: W. Paces Ferry Rd. NW & I-75 SB On/Off Ramps, Video Capture, Location 2 – 03/28/2016 (Before).

Figure B-58: W. Paces Ferry Rd. NW & I-75 SB On/Off Ramps, Video Capture, Location 1 – 04/04/2017 (After).

Figure B-59: W. Paces Ferry Rd. NW & I-75 SB On/Off Ramps, Video Capture, Location 2 – 04/04/2017 (After).

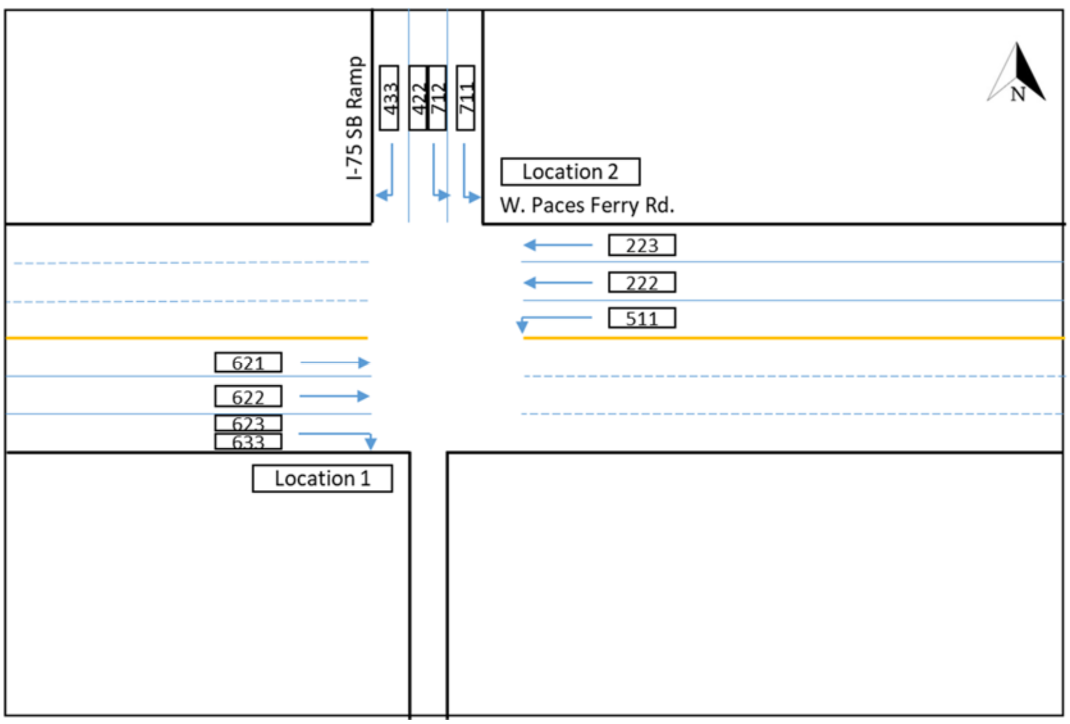

Figure B-60: W. Paces Ferry Rd. NW & I-75 SB On/Off Ramps, Before and After Lane Configuration and Camera Location.

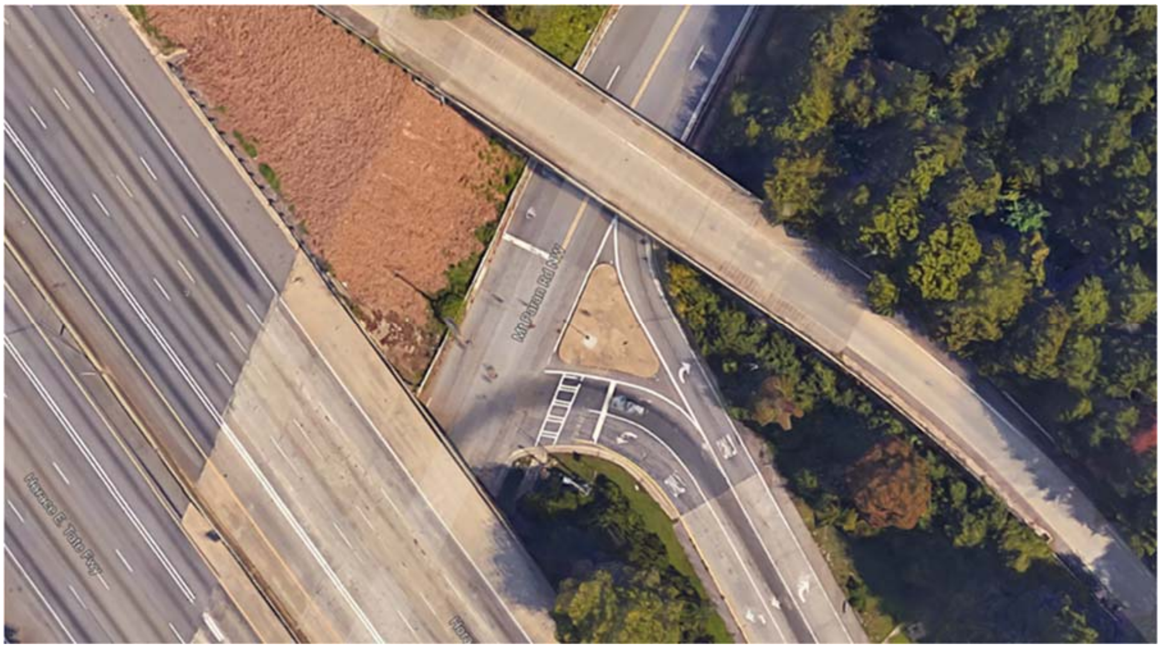

**Figure B-61: Mount Paran Rd. NW at I-75 NB Off Ramp,
Source: Google® Street View.**

**Figure B-62: Mount Paran Rd. NW at I-75 NB Off Ramp,
Video Capture, Location 1 – 03/28/2016 (Before).**

Figure B-63: Mount Paran Rd. NW at I-75 NB Off Ramp, Video Capture, Location 2 – 03/28/2016 (Before).

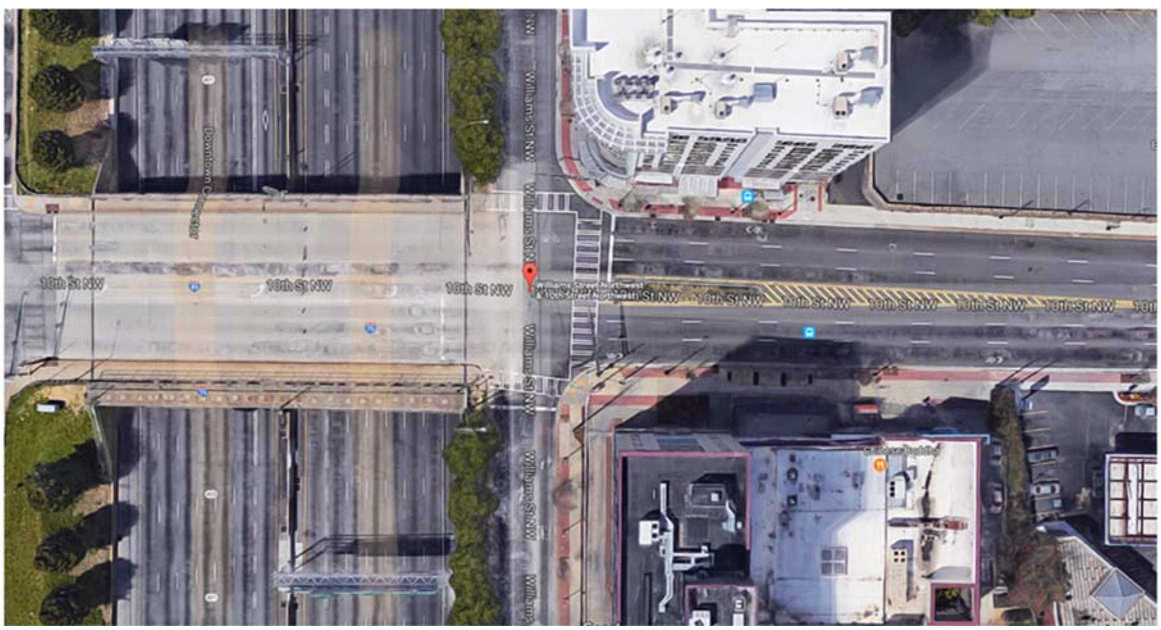

Figure B-64: Williams St. NW & 10th St. NW, Source: Google® Street View.

Figure B-65: Williams St. NW & 10th St. NW, Video Capture, Location 1 – 04/06/2016 (Before).

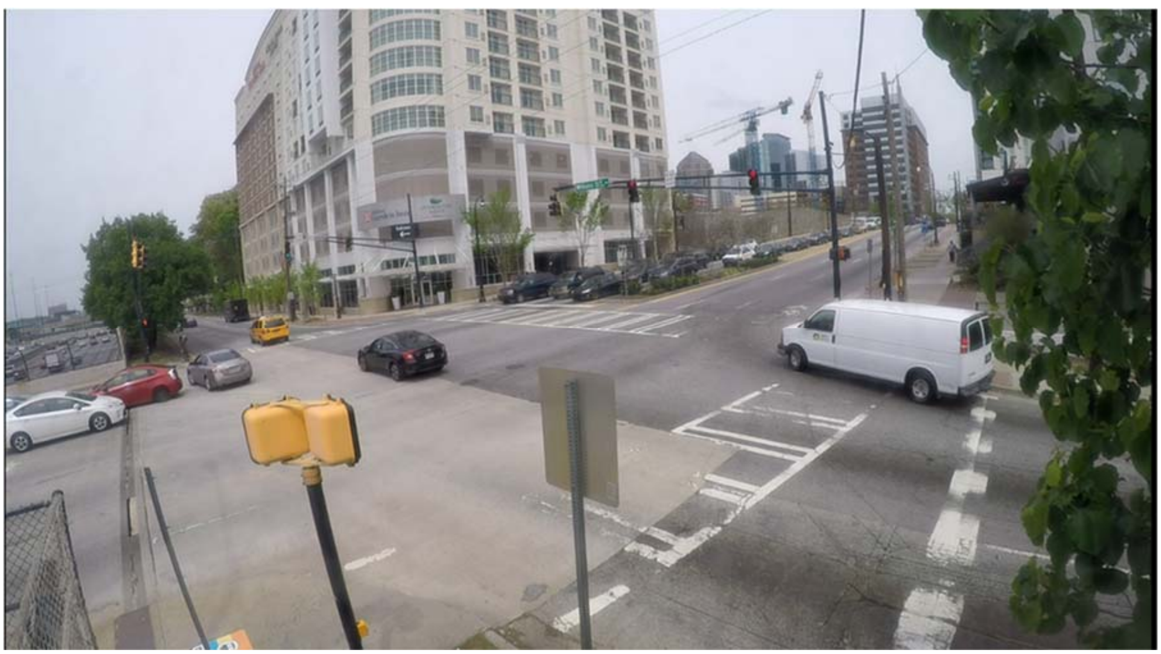

Figure B-66: Williams St. NW & 10th St. NW, Video Capture, Location 2 – 04/06/2016 (Before).

Figure B-67: Williams St. NW & 10th St. NW, Video Capture, Location 1 – 05/09/2017 (After).

Figure B-68: Williams St. NW & 10th St. NW, Video Capture, Location 2 – 05/09/2017 (After).

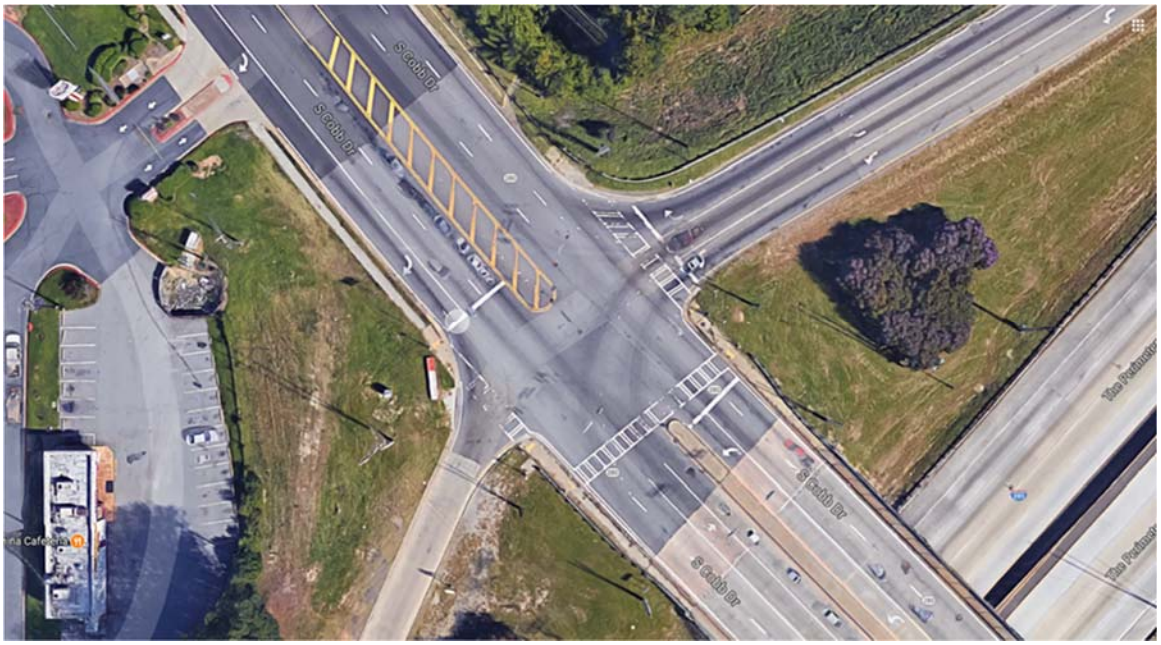

Figure B-69: South Cobb Dr. & I-285 SB On/Off Ramps, Source: Google® Street View.

Figure B-70: South Cobb Dr. & I-285 SB On/Off Ramps, Video Capture, Location 1 – 04/04/2016 (Before).

Figure B-71: South Cobb Dr. & I-285 SB On/Off Ramps, Video Capture, Location 2 – 04/04/2016 (Before).

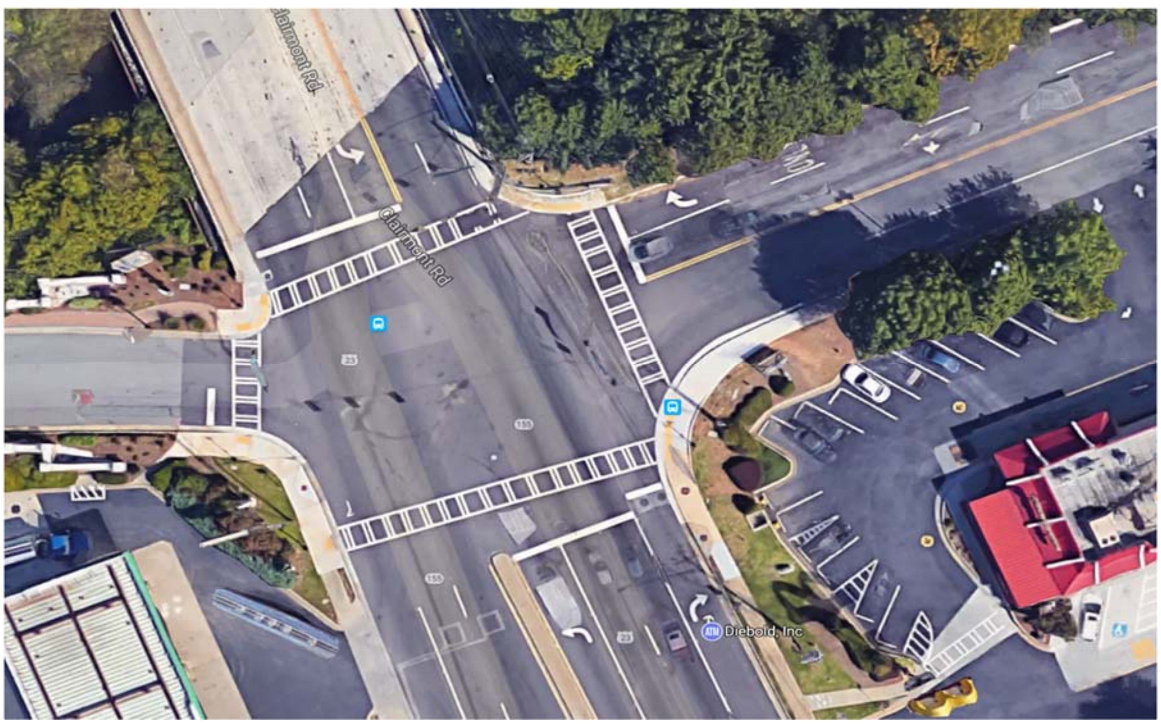

Figure B-72: Clairmont Rd. & I-85 SB, near Sam's Club, Source: Google® Street View.

Figure B-73: Clairmont Rd. & I-85 SB, near Sam's Club, Video Capture, Location 1 – 04/12/2016 (Before).

Figure B-74: Clairmont Rd. & I-85 SB, near Sam's Club, Video Capture, Location 2 – 04/12/2016 (Before).

Figure B-75: Clairmont Rd. & I-85 SB, near Sam's Club, Location 1 – 04/04/2017 (After).

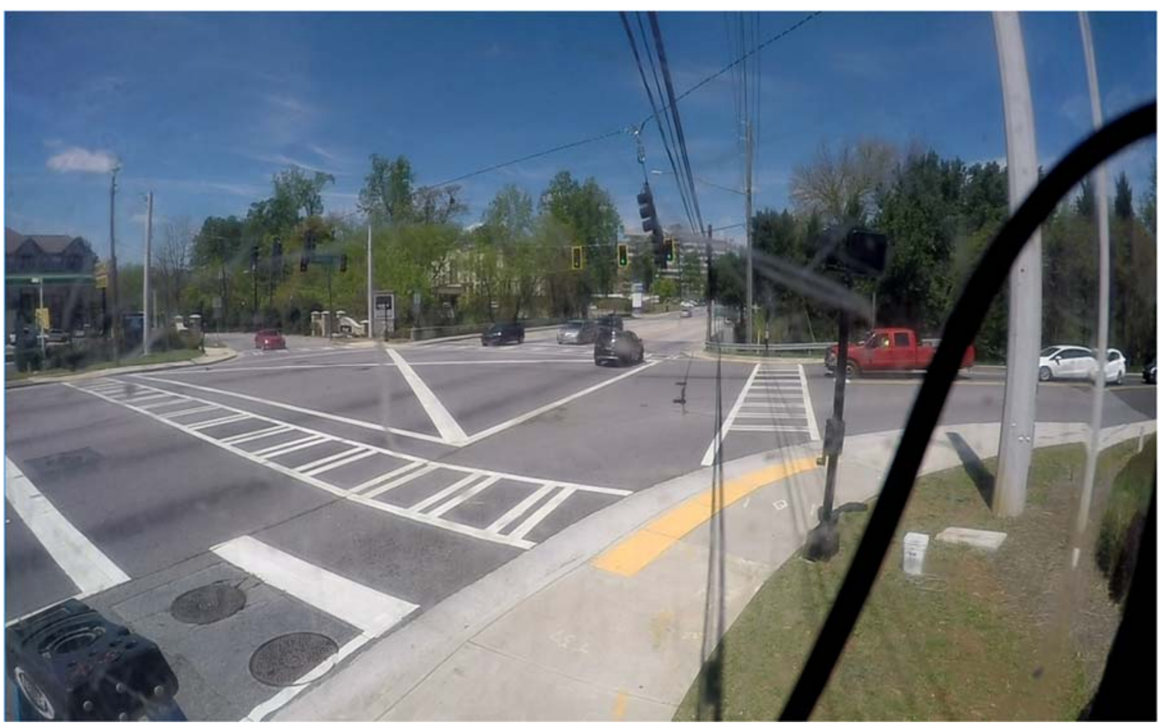

Figure B-76: Clairmont Rd. & I-85 SB, near Sam's Club, Video Capture, Location 2 – 04/04/2017 (After).

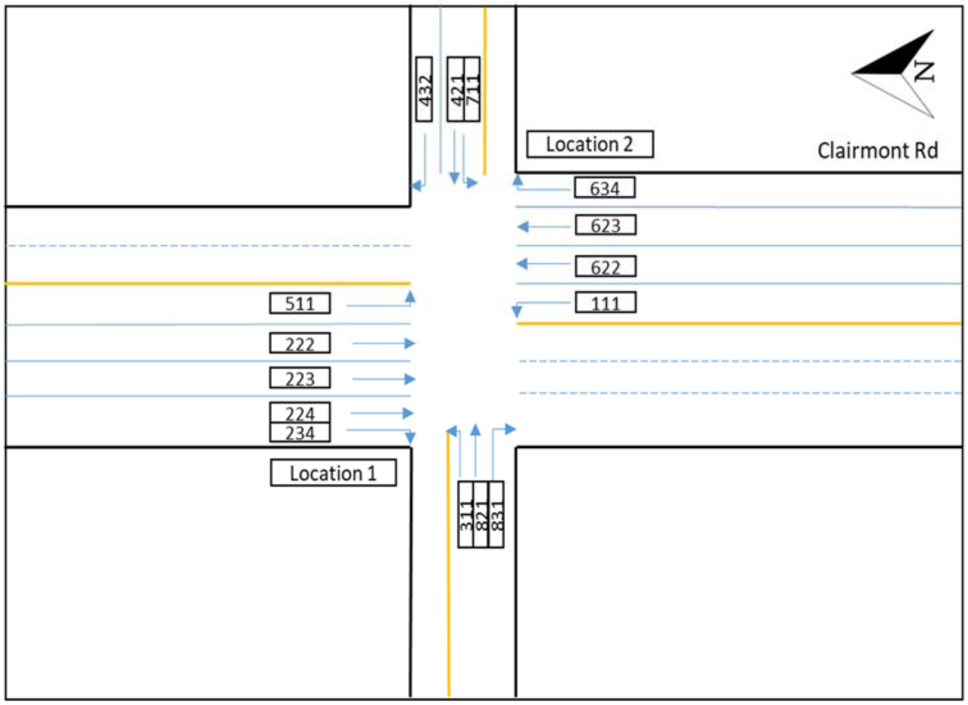

Figure B-77: Clairmont Rd. & I-85 SB, near Sam's Club, Before and After Lane Configuration and Camera Location.

Figure B-78: 14th St. NW & Hemphill Ave. NW, Source: Google® Street View.

Figure B-79: 14th St. NW & Hemphill Ave. NW, Video Capture, Location 1 – 04/14/2016 (Before).

Figure B-80: 14th St. NW & Hemphill Ave. NW, Video Capture, Location 2 – 04/14/2016 (Before).

Figure B-81: 14th St. NW & Hemphill Ave. NW, Video Capture, Location 1 – 05/01/2017 (After).

Figure B-82: 14th St. NW & Hemphill Ave. NW, Video Capture, Location 2 – 05/01/2017 (After).

Appendix C VIDEO TOOL FOR MANUALLY EXTRACTING COMPLEX TRAFFIC DATA

LIST OF FIGURES

C.1 Abstract

Driver behavior studies often require the analysis of highly specific and customized observational data attributes. Due to the complex nature of behavioral data collection, typically requiring some degree of customization depending on the study, there is a lack of generic tools available to transportation professionals to assist in the data collection process. This paper presents a python-based software application "GT-MVP" designed to provide a user-friendly interface to manually collect complex video-based traffic data. GT-MVP's graphical user interface allows users to play multiple videos and operate them synchronously using common controls and to easily review and correct errors during the data collection session. GT-MVP has been used to improve the efficiency of manual data collection in a study of vehicle blocking behavior at intersections. Compared to previous

approaches used to collect behavioral data required for this study, GT-MVP took 65% less time and reduced the missed detection rate. GT-MVP interface can be modified to assist in the collection of complex traffic data for different traffic studies and can also be used to improve efficiency of collection of basic traffic data such as vehicle counts and is available to the community as an open source software.

Keywords: Video data extraction, Data collection, Video annotation, Don't Block the Box

C.2 Introduction

Advancements in traffic data collection technologies have steadily increased the amount of data available to transportation researchers and practitioners. Fixed sensor–based technologies, including intrusive technologies such as inductive loops, pneumatic road tubes, piezoelectric sensors, etc. and non-intrusive technologies such as microwave, RADAR, and video detection systems generate screen-line counts, point speed data, etc. Advancements in using wireless technologies such as GPS, mobile phones, Bluetooth®, and on-road sensors, etc. have enabled probe-based data collection with improved travel-time and space-mean speed data.

In spite of advancements in the efficiency of automatic sensor–based technologies, the roadway environment can adversely affect the accuracy of data generated by these systems [1]. These impacts, when coupled with significant deployment costs can limit the feasibility of using these systems for short-term data collection needs. Traditionally, where permanent technologies are not available or feasible, temporary devices such as video recorders are utilized, with data manually extracted from the video. However, such manual data extraction can be time consuming and costly, motivating interest in automated video-based data collection systems to extract data [2]. Video analysis tools for trajectory determination, vehicle speed measurement, vehicle counts, and vehicle classification, etc. have been developed to study roadway safety and operation [2–7] as well as for vehicle and pedestrian behavioral studies [4, 8]. While these tools have been used for decision-based data extraction without human input for a number of traffic, pedestrian, and behavioral studies [4, 6, 7, 9, 10], many studies may have complex and subjective data extraction requirements that are difficult to fully automate. Existing automated data collection tools may be either insufficient or require considerable time for development of algorithms that can assess complex roadway and traffic conditions. For these applications, effective semi-automatic annotation tools that assist users in more effective manual data extraction are still needed [11].

To address the need for a customizable and efficient interface to aid in manually extracting high resolution and complex data to understand driver behavior, a video data extraction tool, **G**eorgia **T**ech's - **M**ulti **V**ideo **P**layer (GT-MVP), has been developed. This tool allows a user to manually generate data for studies that require basic data (such as vehicle count, vehicle headways, signal timing, etc.) as well as for operational and behavioral studies that require complex data (such as classification of vehicles or pedestrians based on behavior).

The paper is organized as follows: the background section contains studies related to video annotation tools. Development and user interface design of the GT-MVP tool are included under the "Multi-video Player Application" section. Several case studies are presented to demonstrate the use of the tool. Benefits of using GT-MVP are quantified in the "Verification of GT-MVP" section. Finally, the application, benefits, limitations, and potential future work are summarized in the "Conclusions" section.

C.3 Background

Driver behavior studies often require the analysis of highly specific and customized observational data attributes. As such, data collection/extraction protocols typically require some degree of study-specific customization and there is a lack of generic tools available to transportation professionals to assist in the data collection process. In the field of computer vision, a class of tools, known as video annotation tools, provides conceptually similar functionality to the requirements of driver behavior studies, albeit for a different application case. The development and design aspects of video annotation tools are relevant to development of the GT-MVP tool. The significant difference is that video annotation tools focus on the functionality of being able to render overlaid bounding boxes on top of the video, while the GT-MVP tool focuses on data attributes recorded by making manual observations in the frame of the video.

Video annotation has long been a critical step in the research and development process in computer vision. Researchers use video-annotated data to develop algorithms that may be applied in an automated video data extraction system to understand events, recognize objects, and predict future events. Example interactive video annotation tools include LabelMe [12], ViPER [13], GTVT [9], VATIC [14], and GTGT [10]. **LabelMe** allows a user to annotate objects/humans of different shapes in a video. This online, web-based platform allows for extraction of complex event annotations from high-quality videos. The annotation process requires a user to draw a polygon by clicking around the object boundary. The user navigates through the video using video controls and edits the polygon position as the object location changes [11, 12, 14]. Mihalcik et al. presented a flexible video annotation tool **ViPER** (Video Performance Evaluation Resource)[13]. **ViPER** allows for frame-by-frame annotation. File information such as content description, date, and keywords associated with content can be added. It can be used for many purposes such as tracking people, detecting text, etc. [11, 13, 16]. Data obtained using ViPER have been utilized to evaluate computer vision algorithms for text detection, face detection, and vehicle detection, etc. [15, 17]. In 2009, Ambardekar et al. proposed **GTVT** (Ground Truth Verification Tool) for video surveillance systems. GTVT focuses on object detection and classification [9]. In 2014, Mossi et al. proposed a ViPER set up with a simple visual interface and a jog shuttle wheel to speed up generation of ground truth data of traffic systems. This study also asserted that for generating ground-truth data to measure basic traffic system measurements there is no need of pixel level segmentation or frame-by-frame tracking [15]. In 2012, another video annotation platform, **VATIC** **(**Video Annotation Tool from Irvin, California) was introduced. This tool is designed to assist computer vision research. It uses Amazon's "Mechanical Turk"® for crowdsourcing video annotation. Some extensions developed for VATIC include tracking integration with OpenCV, sentence annotations, time interval labeling, and human action labeling, etc. [14, 18]. Designed to generate databases for computer vision research, the interface is rather complicated for data collection of simple traffic measurements. In 2016, Bigaj et al. designed an application for video detection purposes that is targeted toward traffic system video analysis, focusing on a data generation system with just a single mouse click, **GTGT** (Ground Truth Generation Tool) simplified the extraction of road traffic data [10].

Studies requiring vehicle identification across multiple video time steps generally require vehicle re-identification or classification. Re-identification is significantly more complex than presence detection. The current study develops GT-MVP to specifically address manual data collection where re-identification is required, using a semi-automatic procedure that provides the users with an efficient interface to extract low-level traffic data such as vehicle arrivals and departures at specific screen-lines and vehicle behavior–based classifications. Based on insights gained from previous efforts and the literature, GT-MVP seeks to address two challenges: 1) develop a simple interface that may be quickly adapted by new users, and 2) address data collection where multiple views are necessary to extract the needed information. While the first goal is intended to improve efficiency and accuracy in data collection, the second addresses those studies where a single view is often insufficient. Thus, GT-MVP offers a unified interface to synchronize and play multiple videos, thus providing a comprehensive field of view. GT-MVP also offers controls to play multiple videos faster or slower than recorded time or frame-by-frame (backward and forward) in synchronized mode for data extraction. GT-MVP also improves data extraction efficiency by providing an optimized user-friendly graphical user interface (GUI) that minimizes human effort and allows for review and correction of errors.

C.4 Multi-video Player Application

The GT-MVP application has been developed primarily to address manual traffic-related data extraction from pre-recorded videos. GT-MVP is utilized to support transportation research studies that require complex vehicle/driver behavior information in addition to regular data attributes such as vehicle volume counts, signal phase information, etc. A brief description of the GT-MVP application is provided in this section, followed by some case studies that demonstrate specific tool applications.

GT-MVP is developed on the Python® platform. The user interface consists of two video player windows and a control window with common video player controls to operate both video player windows simultaneously (see Figure C-1). The common control window, also referred as the data extraction window, provides an interface to assist the user to record the required data in a semi-automatic fashion, minimizing typing by leveraging the frame-numbers and embedded timestamps of the video stream. Figure C-2: provides a close-up of a single GT-MVP video player window interface.

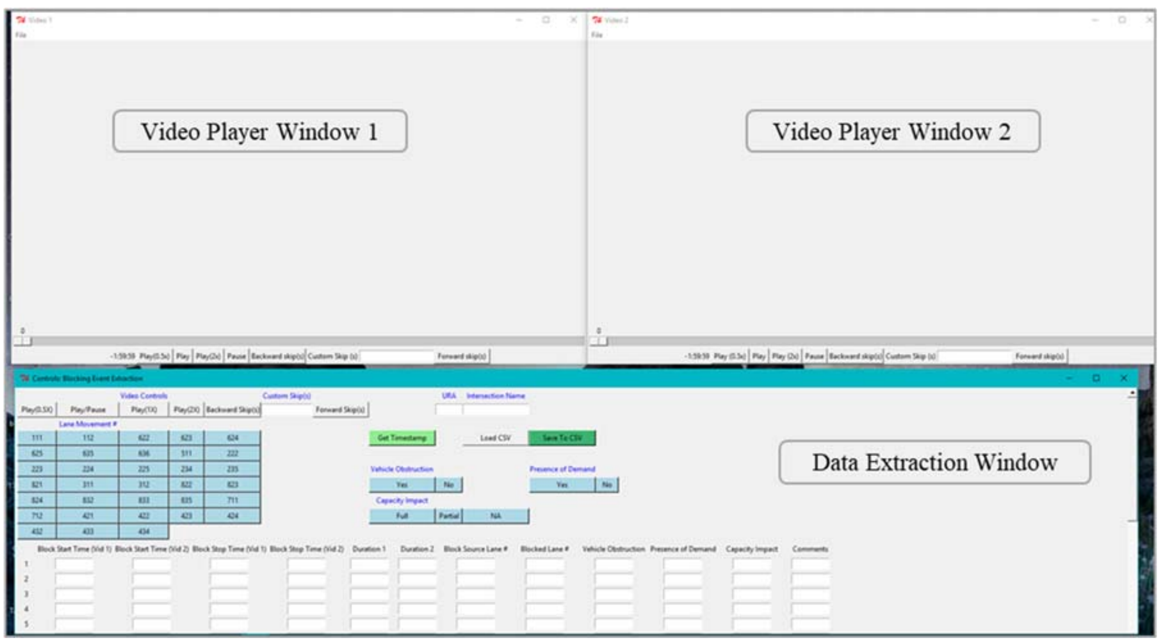

Figure C-1: Snapshot of the Three Windows of GT-MVP's Blocking Event Extraction Module.

Apart from a few generic data collection interfaces, the widgets on the data extraction window are amenable to customization to the requirements of specific studies. For example, it will be seen later that the data extraction window graphical user interface had been customized for data collection for an ongoing “Do-Not-Block-the-Box” study. The Event Extraction Interface window (see Figure C-3:) contains the controls required to play the multiple videos concurrently, as well as the user interface to extract and store blocking event data.

Figure C-2: GT-MVP’s Video Player Window Interface.

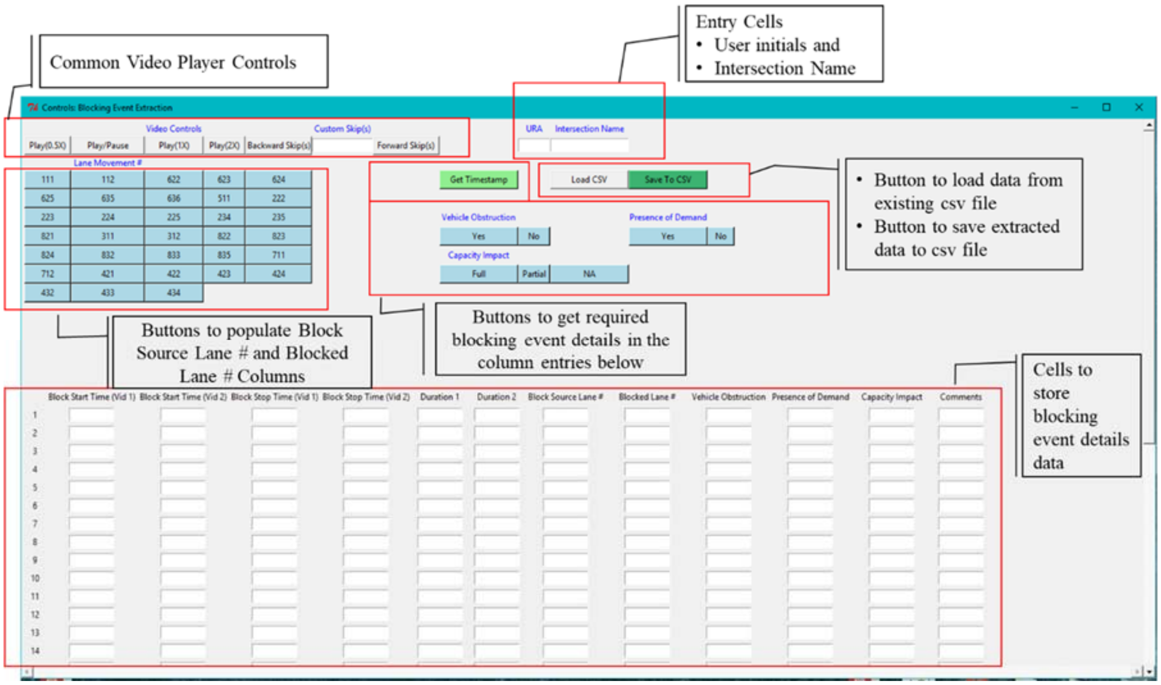

Figure C-3: GT-MVP's Blocking Event Extraction Interface Window, Customized for Do-Not-Block-the-Box Study.

Figure C-4: shows GT-MVP's structural framework. As seen, GT-MVP's graphical user interface is developed using several widgets under Python's Tkinter library [19]. Each video player window contains three Tkinter frames: one frame displays an embedded *VLC media player®* instance, another frame contains the video time slider, and the third frame contains player controls as button widgets and Tkinter entry cells [19–21]. The data extraction window contains two Tkinter canvases. The first canvas contains a frame which holds Tkinter buttons and entry cells for common controls, data extraction buttons (for example, to retrieve the video timestamp), lane movement and vehicle types entry cells, etc. The second canvas contains a frame that consists of a matrix of entry cells. Horizontal and vertical scrollbars are embedded in the second canvas to ease navigation of this matrix. The frame and widgets in the canvas are not affected by vertical and horizontal scrollbars present in canvas 2, thus keeping frame 1 frozen while allowing a user to scroll down the cell matrix where data are stored.

Figure C-5: shows the control flow of the GT-MVP graphical user interface. As seen, the graphical user interface of GT-MVP contains two units of control flow—the video player loop and the data extraction loop. The video player loop contains player controls to operate videos individually as well as common player controls to operate all videos together. When the user interacts with individual player controls respective videos are rendered and when the user interacts with common controls all videos are rendered. The data extraction loop controls user interactions with GT-MVP to extract data from the video. Input is received from the user in the form of mouse click or keyboard press events and extracted data are saved to a CSV file. For instance, when the user clicks the "Get Timestamp" button on the data extraction window, the time instant of last rendered video instance in the video player loop is stored in the data extraction window. If the user stops data collection in the middle of a video, data from the CSV file can be loaded back to the interface to continue data extraction at a later time.

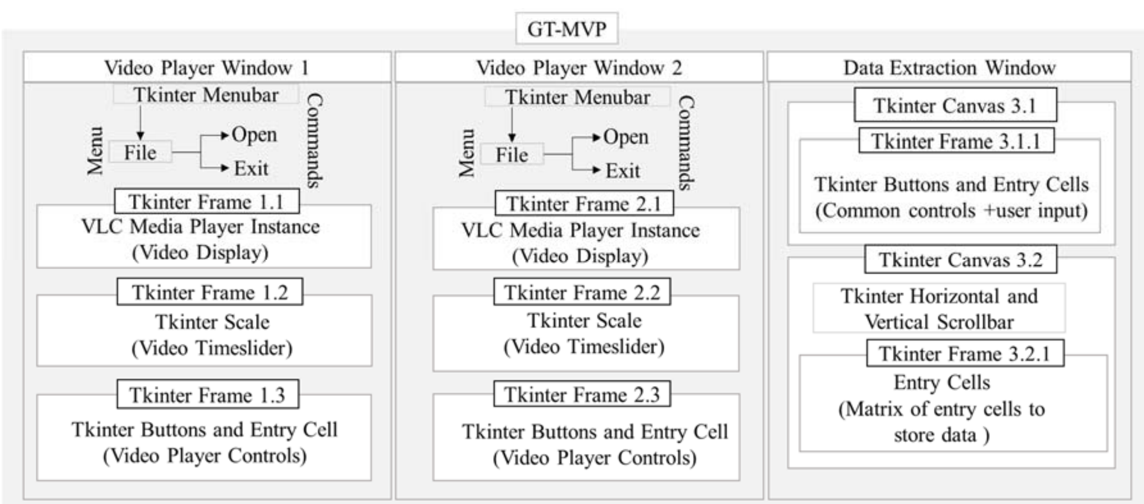

Figure C-4: Structural Frame of GT-MVP's GUI.

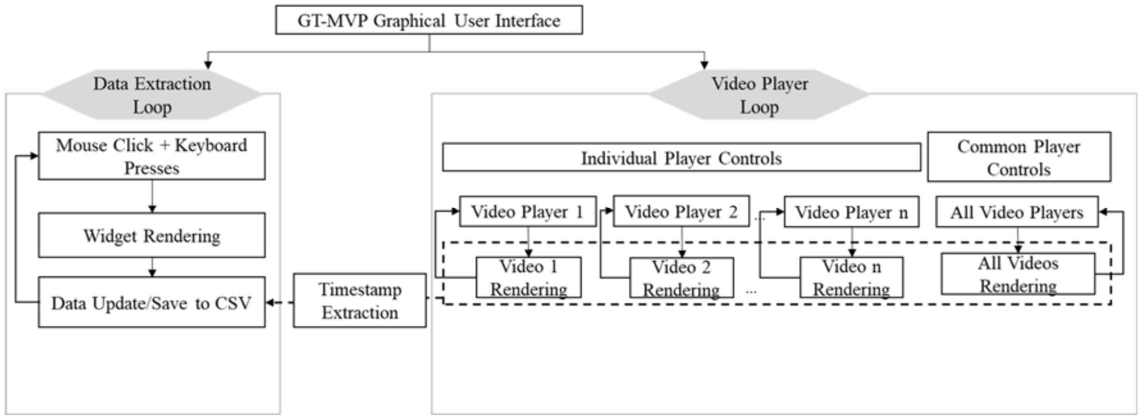

Figure C-5: Control Flow of GT-MVP GUI.

C.4.1 Case Study: Data Extraction for Intersection Blocking Study

The primary motivation for the development of GT-MVP was the data extraction requirements for a study exploring the impacts of vehicle-blocking behavior on traffic operations. In this study, a vehicle is considered to "Block the Box" when it enters the intersection with no space to exit due to the traffic spillback downstream. Use of a "Don't Block the Box" (DBTB) treatment as a control strategy has been adopted by many cities in the U.S. and this research explores the performance of DBTB treatments by quantifying the impact of vehicle blocking behavior on intersection performance [22].

DBTB data analysis includes comparing the characteristics of blocking events and measuring the propensity to block for vehicles on a given intersection approach (i.e., the likelihood of a vehicle to enter an intersection when it cannot exit due to insufficient space downstream of intersection) before and after DBTB signing and marking implementation. To determine the effectiveness of DBTB treatments, blocking event characteristics such as number of blocking events, event duration, vehicle lane movements that block or are blocked, etc., are compared before and after DBTB treatment implementation. In addition, the propensity to block is compared to study the impact of DBTB treatments on driver behavior as well as provide a calibration parameter to allow for simulation of queuing, delay, and travel time analysis with and without a DBTB treatment [22].

To study the blocking event characteristics and to measure a vehicle's propensity to block, two modules of GT-MVP application were developed: 1) a Blocking Event Data Extraction GUI, and 2) a Propensity to Block Data Extraction GUI. In both GUIs, each video player window has a time slider below to indicate the playback position in the video track (see Figure C-1). Video player control buttons below the time slider allow the user finer control over playback. In addition to basic player operations such as Play and Pause, the "Play (0.5X)" and "Play (2X)" buttons enable video playback at half of original speed or twice the original speed, allowing the user to move through the video more efficiently. Backward skip and Forward skip buttons skip the video frame back and forth respectively by the number of seconds the user provides in the "Custom Skip" entry field, providing further flexibility in traversing the video timeline. (For example, in the DBTB efforts a custom skip on the order of half the cycle length of the given intersection allowed efficient skipping of video not relevant to the data collection.) Further details of the features of the data recording window are provided in the case studies. The next subsections provide a summary of data required for the DBTB study and a comparison of the traditional method to extract data from video versus using GT-MVP application modules.

C.4.2 Blocking Event Data Extraction

A blocking event is defined to occur at the start of the green indication of the conflicting phase where the blocking vehicle was not able to exit the intersection right-of-way during their phase. The blocking event ends when the blocking vehicle departs the intersection right-of-way or "box." An approach lane that is blocked is referred to as the "Blocked

Lane" and the approach lane from which the blocking vehicle entered the intersection is referred to as the "Block-Source Lane."

Before the development of the GT-MVP application, data for each blocking event was extracted by playing back the videos in a media player and recording the observations in a spreadsheet manually. A challenge in this data collection was that a different video angle was consistently needed to capture the signal phase data than the vehicles in the blocking event. Thus, the researcher conducting the data extraction was required to manage videos in separate players. The data attributes manually recorded in the spreadsheet included a unique serial ID of the blocking event, the start time of blocking, the end time of the blocking event, and the block source and blocked lanes (coded as a three-digit number). Users recorded the lanes associated with blocking event by entering "1" in the cell below the corresponding lane movement code. The duration of blocking was derived as the difference of the blocking event start and end time.

In a second pass through the videos the blocking event was inspected to determine if capacity was affected. Data were collected regarding whether the blocking event obstructed any vehicles with the right-of-way, whether there was a presence of demand during the blocking event, and whether the event was a full or partial blocking based on whether the blocked vehicles were unable to proceed or were hindered but able to complete their movement. Other relevant details about the blocking event such as impacts on safety of pedestrian crossing or ambiguities in any recorded data were documented under the comments column.

C.4.3 Using GT-MVP's Blocking Event Extraction Module for Data Extraction

In GT-MVP the two intersection videos are played in a synchronized manner using GT-MVP's common controls features. Any offset between two videos is eliminated by going backward or forward using the custom skip functionality in one of the video player windows. After the initial synchronization, the common controls in the data extraction window are used to play (play, pause, play at slow rate, play at faster rate, skip forward or backward, etc.) the two videos concurrently. By clicking relevant widgets on the data extraction interface, blocking event details data are automatically and instantly recorded in the empty cell matrix in the common window. The empty cell matrix consists of columns to store all required blocking data. Mouse clicks on "Get Timestamp," "Lane movement number code," "Yes" or "No" buttons under vehicle obstruction, presence of demand, and capacity impact label, records data in the first empty cell under the corresponding column. In case of a user error during the data extraction process, the recorded data in the cell can be directly edited as with a spreadsheet, providing a familiar interface to the user. Figure C-6: shows a snapshot of GT-MVP being used for blocking event data extraction.

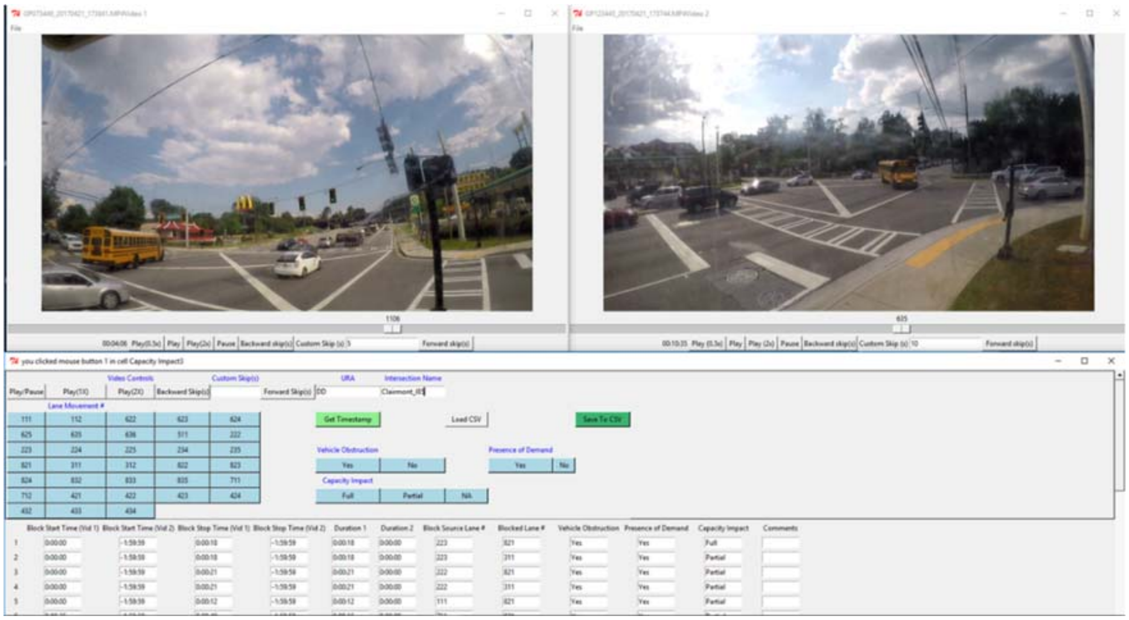

Figure C-6: GT-MVP Being Used for Blocking Event Data Extraction.

C.4.4 Propensity to Block Data Extraction

In the DBTB study analysis, estimation of the drivers' propensity to block was crucial to modeling the impact of blocking on traffic flow. Drivers' propensity to block is measured on the "Block-Source Lane," i.e. the lane from which the blocking vehicles originate. In this effort, a drivers' propensity to block for an intersection-lane is defined as the likelihood of a driver to enter the intersection and block when there is no space to exit downstream of the intersection (i.e., when presented with a blocking opportunity or choice). Drivers' propensity to block is field measured as the ratio of number of vehicles that enter and block the intersection to the total number of vehicles that have an opportunity to block.

Prior to the development of the GT-MVP tool, propensity data were extracted using another in-house developed video player software called "Videoanalyzer"[23]. Videoanalyzer allowed for recording vehicle timestamps from the block source lane when they crossed the stop bar. However, the timestamp recorded by Videoanalyzer was the computer's clock time, rather than the video stream time. This added some complexities to the post processing of the data as the timestamps had to be adjusted after the data extraction process, to coincide with the video time. In addition, Videoanalyzer did not have the capability of displaying the recorded data for review during the data extraction process, which limited the ability to recognize and correct errors. A second pass through the video was done to tag the vehicle IDs in the resulting data as blocking, non-blocking or not-applicable (i.e., if space existed to exit the intersection, the driver does not have an opportunity to block). The need for a second pass significantly increased the data reduction time. In addition, the lack of options to forward and reverse the video in Videoanalyzer made revisiting and re-recording data time consuming. These drawbacks were addressed in the GT-MVP application.

C.4.5 Using GT-MVP's Propensity Extraction Module for Data Extraction

The Data Extraction Window of GT-MVP's Propensity Extraction Module includes common controls to operate the two video player windows simultaneously and also includes buttons and an integrated spreadsheet to extract propensity data from the videos, as shown in Figure C-7: .

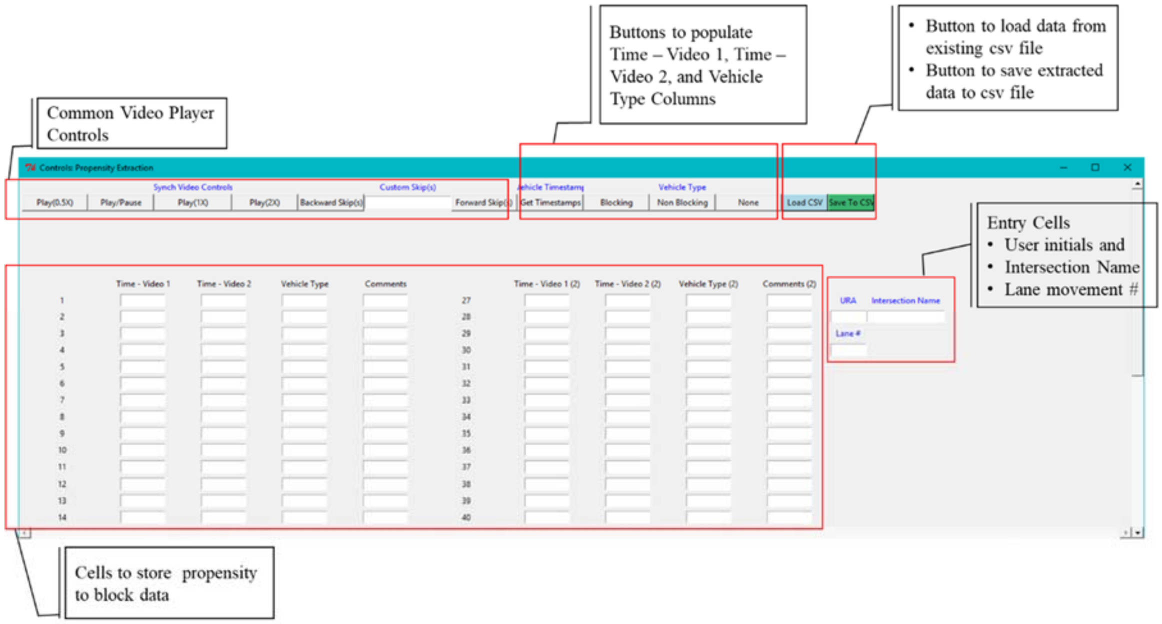

Figure C-7: GT-MVP's Propensity Extraction Interface Window.

Videos captured from two camera angles are synchronized in the two video player windows. Vehicles on the "block source" lane are observed. If the vehicle has no space to exit the intersection then the timestamp when it crosses the stop bar is recorded with a mouse click on "Get Timestamp." Based on the vehicle's action to enter or not enter the intersection the Blocking or Non-Blocking button is clicked to record the vehicle behavior. Thus, propensity data are extracted in a single review of the video. GT-MVP also allows a user to add comments where necessary. The data extracted are displayed in the first empty cell under corresponding column, and again may be edited should an error occur.

C.4.6 Other Potential Application Cases

Apart from the case study described above, there is a wide variety of other studies where GT-MVP may provide efficiency improvements in the video data extraction process.

Several studies the research team has undertaken over the past several years provide excellent examples, such as the following:

Roundabout Capacity Calibration Study. For a traffic study conducted to calibrate the HCM 2010 roundabout capacity equations to include characteristics of Georgia drivers, gap acceptance field data were extracted from video recordings. The study included an investigation of the impact on capacity due to the hesitation of entering vehicles to enter the roundabout when faced with the uncertainty related to whether vehicles in the roundabout are exiting or circulating. The study required the simultaneously recording of two legs of a roundabout. Timestamps for circulating, entering, and exiting vehicles were recorded requiring multiple video viewing. [24]. GT-MVP would have provided an integrated GUI for data-collectors to process both videos simultaneously and record the relevant interface with a single concurrent traversal of the videos.

Left-Turn Interactions Safety Study. This traffic study evaluated effectiveness of post encroachment time (PET) and acceleration-deceleration profiles of vehicles as surrogates for safe left-turn interactions. The PET and acceleration-deceleration data were used to develop a crash data model. For this study the vehicle trajectory over a stretch of road (high speed intersection approach) was tracked to obtain the acceleration-deceleration profiles. Due to the limitation of the field of view of a single camera, two cameras were used to record a sufficient length of roadway. As video synchronization was critical for this effort, a custom software was developed to synchronize videos; however, the interface lacked a run-time review of the data capability, limiting the ability of the user to quality check the data during the data collection process [25]. This limitation has been addressed in GT-MVP through a spreadsheet interface present on the data extraction window.

Vehicle and Pedestrian Behavior under Varying Crosswalk Treatments. Recently, members of the research team investigated the effectiveness of various crosswalk treatments to elicit yielding behavior from crossing vehicles. It was seen that two camera angles were typically necessary to allow for the inference of the crossing intent of the pedestrian while tracking the position of approaching vehicles. The ability to readily synchronize the videos as well as flexibility in forwarding and reversing through the video in time steps would have significantly improved the efficiency of the data reduction team.

C.5 Verification of GT-MVP: Propensity to Block Data Extraction

To quantify the benefits of extracting data using the GT-MVP tool versus using the video playback with manual data entry methods, an experiment was performed where the previously described blocking propensity data were extracted from the same videos using Videoanalyzer and GT-MVP. Different data collectors were assigned to perform the extraction process from the two methods to avoid any bias related to previous knowledge about the events in the videos affecting the data extraction process. While there are some possible differences between efficiency of the data collectors, they all had experience from previous projects and differences are expected to be minimal. An hour of video at a single intersection was used for analysis. These data had been previously analyzed with the results visually inspected for accuracy. Comparisons were performed based on the total time required for extraction, errors in capturing events (missing data), and misclassification of data (errors in data).

Out of 160 vehicle timestamps identified in GT-MVP, seven were missed by the data collector using Videoanalyzer. Videoanalyzer's failure to allow a simple procedure for error correction and easily traverse the video is hypothesized to deter users from going back to revisit and confirm any suspected errors during the data extraction. In addition, 3 out of 36 blocking vehicles were misclassified by Videoanalyzer users, which is likely at least partially attributable to the tedious nature of the extraction process involved and the need for multiple passes through the video. For the overall data extraction process, data collectors required 100 minutes and 35 minutes to process 1 hour of video using Videoanalyzer and GT-MVP, respectively representing a nearly two-thirds reduction in processing time.

C.6 Conclusions

The GT-MVP system was developed to allow users an effective semi-automated procedure for extracting a variety of important data from video recordings to support a wide range of traffic and behavioral studies. The advanced playback features and the integrated data collection and review interface of GT-MVP seek to reduce the manual data extraction time and enhance data accuracy for extraction of information supporting these types of studies. In addition, the ability to play multiple videos concurrently effectively increases the width of field of view for the data collector. For example, for the blocking event data collection, the data collector was able to simultaneously observe the existence of demand, queues, and the signal heads while collecting timestamps, in a single pass through the videos. Compared to previous data extraction methods, e.g., earlier roundabout capacity calibration studies, this feature would have significantly reduced the time required for data extraction by providing a single wide field of view. In addition, the wider field of view helps address issues related to occlusions from large vehicles common under normal field conditions.

The single unified control for simultaneous playback, rewind, and replay of multiple videos in a synchronous fashion increases the efficiency for traversing the videos as well as reduces the possibility of errors caused by switching between videos. The custom-skip feature allows the users to skip over periods with no events relevant to the study while allowing them to slow down the traversal during relevant events thus minimizing the chances of missing any important data.

The interface with preconfigured buttons for the relevant information capture reduces data errors related to typing errors while also ensuring that relevant information is captured with a reduced probability of error. For example, in the blocking event data extraction application, the automatic recording of timestamps initiated by a button click reduces the chances of error in comparison of timestamps entered manually in different cells in the spreadsheet.

The ability to review and edit the recorded data in run time allows the user to deal with erroneous data entries without requiring the user to manually edit the background data file as well as reducing potential errors. Similarly, automatically saving data into automatically named comma-separated-value (CSV) files simplifies subsequent analysis by producing data files that can be easily opened in a standard spreadsheet application or loaded directly into standard statistical software. In addition, this automatic naming of files eases the management and tracking of the datasets over the course of the project by ensuring that the location name, initials of data collector, and time of creation of file are referenced to the data, over the period of the project. Similarly, auto-saving of data after each new entry or edit minimizes data loss and rework. The ability to reload data from an existing data file not only allows for continuity of work flow across data collection sessions but also provides the ability to subsequently review the collected data, which simplifies data quality control.

Although the GT-MVP application was developed to meet the needs of the DBTB study, it is applicable to a wide range of other traffic studies. The key feature of operating two video player windows simultaneously assists the user in collecting data with ease and more accuracy in a single integrated data file. The interface can be easily leveraged for other applications such as performing volume counts, turn movement counts at intersections, etc. GT-MVP can also be used for vehicle headway extraction for studies involving saturation flow rate determination.

This tool, developed on the Python® platform, provides the flexibility of easy modifications by other researchers to modify the interface to record other data attributes specific to the study. One of the features that has been observed in other such studies is the ability to draw guide-lines or overlay grids on the video player pane. This is a feature planned for the next version of the tool. The source code of the application is available for use by the community at http://transportation.ce.gatech.edu/publications.

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