TRAFFIC MANAGEMENT ALTERNATIVES FOR BUSINESS IMPROVEMENT DISTRICTS

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TRAFFIC MANAGEMENT ALTERNATIVES FOR BUSINESS IMPROVEMENT DISTRICTS

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To my loving wife, family, and friends.

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TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iv
LIST OF TABLES	xii
LIST OF FIGURES	xiv
LIST OF SYMBOLS AND ABBREVIATIONS	xix
SUMMARY	xxii
<u>CHAPTER</u>	
1. INTRODUCTION	1
1.1. Research Objectives	1
1.2. Research Methods	2
1.2.1. Literature Review	2
1.2.2. Data Collection Plans	2
1.2.3. Survey Development	3
1.3. Research Scope	3
1.4. Equipment	4
1.4.1. High Definition Video Cameras	4
1.4.2. GDOT's Pan-Tilt-Zoom Traffic Cameras	4
1.4.3. VideoAnalyzer	5
1.5. Thesis Organization	5
2. BOX JUNCTION LITERATURE REVIEW	6
2.1. Background	6
2.1.1. Transportation Management Associations	6

2.1.2. Business Improvement Districts 7

2.1.3. Challenges and Opportunities 7

2.2. Gridlock 8

2.2.1. Gridlock's Impact on the Economy 9

2.2.2. Gridlock's Impact on Safety for Vulnerable Roadway Users 11

2.2.3. Gridlock's Effect on Driver Psyche 13

2.2.4. Gridlock's Impact on Air Quality 17

2.3. Box Junctions 18

2.3.1. History 21

2.3.2. Cost 23

2.3.3. Enforcement 23

2.3.3.1. Current Blocking Laws 24

2.3.3.2. Moving Versus Non-Moving Violations 27

2.3.3.3. Automated Enforcement 28

2.3.3.4. Public Education Campaigns 29

2.3.3.5. Penalty 30

2.3.3.6. Effectiveness 31

3. DESIGN OF THE PROJECT 32

3.1. Introduction 32

3.2. Don't Block the Box Data Collection 32

3.2.1. Site Selection 32

3.2.1.1. Buckhead Community Improvement District 33

3.2.1.2. Sandy Springs 35

3.2.1.3. Midtown 35

3.2.2. Don't Block the Box Data to be Collected 36
3.2.3. Data Collection Time Frame 37
3.2.4. How Don't Block the Box Data will be Collected 37
3.2.5. Deployment Procedures 38
3.2.5.1. Buckhead Community Improvement District's Intersections 38
3.2.5.2. Riverside Drive & Heards Ferry Road 39
3.2.5.3. 10th Street & Williams Street 40
3.3. Don't Block the Box Survey Development 41
3.3.1. Initial Framework 41
3.3.1.1. Phone Interview Questions 41
3.3.2. Drafting the Don't Block the Box Survey 42
3.4. Final Don't Block the Box Survey 42
4. DATA PROCESSING METHODOLOGY 44
4.1. Blocking the Box Defined 44
4.2. VideoAnalyzer 44
4.2.1. Initial Data Extracted from VideoAnalyzer 45
4.2.1.1. Step 1: Open the Program 45
4.2.1.2. Step 2: Select a Video File 46
4.2.1.3. Step 3: Create the Grid 46
4.2.1.4. Step 4: Process the Blocking Data 49
4.2.1.5. Step 5: Collecting the Signal Data 51
4.2.1.6. Step 6: Exit the Program 51
4.2.2. Labeling of Lanes within the Intersection 52

4.2.3. First Data Reduction Phase: Initial Data Extracted from VideoAnalyzer Tool 56

4.2.4. Second Data Reduction Phase: Additional Analysis of Initial Data 59

4.2.4.1. Fill in Missing Data 59

4.2.4.2. Assign Block ID 61

4.2.4.3. Duration of Blocking Sessions 62

4.2.4.4. Conflicting Approaches and Lanes 63

4.2.4.5. Verify the Degree of Block 64

4.2.4.6. Processing Signal Data 67

4.2.5. Final Analysis of Data 68

4.2.5.1. Temporal Analysis of Blocking 69

4.2.5.2. Distribution of Conflicting Approach and Lane Blocks 70

4.2.5.3. Full or Partial Block 72

4.2.5.4. Percent Green with Full and Partial Blocking 73

4.2.5.5. Lost Capacity 76

4.2.5.6. Pedestrian Safety Analysis 80

4.2.5.7. Probability Blocker will Change Lanes to End Block 81

4.2.5.8. Driver Characteristics 82

4.3. Summary of Data Processing Methodology 83

5. RESULTS 85

5.1. Don’t Block the Box Data 85

5.1.1. Data Collection Time Frame for Each Intersection 86

5.1.2. Number of Blockers 87

5.1.2.1. Findings 87

5.1.2.2. Analysis 91

5.1.3. Temporal Analysis of Blocking 92

5.1.3.1. Findings 92

5.1.3.2. Analysis 96

5.1.4. Percent Green Time with Full and Partial Blocking 97

5.1.4.1. Findings 97

5.1.4.2. Analysis 102

5.1.5. Percent of Capacity Lost Due to Blocking 103

5.1.5.1. Findings 103

5.1.5.2. Analysis 107

5.1.6. Entry and Exit of Blockers 108

5.1.6.1. Findings 108

5.1.6.2. Analysis 112

5.1.7. Distribution of Conflicting Approach and Lane Blocks 112

5.1.7.1. Findings 112

5.1.7.2. Analysis 118

5.1.8. Full or Partial Block 119

5.1.8.1. Findings 119

5.1.8.2. Analysis 122

5.1.9. Probability Blocker will Change Lanes to End Block 123

5.1.9.1. Findings 123

5.1.9.2. Analysis 123

5.1.10. Pedestrian Safety Analysis 123

5.1.10.1. Findings 124

5.1.10.2. Analysis 126

5.1.11. Driver Characteristics 126

5.1.11.1. Findings 126

5.1.11.2. Analysis 126

5.1.12. Analysis of DBTB Campaign in Atlanta, Georgia 127

5.2. Don’t Block the Box Survey Responses 128

5.2.1. Respondent with a Don’t Block the Box Campaign 129

5.2.1.1. Background 129

5.2.1.2. Public Education Campaign 130

5.2.1.3. Obstacles 130

5.2.1.4. Controls 131

5.2.1.5. Enforcement 131

5.2.1.6. Effectiveness 132

5.2.2. Respondents Who have Considered Implementing a Don’t Block the Box Campaign and Chosen not to Proceed 133

5.2.3. Respondents Who are Currently Considering a Don’t Block the Box Campaign 133

5.2.4. Conclusion of Survey 133

5.3. Summary of Results 134

6. CONCLUSIONS AND RECOMMENDATIONS 136

6.1. Summary of Results 138

6.1.1. Don’t Block the Box Data 138

6.1.2. Don’t Block the Box Survey 140

6.2. Study Limitations 141

6.2.1. Site Restrictions 141

6.2.2. Video Restrictions 142

6.2.3. Data Processing Time 142

6.3. Future Research 143

APPENDIX A: ORGANIZATIONS AND CONTACT INFORMATION 145

APPENDIX B: DON’T BLOCK THE BOX SURVEY 161

REFERENCES 194

LIST OF TABLES

		Page
Table 1:	Summary of blocking laws for every state, including the District of Columbia.	25
Table 2:	Summary of green time with blocking for each intersection within the project.	97
Table 3:	Entry and exit points for blocks at Peachtree Road & Mathieson Drive.	109
Table 4:	Entry and exit points for blocks at Peachtree Road & Piedmont Road.	109
Table 5:	Entry and exit points for blocks at Peachtree Road & Highland Drive.	110
Table 6:	Entry and exit points for blocks at Peachtree Road & Stratford Road.	110
Table 7:	Entry and Exit points for blocks at Peachtree Road & Lenox Mall entrance.	111
Table 8:	Entry and exit points for blocks at 10th Street & Williams Street.	111
Table 9:	Which approaches were being blocked at Peachtree Road & Mathieson Drive.	113
Table 10:	Which approaches were being blocked at Peachtree Road & Piedmont Road.	113
Table 11:	Which approaches were being blocked at Peachtree Road & Highland Drive.	114
Table 12:	Which approaches were being blocked at Peachtree Road & Stratford Road.	114
Table 13:	Which approaches were being blocked at Peachtree Road & Lenox Mall entrance.	114
Table 14:	Which approaches were being blocked at 10th Street & Williams Street.	115
Table 15:	Total time an approach was partially or fully blocked at Peachtree Road & Mathieson Drive.	120
Table 16:	Total time an approach was partially or fully blocked at Peachtree Road & Piedmont Road.	120
Table 17:	Total time an approach was partially or fully blocked at Peachtree Road & Highland Drive.	120
Table 18:	Total time an approach was partially or fully blocked at Peachtree Road & Stratford Road.	121

Table 19: Total time an approach was partially or fully blocked at Peachtree Road & Lenox Mall entrance. 121

Table 20: Total time an approach was partially or fully blocked at 10th Street & Williams Street. 121

Table 21: Summary of the probability a blocker will change lanes to stop blocking for each intersection. 123

Table 22: Driver characteristics for the intersection of 10th Street & Williams Street. 126

Table 23: What particular issued were addressed by DBTB. 129

Table 24: Partnerships that organizations found critical to the success of their DBTB campaign. 130

Table 25: Level of Improvement in traffic operations since DBTB campaign started. 132

Table 26: Observed benefits of the DBTB campaign over time. 132

Table 27: Cities and department of transportations included in survey. 145

Table 28: Police departments included in survey. 151

Table 29: TMAs included in survey. 155

LIST OF FIGURES

Page

Figure 1: The number of aggressive drivers observed as a function number of vehicles on the road in the same direction of travel (4 hr period). 14

Figure 2: Percentage of diary entries involving each type of driver behavior (n=689). 15

Figure 3: Percentage of critical (n = 197) and non-critical (n = 492) event diary entries involving each type of driver behavior 16

Figure 4: Box Junction on Canal Street in Manhattan. 19

Figure 5: MUTCD standards for box junctions. 20

Figure 6: An example of a Don’t Block the Box sign. 21

Figure 7: Locations of MPD Gridlock Cameras in Washington D.C.. 29

Figure 8: The three locations considered for DBTB data collection. 33

Figure 9: BCID boundary. 34

Figure 10: BCID DBTB data collection intersections along Peachtree Road 34

Figure 11: Sandy Springs DBTB data collection intersection location. 35

Figure 12: Midtown Atlanta DBTB data collection intersection location. 36

Figure 13: Georgia Navigator program. 38

Figure 14: Sandy Springs’s camera placements. 39

Figure 15: Midtowns’s camera placements. 40

Figure 16: VideoAnalyzer icon. 46

Figure 17: Selection of video file in VideoAnalyzer. 46

Figure 18: Selecting grid boundary points in Video Analyzer. 48

Figure 19: Grid created in VideoAnalyzer. 49

Figure 20: Creating screenshots,entry zones, and entry time stamps in VideoAnalyzer. 50

Figure 21: Creating exit zones and exit time stamps in VideoAnalyzer. 51

Figure 22: Labeling scheme for Peachtree Road & Mathieson Drive. 53

Figure 23: Labeling scheme for Peachtree Road & Piedmont Road. 53

Figure 24: Labeling scheme for Peachtree Road & Highland Drive. 54

Figure 25: Labeling scheme for Peachtree Road & Stratford Road. 54

Figure 26: Labeling scheme for Peachtree Road & Lenox Mall Entrance. 55

Figure 27: Labeling scheme for Riverside Drive & Heards Ferry Road. 55

Figure 28: Labeling scheme for 10th Street & Williams Street. 56

Figure 29: Example of raw blocking data from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 57

Figure 30: Example of raw signal data from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 58

Figure 31: Filled in data from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 60

Figure 32: Number of blocks from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 61

Figure 33: Duration of blocking sessions from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 62

Figure 34: Example of the conflicting approach and lane data from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 64

Figure 35: Example of full block at the 10th Street & Williams Street intersection. 65

Figure 36: Example of partial block at the 10th Street & Williams Street intersection. 65

Figure 37: Example of degree of partial and full blocking data that was recorded from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 66

Figure 38: Example of processed signal data that was recorded from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 68

Figure 39: Example of how the temporal analysis was calculated from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 70

Figure 40: Example of determining the percentage of total blocks that blocked an approach for the two hour data collection period from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 71

Figure 41: Example of determining the percentage of total blocks that blocked a lane from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 72

Figure 42: Example of percent of partial and full blocks data from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014. 73

Figure 43: Example of percent of partial and full blocks data from the intersection of Peachtree Road & Lenox Mall entrance on February 4th, 2014. 75

Figure 44: Example of the analysis for percent green with blocking from the intersection of Peachtree Road & Lenox Mall entrance. 76

Figure 45: Example of the analysis for capacity lost from the intersection of Peachtree Road & Lenox Mall entrance. 79

Figure 46: Pedestrians crossing Peachtree Road with several vehicles blocking the intersection. 81

Figure 47: Pedestrians almost being hit by a blocking vehicle that was vacating the intersection. 81

Figure 48: Total number of blocks for each intersection. 87

Figure 49: Number of blockers for each date of analysis at Peachtree Road & Mathieson Drive. 88

Figure 50: Number of blockers for each date of analysis for Peachtree Road & Piedmont Road. 88

Figure 51: Number of blockers for each date of analysis for Peachtree Road & Highland Drive. 89

Figure 52: Number of blockers for each date of analysis for Peachtree Road & Stratford Road. 89

Figure 53: Number of blockers for each date of analysis for Peachtree Road & Lenox Mall entrance. 90

Figure 54: Number of blockers for each date of analysis for 10th Street & Williams Street. 90

Figure 55: Temporal analysis for Peachtree Road & Mathieson Drive. 93

Figure 56: Temporal analysis for Peachtree Road & Piedmont Road. 93

Figure 57: Temporal analysis for Peachtree Road & Highland Drive. 94

Figure 58: Temporal analysis for Peachtree Road & Stratford Road. 94

Figure 59: Temporal analysis for Peachtree Road & Lenox Mall entrance. 95

Figure 60: Temporal analysis for 10th Street & Williams Street. 95

Figure 61: Percent of green time that experienced blocking for each day of analysis at Peachtree Road & Mathieson Drive. 98

Figure 62: Percent of green time that experienced blocking for each day of analysis at Peachtree Road & Piedmont Road. 99

Figure 63: Percent of green time that experienced blocking for each day of analysis at Peachtree Road & Highland Drive. 99

Figure 64: Percent of green time that experienced blocking for each day of analysis at Peachtree Road & Stratford Road. 100

Figure 65: Percent of green time that experienced blocking for each day of analysis at Peachtree Road & Lenox Mall entrance. 100

Figure 66: Weekday breakdown of percent of green time that experienced blocking for Peachtree Road & Lenox Mall entrance. 101

Figure 67: Percent of green time that experienced blocking for each day of analysis at 10th Street & Williams Drive. 101

Figure 68: Percent of capacity lost due to blocking at Peachtree Road & Mathieson Drive. 104

Figure 69: Percent of capacity lost due to blocking at Peachtree Road & Piedmont Road. 104

Figure 70: Percent of capacity lost due to blocking at Peachtree Road & Highland Drive. 105

Figure 71: Percent of capacity lost due to blocking at Peachtree Road & Stratford Road. 105

Figure 72: Percent of capacity lost due to blocking at Peachtree Road & Lenox Road entrance. 106

Figure 73: Percent of capacity lost due to blocking at 10th Street & Williams Street. 106

Figure 74: Aggregate percent of northbound and southbound lanes being blocked at Peachtree Road & Mathieson Drive. 115

Figure 75: Aggregate percent of northbound, eastbound, westbound, and southbound lanes being blocked at Peachtree Road & Piedmont Road. 116

Figure 76: Aggregate percent of northbound and southbound lanes being blocked at Peachtree Road & Highland Drive. 116

Figure 77: Aggregate percent of northbound and southbound lanes being blocked at Peachtree Road & Stratford Road. 117

Figure 78: Aggregate percent of northbound and southbound lanes being blocked at Peachtree Road & Lenox Mall entrance. 117

Figure 79: Aggregate percent of northbound, eastbound and westbound lanes being blocked at 10th Street & Williams Street. 118

Figure 80: Number of pedestrians during blocking sessions for Peachtree Road & Highland Drive. 124

Figure 81: Number of pedestrians during blocking sessions for Peachtree Road & Stratford Road. 125

Figure 82: Number of pedestrians during blocking sessions for Peachtree Road & Lenox Mall entrance. 125

Figure 83: Will organizations consider DBTB campaigns if they are proved effective. 134

LIST OF ABBREVIATIONS

ADT	Average Daily Traffic
AERIS	Applications for the Environment Real-Time Information Synthesis
BART	Bay Area Rapid Transit
BCID	Buckhead Community Improvement District
BID	Business Improvement District
BSM	Basic Safety Message
CCH	Control Channel
CCS	Congestion Charging Scheme
CCTV	Closed Circuit Television
CID	Community Improvement Districts
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CW	Contention Window
DBTB	“Don’t Block the Box”
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
EB	Eastbound
EBL	Eastbound Left
EBR	Eastbound Right
EBT	Eastbound Through
GDOT	Georgia Department of Transportation

IEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ITS	Intelligent Transportation System
IVPM	In-Vehicle Parking Meter
LED	Light Emitting Diode
LMA	Longwood Medical and Academic Area
MAC	Medium Assess Control
MASCO	Medical Academic and Scientific Community Organization
MOVN	Meeting our Vehicular Needs
MPD	Washington D.C. Metropolitan Police Department
MUTCD	Manual on Uniform Traffic Control Devices
NB	Northbound
NBL	Northbound Left
NBT	Northbound Through
NHTSA	National Highway Traffic Safety Administration
NO_x	Nitrogen Oxides
OBU	On Board Unit
OSI	Open Systems Interconnection model
PM	Particulate Matter
PTZ	Pan-Tilt-Zoom Cameras
RFID	Radio-Frequency Identification
RSU	Road Side Unit
SAE	Society of Automotive Engineers
SB	Southbound

SBL	Southbound Left
SCH	Service Channels
SPaT	Signal Phase and Timing
TMA	Transportation Management Associations
TMC	Traffic Management Center
TMD	Transportation Management District
TMI	Transportation Management Initiative
TMO	Transportation Management Organization
USDOT	United States Department of Transportation
USA	United States of America
UTC	University Transportation Center
VANETS	Vehicular Ad-Hoc Networks
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
VII	Vehicle Infrastructure Integration
VMT	Vehicle Miles Traveled
VRU	Vulnerable Road Users
WAVE	Wireless Access in Vehicular Environments
WB	Westbound
WBL	Westbound Left
WBT	Westbound Through
WBR	Westbound Right
WSMP	WAVE Short Message Protocol

SUMMARY

When a vehicle enters an intersection with insufficient space to exit on the opposite side the result is often the obstruction of pedestrians and other vehicles, this phenomenon is usually referred to as “blocking the box.” The purpose of this study was to determine different characteristics of blocking that might be considered in determining the installment of a "Don't Block the Box" (DBTB) campaign. This study identified potentially problematic intersections in Atlanta, Georgia and collected information, such as the number of vehicles that block the intersection (box junction), the amount of green time with blocking, and the percentages in which approaches were blocked.

Based on the results it was found the characteristics of the number of blockers, percentage of green time with blocking, and the percentage of lost capacity are excellent indicators for a possible DBTB campaign. Organizations interested in potentially starting a DBTB should consider these characteristics part of the determination of suitability of DBTB for an intersection. Within this study is was found that the intersections of Peachtree Road & Highland Drive, Peachtree Road & Stratford Road, Peachtree Road & Lenox Mall Entrance, and 10th Street & Williams Street showed to be potential candidates for a DBTB campaign in Atlanta, Georgia. During the study period these intersections had high percentages of lost capacity, high number of blocks, and high percentages of green time with blocking.

In conjunction with the DBTB data analysis a “DBTB survey” was developed. The objective of this survey was to help gain a better understanding of the current trends in DBTB campaigns around the United States. The “DBTB Survey” received 75 responses from 415 organizations around the nation, a 18.1% response rate. Six (60%) of the ten participants that currently have a DBTB campaign found a sufficient level of improvement in traffic operations and 46 of the total respondents (60%) proclaimed that if DBTB campaigns were shown to be an economical alternative for traffic management they would consider starting one to help congestion and safety.

CHAPTER 1

INTRODUCTION

In a previous study it was found that Transportation Management Associations (TMAs), such as Transportation Management Organizations (TMOs) Business Improvement Districts (BIDs) and Community Improvement Districts (CIDs), had limited involvement in real time traffic operations *(1)*. Maddox et al. found that one of the most frequently cited reasons for the limited involvement of TMAs in traffic operation services is because of their budgetary limitations *(1)*. In response to these findings, this thesis explores “Don’t Block the Box” campaigns, to help increase the feasibility of involvement of TMAs in traffic operations.

Box junctions, normally referred to as “Don’t Block the Box” (DBTB) campaigns within the United States, is an economical traffic management alternative that has shown success in several countries around the world. A box junction is composed of two elements: a box painted in the middle of an intersection and several signs placed at and before the intersection. The objective of a box junction is to prevent vehicles from blocking opposing approaches when they have the right-of-way. By averting blockers, especially during peak volume hours, unnecessary gridlock can be avoided, resulting in a many positive externalities, such as reductions in travel times.

1.1. Research Objectives

This project has four main objectives. The first objective of this study is to evaluate the current traffic patterns within the Buckhead Community Improvement District (BCID) and other selected sites to determine the magnitude of existing blocking. The second objective of this study is to develop a DBTB survey that will quantify the current state of box junctions within the United States and also help inform guidance on the potential use of DBTB campaigns as an economical alternative for traffic management. Additionally, the third objective of this study is determine which characteristics an organization should look for when they are determining if a DBTB campaign is viable choice for traffic operations management. Lastly, the fourth goal of this thesis is to provide a recommendation for which intersections within the study could benefit from a DBTB campaign.

1.2. Research Methods

1.2.1. Literature Review

The literature review focuses on TMAs and box junctions. First, the differences in the characteristics of TMAs are explored, along with their applications to the community where they are found. Next, the impact that gridlock and congestion have on the economy, driver psyche, air quality, and safety for vulnerable road users (VRUs) is examined. Along with the effects of gridlock that blocking an intersection causes, the history, current laws, enforcement tactics, effectiveness, and cost of box junctions are assessed.

1.2.2. Data Collection Plans

To gain a better understanding of the extent of the blocking that occurs in Atlanta, Georgia, a deployment plan for collecting blocking data is developed. First, a group of intersections are selected. The appropriate data collection methods, either high definition cameras onsite or Pan-Tilt-Zoom cameras (PTZ) on existing infrastructure, are chosen for each site once the intersections are selected. Furthermore, the blocking data is collected for each intersection for some predetermined period of time. Lastly, the blocking data is processed and analyzed.

1.2.3. Survey Development

Subsequently, the literature review revealed that there is a lack of information on the effectiveness and potential of box junctions. Apart from a few studies on the enforcement and effectiveness of box junctions detailed information on the efficiency and potential benefits of box junctions is not currently attainable. To help gather more information on the current state of DBTB campaigns across the United States a 52 question survey is developed. The goal of this survey is to generate further guidance on how DBTB campaigns can act as a economical alternative for traffic management. In addition, information gathered from the survey's results will help develop guidelines on how to implement DBTB campaigns and help improve pervious congestion constraints. With these guidelines in place Department of Transportations (DOTs), cities, TMAs, BIDs, CIDs, etc. will be able to use a DBTB campaign as an economical transportation management application.

The survey is divided into three sections: the first section collects information on organizations that currently have a DBTB campaign, the second section is for organizations that have considered implementing a DBTB campaign and chosen not to proceed, and last section of the survey is for organizations currently considering a DBTB campaign. The final survey is located in Chapter 3 - Design of the Project.

1.3. Research Scope

As alluded to previously there are only a few studies on the effectiveness and enforcement issues of a DBTB campaign. One reason for the absence of DBTB studies could be that many transportation organizations may feel that tracking performance measures on an inexpensive traffic management solution is too costly. There is a possibility that more studies on DBTB campaigns exist, either in different countries or reserved within the owners of the DBTB campaign. However, this thesis is confined to only reports by the Medical Academic and Scientific Community Organization (MASCO) and Office of Manhattan Borough President. The number of transportation agencies and private organizations that currently have a DBTB campaign is also unknown. The project could only reach out to organizations that provided email addresses and phone numbers on their website.

1.4. Equipment

The primary equipment types that were used in the collection and processing of the DBTB data are Panasonic high definition cameras, Georgia Department of Transportation's (GDOT's) PTZ traffic cameras, VideoAnalyzer, and VehicleCounter. The high definition video cameras and GDOT's PTZ traffic cameras are the main tools for the DBTB data collection. VideoAnalyzer, a computer program, and VehicleCounter, a tablet application, provide the main tools for processing the DBTB data. These equipment types are described in the following sections.

1.4.1. High Definition Video Cameras

High definition video cameras are used at site locations where GDOT's PTZ traffic cameras are not available. The brand of high definition video cameras used is the Panasonic 700S series. These cameras are mounted on tripods and are placed on either sidewalks, inside building windows, or within a private yard. These cameras are positioned so that they are facing the middle of the intersection and the signal head can be seen.

1.4.2. GDOT's Pan-Tilt-Zoom Traffic Cameras

GDOT's PTZ traffic cameras are used at a majority of the site locations in this study. The PTZ cameras are positioned on utility poles along the side of the roadway, providing a great vantage point for blocking data. The PTZ cameras are accessed through a virtual client on a secure Georgia Tech computer. Once the virtual client is running, a user can select a range intersections and move the cameras to select the appropriate field of view. Presets are made to help move the PTZ cameras to the same position for each data collection session.

1.4.3. VideoAnalyzer

VideoAnalyzer is a video processing computer program developed by the Georgia Institute of Technology's Transportation department, which can be installed on any computer running Windows. The main function of VideoAnalyzer is to collect an image of the blocking vehicle and timestamps of when a blocking event starts and ends. Another function in VideoAnalyzer is the ability to overlay a grid on the video. The grid helps record the entry and exit points for blocking vehicles. Lastly, VideoAnalyzer also is used in the collection of signal timing data. When a signal head changes to the next phase the user is able to generate a timestamp which is stored for later analysis. When VideoAnalyzer has completed processing a video the image, blocking data, and signal data is saved to an Excel file.

1.5. Thesis Organization

This thesis is organized in the following manner. Chapter 2, the literature review of box junctions, presents background information on TMA's and DBTB campaigns, such as general definitions and history. Chapter 2 begins by providing insight on how blocking and the gridlock it creates affect the economy, air quality, driver psyche, and safety for VRUs. After these issues are discussed, a more thorough analysis of box junctions, including enforcement and cost, is provided. Chapter 3 describes the methodology used to gather the box junction data, including site selection and deployment procedures, and reviews the development of the survey. Chapter 4 describes the data processing methodology for the DBTB the data. Chapter 5 analyzes the findings for both DBTB data and survey responses within the project and discusses the results of those the findings. Lastly, Chapter 6 concludes the thesis, provides recommendations based on the results of the project, identifies research limitations, and presents future research needs.

CHAPTER 2

BOX JUNCTION LITERATURE REVIEW

This chapter serves a background on TMAs, looks into gridlock's impact on TMAs, and examines box junctions.

2.1. Background

2.1.1. Transportation Management Associations

TMAs are organizations of private and public businesses that share the goal of enhancing the movement of people and goods within a defined region. TMAs are usually located in dense activity centers within cities or towns and commonly offer employment opportunities, as well as other services such as residential living. "TMAs are generally initiated by local governments, chambers of commerce, or major businesses and are member controlled and funded by local businesses that pay membership dues *(1)*." Recently, TMAs have expanded their responsibilities to the business community. TMOs, Transportation Management Initiatives (TMIs), and Transportation Management Districts (TMDs) are alternative ways to define the more often used acronym of TMAs, with the only differences being they have operational differences *(1)*.

One objective of a TMA is to prevent roadway congestion by advocating alternative transportation methods, such as ride sharing, and provide financial savings. TMAs also provide services in parking management systems and help build and maintain transit infrastructure that match the surrounding community around. There are several classifications of TMAs and their activities and scope of services vary widely. Some of the most common classifications are TMOs and BIDs. Each is discussed in the following sections.

2.1.2. Business Improvement Districts

BIDs are a classification of TMAs that focus more on the business community instead of having a direct focus on transportation. “The most general definition of a BID is an organization in which a geographically defined majority of property owners and/or merchants agree to provide an extra level of public service in a specific area by imposing an added tax or fee on all of the properties and or businesses in the area *(1)*.” BIDs can also provide insightful information to larger agencies, such as the city and the local department of transportation, because they have familiarity on what the specific traffic challenges are within their district.

“A local government must legally establish the district, collect the tax assessment or fees, and transfer the funds to the BID, thus, BIDs are considered private organizations that focus on enhancing the safety, cleanliness, image, and competitiveness of city centers *(1)*.” The objective of BIDs is to attract more people to the part of the city the BID covers, thus making them more competitive to other surrounding areas, such as suburbs, and to offer a multitude of benefits to the surrounding community, including city services such as signal optimization, and landscaping.

2.1.3. Challenges and Opportunities

As stated previously, in a previous study it was found that “TMAs have many challenges, such as limited budgets, administrative authority of roadway operations and competing priorities, with the most prominent challenge being limited budgets *(1)*.” Nonetheless, there has been several advancements in the field of intelligent transportation technologies, which provides TMAs the opportunity to become more active in real-time traffic operations and traffic control services. For instance, the United States Department of Transportation (USDOT) Connected Vehicle program could be taken advantage of once larger transportation agencies implement the infrastructure.

“Along with these advancements, TMAs can also look at other means to reduce congestion and provide real-time traffic information for users within their community, such as traditional transportation demand management strategies. For instance, local TMAs could utilize free services available, such as Google Traffic and DOT cameras, to provide their constituents with useful transportation information *(1)*." Limited technology solutions, such as a DBTB campaigns can also serve as a potential effective tool in reducing gridlock while being cost effective. The following sections provide a thorough description of the impact that gridlock and blocking can have within a TMA or BID as well as a description of what constitutes a DBTB campaign.

2.2. Gridlock

Excluding the years of recession, the trend in vehicle registration within the United States of America (USA) has seen substantial growth in the last century. Recently, between 1984 and 2011, the vehicle registration for light duty vehicles has increased by nearly 33% *(2)*. One correlation that can be drawn from an increase in vehicle registrations is that the more vehicle registrations you have the more vehicles there are on the local roads, arterials, and highways. With more vehicles on the roadways, there is a potential for further traffic congestion. Traffic congestion can best be defined as a condition of traffic delay because the number of vehicles on the roadway exceed the design capacity of the roadway network, which in turn reduces the flow of traffic *(3)*. Gridlock is another word used to describe traffic congestion and can be defined as a state of the roadway network with minimal throughput in which roads are severely congested and queues of vehicles prevent movement completion *(4)*.

Gridlock usually propagates from a central source and then expands outward within the roadway network. One main cause of gridlock is when a vehicle enters an intersection without an adequate amount of space to exit the same intersection. When a vehicle stops and becomes trapped inside an intersection, they block opposing movements from being able to enter and vacate the same intersection. If a driver from the opposing movement decides to enter the intersection, either because they are tired of waiting or because they are an aggressive driver, they then block the same movement that blocked them, creating a larger blocking event. If gridlock becomes too severe the intersections that are in close proximity to the initial congested intersection could also experience gridlock.

As a result, gridlock presents several externalities, such as declines in safety for VRUs, decreases air quality, prompting aggressive acts in drivers, and potential negative impacts on the economy, for the surrounding communities. In some cases, the externalities produced by gridlock are intensified under certain circumstances. For instance, when a roadway network is closely connected, such as the grid pattern seen in Manhattan, New York, gridlock can propagate at a much faster rate when compared to cities with a more spread out roadway network. Inclement weather is another factor that can intensify gridlock. An excellent example of inclement weather creating gridlock is the snow storm (SnowJam ‘14) that struck Atlanta, Georgia on January 28, 2014. The city was essentially shut down because the gridlock became so serve. Gridlock’s impact on the economy, safety for VRUs, drivers psyche, and air quality are discussed in more detail in the following sections.

2.2.1. Gridlock’s Impact on the Economy

As stated earlier, gridlock is occurring with more frequency within TMAs, BIDs, and CIDs. This increase presents a strain on not only local economies but also on the economies of different States as well as the USA as a whole. This relationship has also been observed in other countries, such as Australia. Recently in Sydney, Australia, a multi regional model showed that in addition to the direct costs of congestion found in Sydney there would also be significant losses in other regions within the country *(6)*. From 1982 to 2011, the total cost of congestion on the USA’s economy has experienced a steady increase, never decreasing once during that time period. In 2011, the congestion cost on the National economy was estimated to be $121 billon *(7)*.

The National, State and local economies are interconnected by the shipment of goods and services by truck, ships, and rail. Perhaps the most vulnerable mode of the shipment of goods to businesses and manufacturers is with the use of trucks. Truck transport is susceptible because this mode of shipment has to deal with the congestion of the roadways. When a truck experiences an increase in traffic congestion the entire truck distribution network is impacted. Managers of trucking companies operating in California confirmed that "congestion has a substantial effect on trucking operations with 80 percent of managers indicating that traffic congestion was a 'somewhat serious' or 'critically serious' problem *(7)*."

Within the $121 billion in congestion costs the USA experienced, $27 billion was directly related to trucking congestion cost *(6)*. As for local regions, New York/Newark, Chicago, and Los Angeles were among the top cities that had the most congestion cost. Atlanta was ranked 4th in the Nation in truck congestion cost ($775 million) and 9th in the Nation in total congestion cost ($3.1 billion) *(6)*. The congestion costs discussed above translates to decreases in consumer satisfaction and business profit because delivery times were missed and a preferred level of services was not provided. To adjust for the additional expenses provided by congestion some business pass the cost to the consumer, showing congestion effects extend far beyond the region where congestion occurs *(6)*.

There have been several studies conducted to confirm the negative impacts of traffic congestion on economic growth. Daniel Graham showed that "a comparison of spatial variance in estimates indicates that road traffic congestion plays an important role in explaining diminishing returns for most highly urbanized locations *(8)*." The diminishing returns Graham referred to present constraints on local and regional business, such as construction, hotels, banking, and public services. Another constraint gridlock can impose on a business is reductions in employment growth. Research has found that "high initial levels of congestion diminish employment growth in a non-linear fashion, meaning declines in employment growth are greater in highly congested environments *(9,10)*." If the trend of increased congestion continues with no or minimal mitigation measures taken, there will be considerable repercussions in the future for businesses. For instance, some businesses experiencing congestion are "forced to use roadways that are not close to their respective market, causing a distribution in the planning of supply chain activities *(11)*."

Weisbrod et al. observed that there is a "certain point to which businesses are willing to deal with gridlock *(6)*." As congestion increases to this point current businesses will invest less resources because they are trying to cover their losses. If congestion surpasses this point businesses will "adjust by moving away because their supply flows are diminished because the high congestion costs reduces or eliminates the profitability of supplying those markets *(5,13)*." This effect was confirmed by Konur and Geunes when their study showed that businesses prefer to locate their facilities in market areas with "higher potentials, naming lower sensitivity to the supply quantities as a key factor *(11)*." Weisbrod et al. also stated that "businesses that can not move away or adjust their inventory accordingly will go out of business *(6)*." The economical impacts presented in this section propose serious concerns for BIDs because congestion makes the region undesirable, leading to decreases in investments.

2.2.2. Gridlock's Impact on Safety for Vulnerable Roadway Users

Congestion and gridlock not only present safety concerns for drivers but also VRUs. VRUs are classified as pedestrians, bicyclists, or motorcyclists. Worldwide, VRUs account for nearly half (46%) of the traffic fatalities *(12)*. However, in the past several years, countries such as the USA, United Kingdom, and Germany have implemented strategies that resulted in steady declines in the amount of crashes that involve VRUs, in particular, pedestrians. This is not to say that pedestrian crashes are not an issue or concern anymore within countries that have shown improvements in VRU safety. Pedestrians fatalities still constitute approximately 13% of all traffic related deaths, with 70% of this percentage being male *(13)*. There are also direct incentives to BIDs and other agencies to take serious precautions in planning and designing for VRU safety within their communities. Safer VRU access with a community, especially for pedestrians, has a direct affect on the surrounding businesses. If the community's environment feels unsafe or unusable there will be a decline in attractiveness to the area. These concerns for the safe mobility of VRUs will only increase in the forthcoming years as the current trend towards urbanization continues *(12)*.

There are several factors that are associated with a higher likelihood of pedestrian crashes that organizations and agencies, including BIDs, can focus on to make their communities safer. The first two factors are traffic volumes and the number of lanes. Higher traffic volumes and how many lanes the roadways have been found to correlate with higher pedestrian crashes *(13,14)*. Another factor that plays a significant role in pedestrian crashes is the average daily traffic (ADT) for the minor and major approaches. If the ratio of ADT in the minor road relative to major road is small there is a potential for more pedestrian crashes *(13)*. Lastly, the presence of "bus stops, schools, and alcohol establishments have also shown to have a strong connection to pedestrian crashes *(13)*."

The factors that do associate with a higher likelihood of pedestrian crashes have shown to increase in denser environments. In 2007, approximately 73% of pedestrian fatalities in the United States occurred in urban areas, in part because of the greater number of pedestrian trips in these areas *(13)*. There are several approaches that can be taken to help reduce pedestrian fatalities in urban areas, for example, designing accessible and safe facilities for pedestrians. Several studies have shown that engineering solutions can have a profound impact on lowering pedestrian crashes. For example, traffic signal related measures have been found to significantly reduce pedestrian crashes *(13)*. In addition, certain types of signs, markings, and operational countermeasures can reduce pedestrian crashes *(13)*. Police enforcement, including automated enforcement, has also shown to reduce pedestrian crashes by influencing potential violators to not run red lights or block intersections, thus improving safety for pedestrians.

2.2.3. Gridlock's Effect on Driver Psyche

A driver's psyche during gridlock is also an important issue to consider because a driver's emotions while driving can often lead to aggressive or irresponsible acts on the roadway. "Physiological stress measures like blood pressure and heart rate have shown to suggest rush hour traffic congestion is interpreted as stressful by many drivers *(15)*." Additional studies have shown correlations to congestion and stress, adding that "high time pressure and unsafe descriptive norms increased drivers intentions to commit violations *(16,17)*." In addition to congestion, drivers that possess certain traits, such as overconfidence, being younger, and being a male also result in more risky and aggressive driving, and ultimately, increasing the risk of motor vehicle collision *(17,18)*.

Conversely, there has been some debate on whether the observation time (weekday peak hours, weekend hours, and weekday non-peak hours) of congestion actually contributes directly to the aggressive acts by drivers. Two studies were conducted to analyze the effect of observation time of congestion on aggressive drivers, one independent of the level of congestion and the other independent of the observation time. Taking into account the observation time, independently of the level of congestion, the relative risks of aggressive driving decreased from weekday peak hours, to weekday non-peak hours, to weekend hours. Moreover drivers are one and half times more likely to commit aggressive actions during peak hours than during weekend hours *(17)*.

As for the effects of congestion on aggressive driving independent of the observation time, Shinar and Compton conducted a "regression analysis on the number of aggressive actions and traffic counts and found that while the likelihood of aggressive driving increases when the value of time is high *(17)*." Shinar and Compton also found that congestion does not seem to significantly Effect the likelihood of aggressive driving for a given driver when the observation time is neglected *(17)*. In summary, the increase in the number of aggressive acts observed during congestion was simply because there were more vehicles on the road *(17)*. The relationship between time, the number of aggressive drivers, and the number of vehicles can be seen in Figure 1 below.

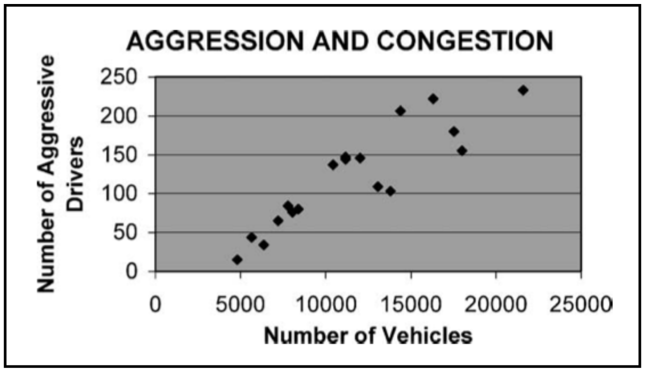


Figure 1: The number of aggressive drivers observed as a function number of vehicles on the road in the same direction of travel (4 hr period) *(17)*.

Recently, a study conducted by Lajunen et al. showed that the frustration created by traffic congestion does not always lead to aggressive acts, yet, drivers that were "frequently exposed to congestion committed traffic violations having instrumental aims *(15)*." That is to say, drivers commit violations. For example, they run red lights or block intersections in order to gain a benefit or to maintain advancement. Correlation between rush hour traffic and ordinary violations in Lajunen et al.'s study also found that "violating behavior actually pays off in rush hour traffic *(15)*." Acts that usually lead to emotional responses and aggression on the roadway while driving were mainly caused by unexpected congestion or delays that exceed standards that a driver is accustom to.

When a driver does decide to perform an aggressive act, regardless of intention or emotion, on the roadway there are certain behaviors that occur with more frequency then others. Wickens et al. administered driving diaries and found that the most frequently reported driver behaviors, shown in Figure 2, are weaving/cutting (32.7%), slow driving (19.9%) , and speeding (13.4%) *(18)*.

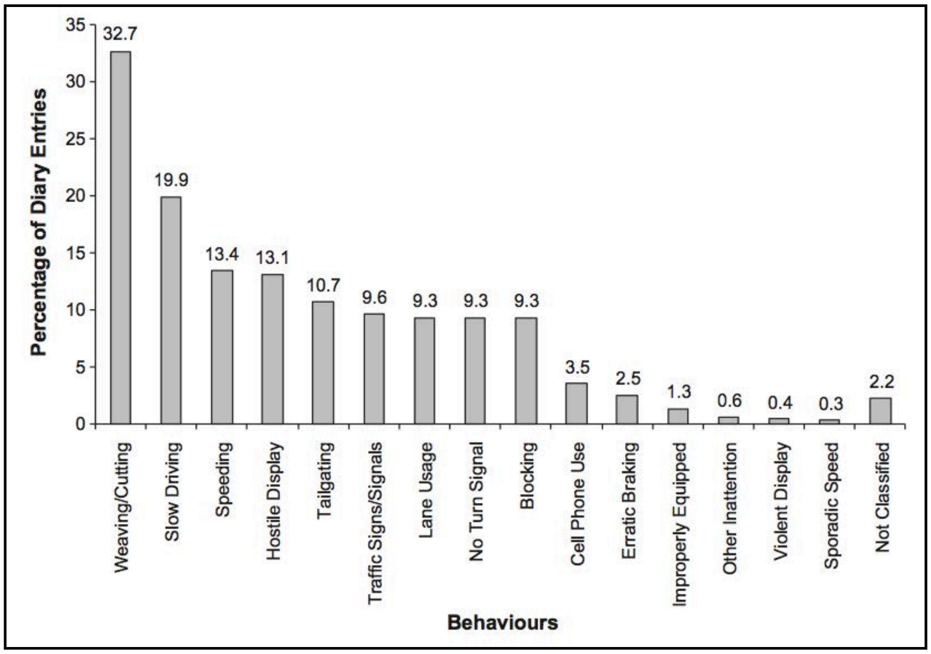


Figure 2: Percentage of diary entries involving each type of driver behavior (n=689) ***(18)*****.**

Another important driving behavior to point out is blocking because it has a particular importance to this thesis. Based on Figure 2, blocking was found to be the 9th most frequently reported driving behavior with 9.3%. To help gain a better understanding of the degree in which a violation was perceived, drivers were asked to rank the aggressive acts as either critical "(the entry was identified as the most negative and distressing)" or non-critical "(the act was not as aggressive) *(18)*." In Figure 3, below, the percentage of critical and non-critical event diary entries can be seen.

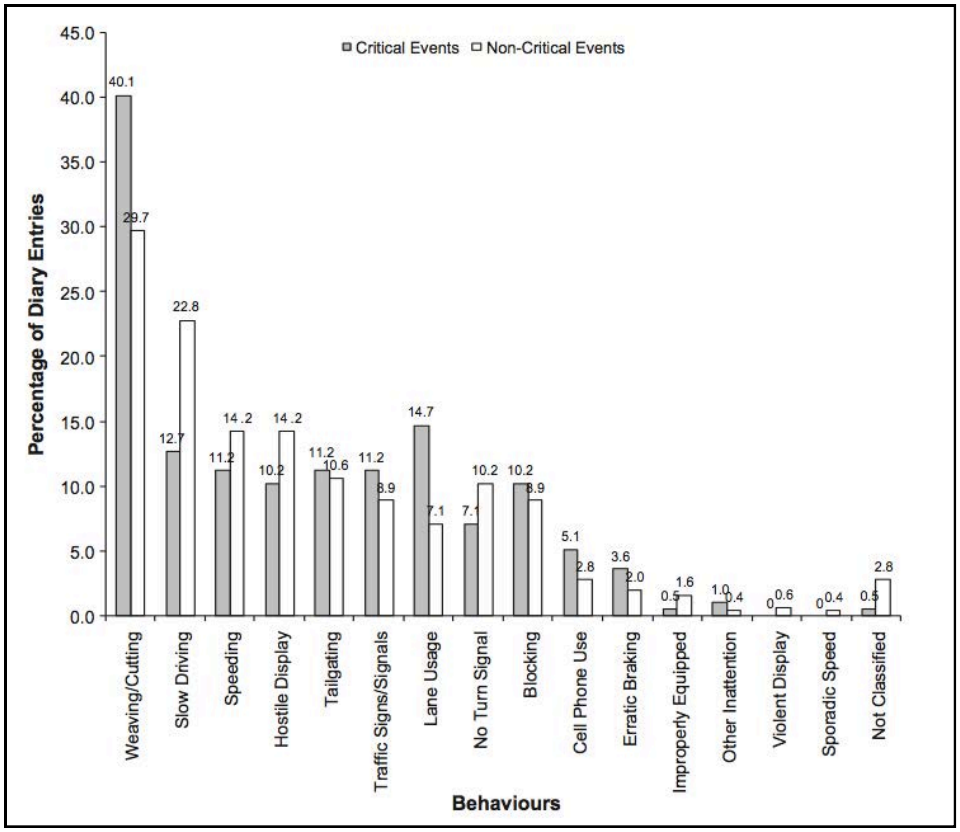


Figure 3: Percentage of critical (n = 197) and non-critical (n = 492) event diary entries involving each type of driver behavior *(18)*.

Referring to Figure 3, blocking was reported by drivers 10.2% in critical diary entries and 8.9% in non-critical diary entries. As discussed previously, drivers can become infuriated by gridlock and Wickens et al. confirmed this in their analysis of a mean anger rating associated with behaviors *(18)*. After reviewing the mean anger ratings, the driver behavior of blocking was found to be a significant contributor to aggression in drivers. Wickens et al. also looked into the percentage of offensive driving behaviors reported in critical event diary entries involving each type of perceived cause *(18)*. Continuing with the focus on the driving behavior of blocking, Wickens et al. determined that 15% of the time blocking was reported was because of retaliation or time urgency, and 25% of of the time blocking was reported was because of negligence *(18)*.

2.2.4 Gridlock's Impact of Air Quality

Congestion that is caused by increased traffic volumes Effects mobility of travelers, the air quality of surrounding communities and can lead to the increase vehicle emissions, such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), particulate matter (PM) *(19)*. Sjodin et al. observed that CO and NOx emissions increased by 2 to 3 percent in congestion when compared to uncontested conditions *(20)*. In addition, Frey at al. found a 50% increase in emissions during congestion *(21)*. In 2012, the CO_2 produced during congestion in the USA was 2.9 billions of pounds, with Atlanta contributing 1.3 million pounds of CO_2 to the Nation's total *(6)*. Vehicle emissions, like CO_2, are spurred by the changing driving patterns observed during congestion. For instance, the starting and stopping of a vehicle creates a "diminishment of dispersion of vehicle related pollutants since induced turbulence depends on vehicle speed *(22)*."

Decreases in air quality present negative externalities on organizations such as BIDs. As the level of congestion increase within a community, the pollution levels directly related to vehicle pollutants reduce the livability or attractiveness of an area. As a result, limiting business returns *(13)*. The effect of traffic pollutants can also present challenges for entire regions. In 1999, Atlanta lost their federal highway funding because they failed to meet the Federal Air Standards.

Exposure to traffic related pollution is also associated with a wide variety of health effects *(23)*. Kim et al. found associations between respiratory symptoms and traffic related pollutants *(24)*. Zhang and Batternman confirmed that health risks from congestion are potentially significant and that additional traffic can considerably increase risks, depending on the type of road and other factors *(19)*. For example, arterial roads showed that health risks increased sharply for both on and near road populations as traffic increased, including individuals living or working near roads *(22)*.

Traffic management strategies have also shown to be a successful approach to help reduce to traffic related pollutants. For example, a emission dispersion model conducted before and after the Congestion Charging Scheme (CCS) in London was installed, a localized scheme targeting traffic congestion, showed the CCS to have modest impact on air pollution levels and life expectancy *(25)*.

The next section presents methods to prevent gridlock and the externalities presented in this pervious subsections within this section.

2.3. Box Junction

There are several methods that can be used to help prevent gridlock: retiming signals, move minor crashes from the main road, promote transit use, move police encounters off the main road, or install box junctions. Operational treatments have shown to have a substantial impact on not only the USA but also Atlanta, who is ranked 11th in the USA in terms of money saved by operational treatments *(6)*. According to the 2012 Mobility Report, operational treatments yearly travel delay saved was $374 million and yearly congestion costs saved was $8.5 billion *(6)*. As stated previously, traffic congestion has negative effect on the surrounding businesses, in particular BIDs. As a result, it is possible that BIDs may be willing to cooperate with government agencies or may cooperate with each other to mitigate traffic congestion, and, thereby reduce the negative effects of traffic congestion *(26)*.

For the purpose of this thesis, box junctions will be the main focus of a traffic management alternative for BIDs. In no way is this thesis saying box junctions will completely alleviate traffic congestion. This thesis will try to confirm if box junctions can help lead BIDs on a path that will correct their traffic congestion problems. There are no silver bullets for traffic congestion relief. However, box junctions is one way, out of many, that can help reduce traffic congestion.

The premises of a box junction is to control traffic operations by painting a boundary of a box within an intersection. An example of a box junction in Manhattan can be seen in Figure 4 below. The rules of the box junction are simple, if a vehicle is inside the box when the opposing movement has the right of way the vehicle is in violation and is subject to a ticket. The primary advantage of installing a box junction is that the intersection should remain clear, even if one approach has large queues. By containing the larger queues the surrounding intersections should not experience unnecessary congestion.

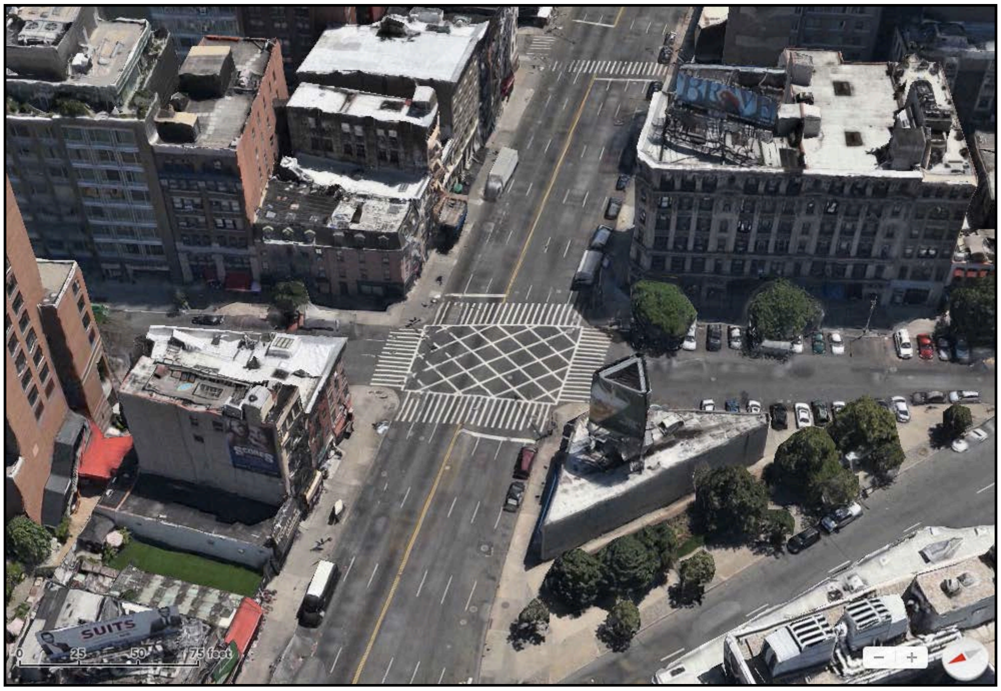


Figure 4: Box Junction on Canal Street in Manhattan *(27)*.

The process of installing a junction box is also straightforward. First, an outline of a box is painted inside the intersection in accordance with the standards in the Manual on Uniform Traffic Control Devices (MUTCD). The visual of the painted box allows a driver to understand where they should not be once their signal phase is complete. To enhance the visual appearance of the box junction there are different designs, shown in Figure 5, that can be painted inside the box, such as hash marks (option C), the words "Do Not Block" (option B), or a giant "X" (option C) *(28)*. To further reinforce the box junction, the United Kingdom's Transport for London has painted the box junction's boundaries yellow. In a survey conducted by Houldin et al., 95% of United Kingdom driver respondents knew what a box junctions was and said it was easy to notice because of the yellow paint *(29)*. Signs, as the one seen in Figure 6 below, are also placed before and around an intersection to inform drivers that the intersection has a box junction. The signs usually state "Don't Block Intersection" or "Don't Block the Box." In some cases, signs are installed without the box junction's boundaries being painted in the intersection. For example, the European Union defines their box junction as the area inside the intersection, whether the outline of the box (option A in Figure 5) is marked clearly or not.

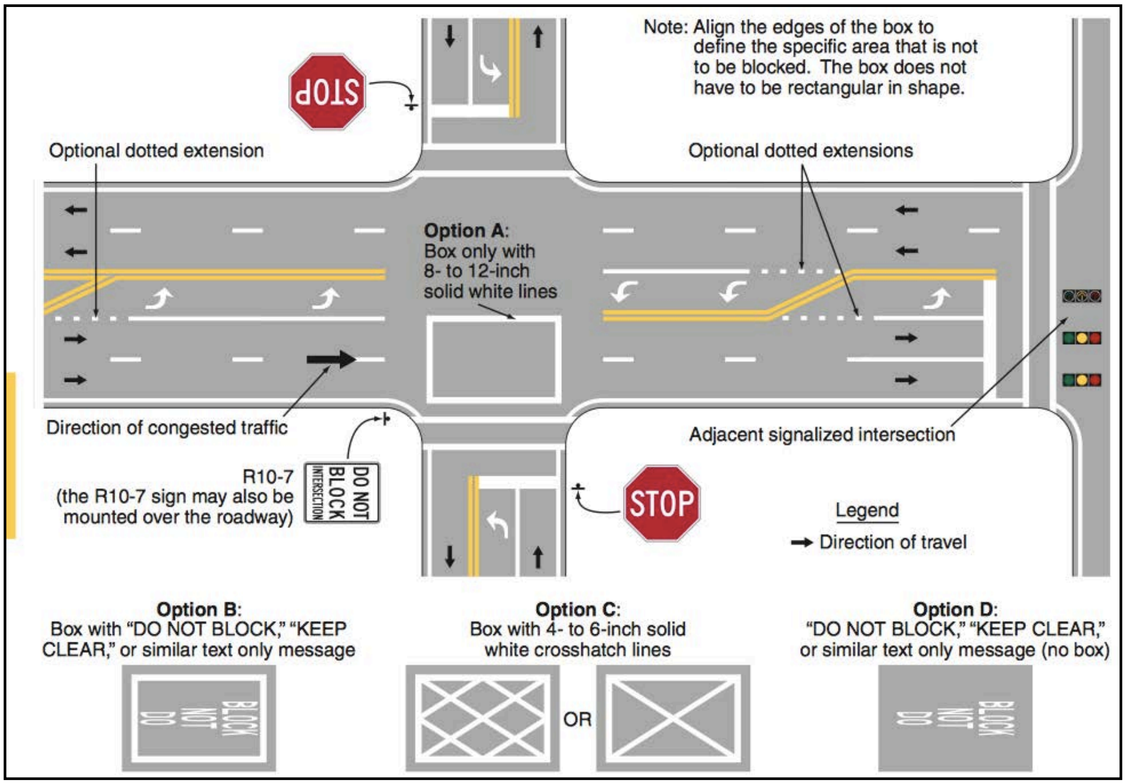


Figure 5: MUTCD standards for box junctions *(28)*.

Figure 6: An example of a Don't Block the Box sign *(30)*.

2.3.1. History

The first box junction was installed in London in 1964 and was regarded as being successful *(31)*. Not long after the first installations of the box junctions the idea spread to different countries. First, countries with close ties to the United Kingdom, including Canada, Australia, Ireland, and New Zealand, started utilizing the traffic control tactic. Later countries in the current European Union, South Africa, Hong Kong, Singapore, Russia, Taiwan, Malaysia, and Brazil took advantage of box junctions.

As for the United States, box junctions did not appear until 1971. A television editorialist by the name of Bill Wilt saw the box junctions in a London video feed and decided they were interesting enough to do an editorial on them *(32)*. The day after the editorial was released, the New York City Department of Transportation commissioner called Mr. Wilt and asked him to bring a camera crew to the intersections of 6th & 50th, 5th & 49th, and a few more near the 59th street bridge *(32)*. When Mr. Wilt showed up, there were workers in the process of painting box junctions in the previously stated intersections. Mr. Wilt later found out that these intersections were chosen by the commissioner because they were deemed to have the most problems with gridlock. After some time, Mr. Wilt did a follow up editorial on the box junctions and found that they showed improvements in the traffic operations *(32)*.

During the 1980's, the DBTB campaign became increasingly popular in New York City. With congestion getting worse the Mayor and Transportation Commissioner of New York City decided to install box junctions, which they referred to as "antigridlock boxes", at 10 more intersections near in Manhattan *(32)*. In conjunction with the new boxes, there were several multicolor signs placed around the intersections that read: "Fight Gridlock! Don't Block the Box!" *(32)*. With the DBTB campaigns in New York City showing to be successful, other cities in the United States began to adopt the idea. As of today, the District of Columbia and the Cities of Boston and Miami have shown to be the most progressive with box junctions. One reason Miami and Boston's DBTB campaigns have been successful is because there have been major strides in public and private partnerships. One of the most critical aspects of box junctions is to make sure the City government, DOTs, police department, and private business are on the same page. With all these entities working together they not only make their surrounding community a better place, but they make the process of installing and maintaining a box junction easier.

In the case of Miami, the police department, City government, and private businesses got together and created the Meeting our Vehicular Needs (MOVN) committee. The Miami DBTB campaign was successful because everybody involved to so adamant on fixing the traffic issues in their community and they were also all willing to do their part to make it happen. As for Boston, the MASCO saw a life threatening situation in their community, the Boston's Longwood Medical and Academic Area (LMA). The intersections around MASCO's community is composed of hospitals and the emergency vehicles were being delayed because of gridlock. Knowing that every second counts for a patient, MASCO, the City of Boston, and the Boston police department collaborated to set up box junctions. It has been found that the DBTB campaign in the LMA has shown a 50% decrease in the amount of intersection blocking *(33)*. The effectiveness of this DBTB campaign will be further explored in 2.4.3.6.- Effectiveness.

2.3.2. Cost

As previously stated, DBTB campaigns are usually paid for by either private organizations, local transportation jurisdictions, or as a collaboration of both. The cost of a DBTB campaign can be broken into two parts: the installation of pavement markings and the signs. The cost of the actual pavement marking or sign is minimal when compared to the cost of the crews that are designated to install the box junction and signs. Based on phone interviews with MASCO, the City of Sandy Springs, and MOVN the average cost for a DBTB intersection is between $1,100 and $1,800.

Additional cost can arise with DBTB campaigns. Maintenance is always a cost that must be kept in mind. Fortunately, pavement markings and signs have an extended life cycle. Depending on the geographical location, the cost of maintaining pavement marking and signs should be $1,100 to $1,800 every 20 years. Additionally, some organizations install light emitting diode (LED) signs above certain lanes to catch driver's attention. Depending on the type and size of the LED sign the cost can be between $1,500 and $10,000 *(34)*. Perhaps the most costly component of a DBTB campaign is enforcement. Officers or parking attendants must be paid to enforce the DBTB campaign. The average annual salary for an officer to enforce box junctions could cost around $26,000 per officer *(1)*. In some cases, automated enforcement is used to monitor box junctions and according to the phone interview with the MPD this can cost between $65,000 to $140,000 per installation.

2.3.3. Enforcement

One of the major components of box junctions is the way in which they are enforced. The City of Sandy Springs in Georgia is an example of a city that does not use any type of enforcement for their box junction. Since the junction boxes are located in a residential neighborhood, the City of Sandy Springs relies on its citizens to follow the rules of the box junctions. In most other instances, the use of enforcement from the police department or parking services have been used because the boxes are located in congested environments and tourist hotspots.

2.3.3.1. Current Blocking Laws

In order to provide enforcement, there needs to be a law set in place to allow police officers the ability to give tickets to drivers who "Block the Box." Within the traffic codes that have been established in every state and the District of Columbia, there are three sets of laws in place that provide a police officer the ability to ticket a box violator *(36)*. The first law explicitly states that a driver should not enter an intersection without obstructing other movements. An example of this law is provided by the 2013 Georgia Code 40-6-205;

> "No driver shall enter an intersection unless there is sufficient space on the other side of the intersection to accommodate the vehicle he is operating without obstructing the passage of other vehicles or pedestrians, notwithstanding any traffic-control signal indication to proceed *(35)*."

The next law a police officer can use to ticket a blocking violator states that a driver shall not stop in an intersection. An example of this law is under the 2013 revised Code of Washington 46.61.570 - Stopping, standing or parking prohibited in specified places;

> "(1) Except when necessary to avoid conflict with other traffic, or in compliance with law or the directions of a police officer or official traffic control device, no person shall:

(a) Stop, stand, or park a vehicle:

(iii) Within an intersection; *(36)*"

Under some State's traffic codes, there is an addition to the second law presented in this text. The addition states that a driver cannot stop in any place where a sign prohibits it. An example of this addition is under the the 2013 Minnesota Statute 169.34 Prohibitions; Stopping, Parking;

"Subdivision 1. Prohibitions. (a) No person shall stop, stand, or park a vehicle, except when necessary to avoid conflict with other traffic or in compliance with the directions of a police officer or traffic-control device, in any of the following places:

(15) at any place where official signs prohibit stopping *(37)*."

Table 1 below presents a summary of which states, together with the District of Columbia, have the three laws identified above.

Table 1: Summary of blocking laws for every state, including the District of Columbia *(38)*.

State	Obstructing Law	Stopping Law	Sign Law
Alabama	✓	✓	✓
Alaska	✓		
Arizona		✓	✓
Arkansas		✓	✓
California	✓	✓	✓
Colorado	✓	✓	✓
Connecticut			
Delaware	✓	✓	
District of Columbia	✓	✓	
Florida	✓	✓	

State	Obstructing Law	Stopping Law	Sign Law
Georgia	✓	✓	✓
Hawaii	✓	✓	✓
Idaho	✓	✓	
Illinois		✓	✓
Indiana			
Iowa			
Kansas		✓	✓
Kentucky			
Louisiana		✓	✓
Maine			
Maryland		✓	✓
Massachusetts			
Michigan	✓	✓	
Minnesota	✓	✓	✓
Mississippi		✓	✓
Missouri	✓		
Montana		✓	
Nebraska		✓	✓
Nevada	✓	✓	
New Hampshire		✓	✓
New Jersey	✓		
New Mexico		✓	✓
New York	✓	✓	
North Carolina	✓		
North Dakota	✓	✓	✓
Ohio	✓	✓	✓
Oklahoma		✓	✓
Oregon	✓	✓	
Pennsylvania	✓	✓	✓
Rhode Island		✓	✓
South Carolina	✓	✓	
South Dakota		✓	✓
Tennessee		✓	✓
Texas		✓	✓

State	Obstructing Law	Stopping Law	Sign Law
Utah	✓		
Vermont		✓	✓
Virginia	✓		
Washington	✓	✓	✓
West Virginia		✓	✓
Wisconsin			
Wyoming		✓	✓

It is important to note that the laws described above are state laws and not city laws. A city can pass a traffic regulation concerning the obstruction of intersection without a state law stating the same matter. For example, Massachusetts traffic codes did not have a law that stated anything about obstructing, stopping, or following the direction of signage to stop in an intersection. However, the Traffic Rules and Regulation for the City of Boston does have an obstructing an intersection law in place *(39)*. As for enforcement in other countries, laws similar to the previously stated United States laws can be found in New Zealand, the United Kingdom, and Russia *(40, 41, 42)*.

2.3.3.2. Moving Versus Non-Moving Violations

The act of blocking an intersection can be seen as a moving or non-moving violation. In general, the law that prohibits obstructing an intersection is classified as a moving violation because the vehicle is in gear. However, some cities, such as New York City, have reclassified the blocking law as a non-moving violation for the sole reason of allowing parking attendants the ability to ticket blocking violators. With parking attendants being able to ticket blockers, it increases the number of enforcers which allows police officers to tend to more pressing matters. Recently, there has been a shift from police officers and parking attendants giving out tickets to automated enforcement.

2.3.3.3. Automated Enforcement

Due to its potential safety and economic benefits, automated enforcement has gained popularly with city governments and department of transportations. London and Washington D.C. are the leaders in automated gridlock enforcement. By using automated enforcement, there is no longer a need for an actual person to be present inside an intersection in order to give tickets. This provides a safety benefit because intersections are dangerous places for people to stand in during peak hours of traffic. Automated gridlock cameras have a large upfront cost of approximately $65 to $140 thousand (depending on vendor and camera type). However, cities or organizations will save money in the long run. The cities of London and Washington D.C have been the leaders in this department.

The Washington D.C. Metropolitan Police Department (MPD) started the DC StreetSafe initiative in late 2013. Within the DC StreetSafe initiative, there is a focus on gridlock and blocking intersections. The MPD chose 20 intersections, shown in Figure 7 below, that showed to provide the greatest cost to the City in terms of pollution and commuting cost *(43)*. London has been using closed circuit television (CCTV) cameras to catch blocking violators for the past several years. In heavily congested areas, the automated enforcement of box junctions catches on average 100 drivers each day, which amounts to an average of 40,000 drivers each year that "block the box" *(44)*. According to the Transport of London, the number of drivers caught within the box junction was three to five times higher than previous years without automated enforcement *(45)*.

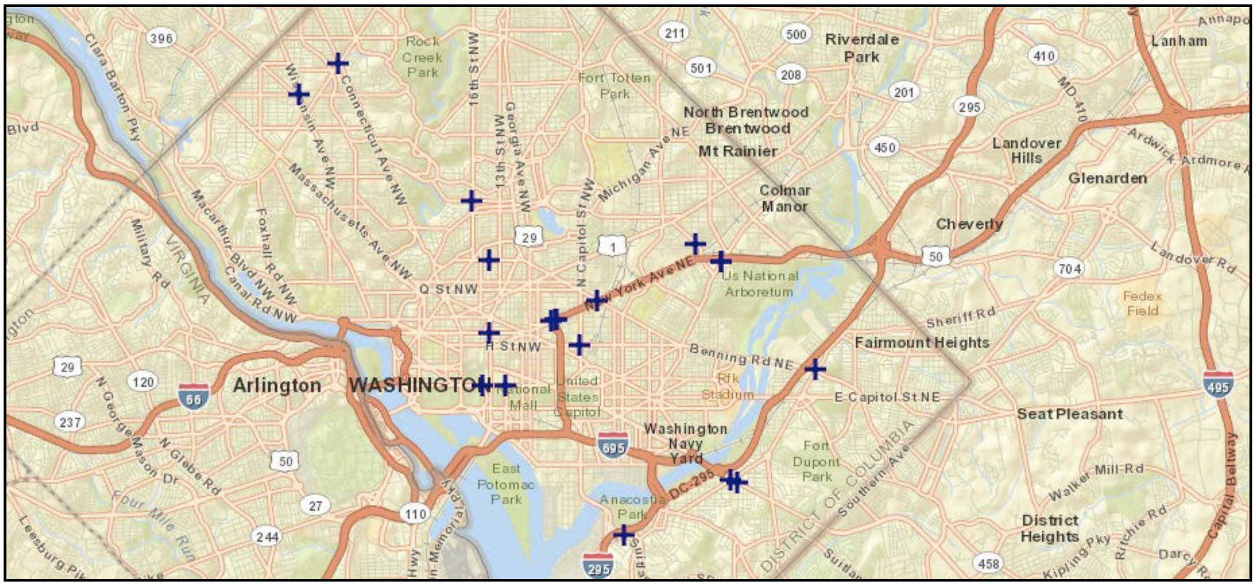


Figure 7: Locations of MPD Gridlock Cameras in Washington D.C. ***(43)*****.**

<u>2.3.3.4. Public Education Campaigns</u>

Once a law is set in place, there needs to be a way to inform the public. A common method to notify citizens about the box junctions is the utilization of public education campaigns. One of the first public education campaigns in the United States was in 1986. New York City department of transportation awarded drivers that showed the capability to not “Block the Box” with tokens, bumper stickers, lapel pins, and T-shirts that read, “Gridlock Busters - Don’t Block the Box” *(32)*. Other methods of notifying the public were television commercials, billboards, and pamphlets. With the current advancements in technology, there have also been improvements in public education campaigns.

The smartphone has provided a way for alerts and messages to be sent directly to a driver. Also, the computer has allowed an informative way to pass along information. Website, social media, and emails can be used to let the public know of a new blocking law. Perhaps the best way to enlighten the public is by example. The MOVN organization provides the public with a 30 day public education campaign on the law of DBTB. Once the campaign is finished, there is an increase in enforcement at intersections that showed the most problems with gridlock. This way other drivers can see the consequences of breaking the obstruction of the intersection law. It has been noted by the MOVN organization that this tactic works so well that there is a decline in box violators for several months. Once the violations start to increase MOVN starts the enforcement campaign again.

2.3.3.5. Penalty

While enforcement of the obstructing and blocking laws is critical to the effectiveness of box junctions, there also needs to a sufficient penalty to convince drivers not to stop within the intersection. If the penalty is not severe enough, drivers will continue to “Block the Box” because they might believe the fine is worth the risk of getting caught. For example, the City of Toronto’s fine for obstructing an intersection is $40 and there is much discussion to increase this fine because drivers feel the fine is worth the risk *(46)*. In 1981, the fine for “blocking the box” was set at $25. Calculating for inflation, the 1981 fine of $25 is roughly $64 in today’s monetary standards *(32)*. Currently the fine for obstructing an intersection is $115 in New York City and the fine could increase to $300 if taken to court *(47)*. In Miami, the fine is $179 which can be increased up to $500 if taken to court. Boston’s fine is $150 and Washington D.C.’s fine is in the range of $50 and $250 *(48)*. As for the London, the fines are within the range of £60 and £130 *(44)*.

To increase the severity of the penalty for “Blocking the Box” many cities have added the penalization of points on a driver’s license. The added points on a driver’s license cause insurance rates to increase, which impacts the driver in the long term when compared to a one time fine. When the City of New York started its Gridlock Busters campaign in the 1980’s the signs stated that box violations would incur 2 points being added to your license. Over time New York City has changed its stance on adding points on driver’s license for drivers caught in box junctions. As of 2009, the blocking violation can be ticketed as a moving violation, with 2 points being added to a driver's license, or a non-moving violation, with no points being added to a driver license. Other cities, such as Miami will add 3 points to a driver's license to make sure drivers have incentive to not "Block the Box."

2.3.3.6. Effectiveness

During the literature review for DBTB there was only one study found that conducted an analysis from June 2012 to March 2013 on the effectiveness of a DBTB campaign. MASCO hired an engineering consultant to compare traffic operations before and after an extensive enforcement campaign was conducted. Four intersections out of the 15 intersections in the LMA were included in the study. The four intersections were observed on typical weekdays from 8:00 to 9:00 A.M. and 5:00 to 6:00 P.M. *(49)*. Within this study a vehicle blocking the intersection was defined as a vehicle stopping anywhere inside the intersection or on top of a crosswalk.

The total number of violations (blocking of the intersection and crosswalks) and the total number of vehicles blocking the intersection was recorded. In conclusion, this report found that the total violations observed, for morning and afternoon peak, for all four intersections decreased a 22% to 64% after the enforcement campaign was conducted *(49)*. The report also found that the observed number of vehicles blocking the intersection, for the morning and afternoon peak, for all four intersections decreased 13% to 63% *(49)*. In summary, the DBTB campaign established by MASCO in Boston reduced the number of vehicles blocking the intersections by half.

CHAPTER 3

DESIGN OF PROJECT

3.1. Introduction

This chapter discusses the design process for the DBTB data collection and the DBTB survey. Once the intersections have been selected, blocking data was examined through a series of deployments using two different data collection methods: High definition video cameras onsite and GDOT PTZ cameras video feeds. The primary goals of the blocking data were to count the number of blocks, understand where the blockers where coming from and going to, and the duration of the blocks. The DBTB survey was constructed to analyze the current state of DBTB campaigns across the United States. The main objective of the survey is to provide further guidance regarding how DBTB campaigns can be used as an economical alternative for traffic management.

3.2. Don’t Block the Box Data Collection

The DBTB data collection can be divided into five parts: site selection, what data will be collected, time of day and period of time to collect data, how data will be collected, and deployment procedure for each intersection.

3.2.1. Site Selection

The selection of the intersection for this project was confined to three locations, the BCID, Sandy Springs, and Midtown. These locations can be seen in relation to the center of Atlanta, Georgia in Figure 8 below.

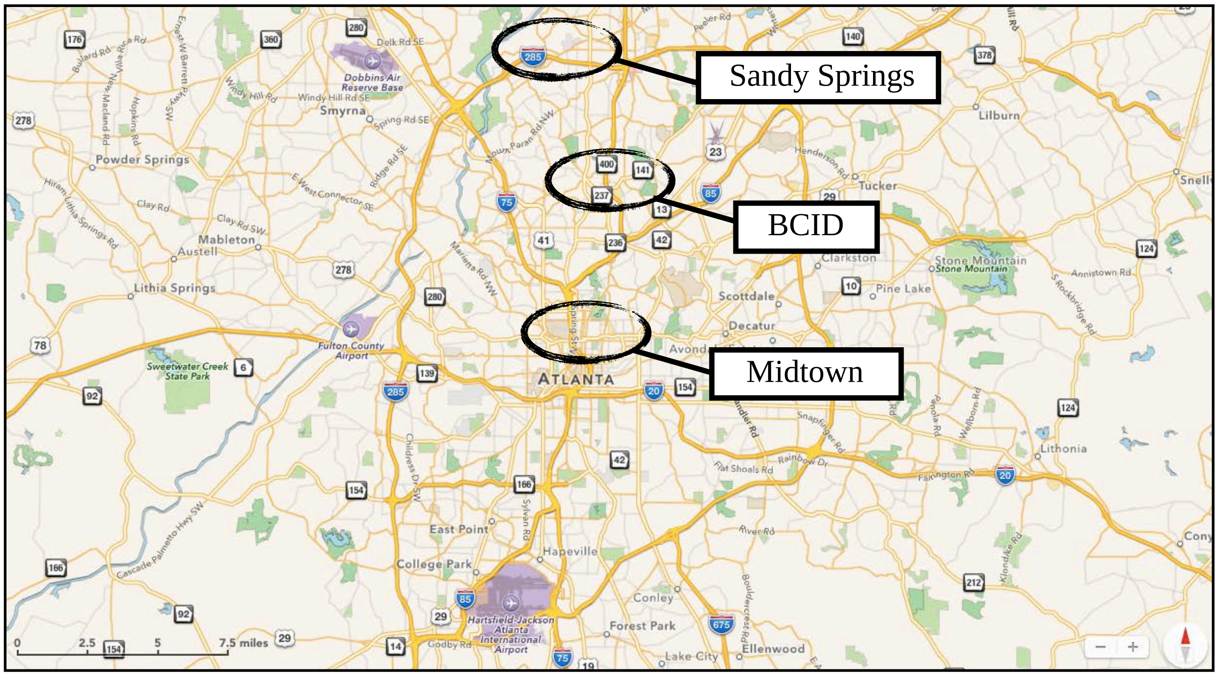


Figure 8: The three locations considered for DBTB data collection *(27)*.

3.2.1.1. Buckhead Community Improvement District

Since this project is a part of a larger University Transportation Center (UTC) project with the BCID, the initial set of candidate intersections were confined to the boundary of the BCID, seen in Figure 9 below. Each intersection within the BCID boundary was considered for DBTB data collection by going through a series evaluations. First, the traffic patterns for each intersection were observed during the morning (7:00 A.M. to 9:00 A.M.) and evening peak hours (5:00 P.M. to 7:00 P.M.), the most likely periods for intersection blocking. The main objectives during the observations of the traffic patterns were to ensure that high volumes were present and several instances of vehicles blocking the opposite approach were recorded. The traffic patterns were analyzed using GDOT PTZ cameras and onsite visits. Each intersection was observed each day during a span of three weeks. If this set criteria was met, the intersection moved on to phase two of the intersection selection evaluation. Phase 2 consisted of checking to see if the intersection had a GDOT PTZ camera. If the intersection met the criteria for both phases it was

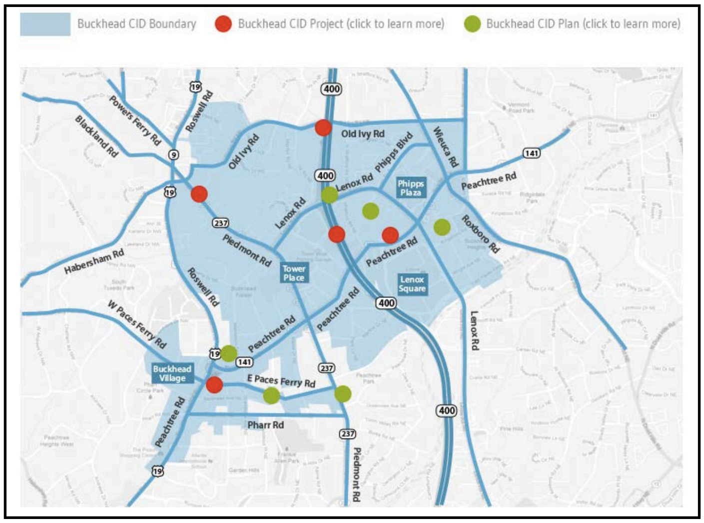


Figure 9: BCID boundary *(50)*.

selected for DBTB data collection. The intersections chosen for the BCID are 1.) Peachtree Road & Mathieson Drive, 2.) Peachtree Road & Piedmont Road, 3.) Peachtree Road & Highland Drive, 4.) Peachtree Road & Stratford Road, and 5.) Peachtree Road & Lenox Mall entrance. Figure 10 below shows the location of each intersection in Buckhead, Georgia.

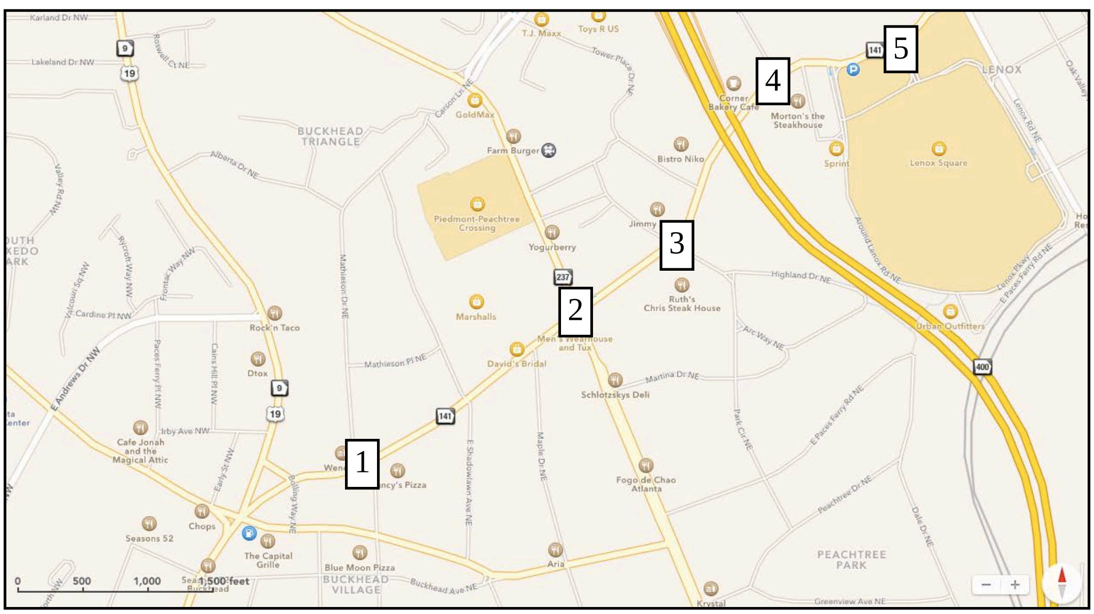


Figure 10: BCID DBTB data collection intersections along Peachtree Road *(27)*.

3.2.1.2. Sandy Springs

The City of Sandy Springs was selected as a DBTB data collection location because they currently have the only box junctions in Atlanta, Georgia. Since this location already has several box junctions, there was no need to go through the same criteria as the other locations. However, this location does not have PTZ cameras. As a result, the time and resources needed to collect DBTB data limited the number of intersections that could be studied to one. The intersection of Riverside Drive & Heards Ferry Road was selected after several site visits to each box junction. This intersection presented several advantages, including, the highest traffic volumes, adequate HD camera setup locations, and the intersection had an acceptable geometry. Figure 11 below shows the location of the intersection circled in Sandy Springs.

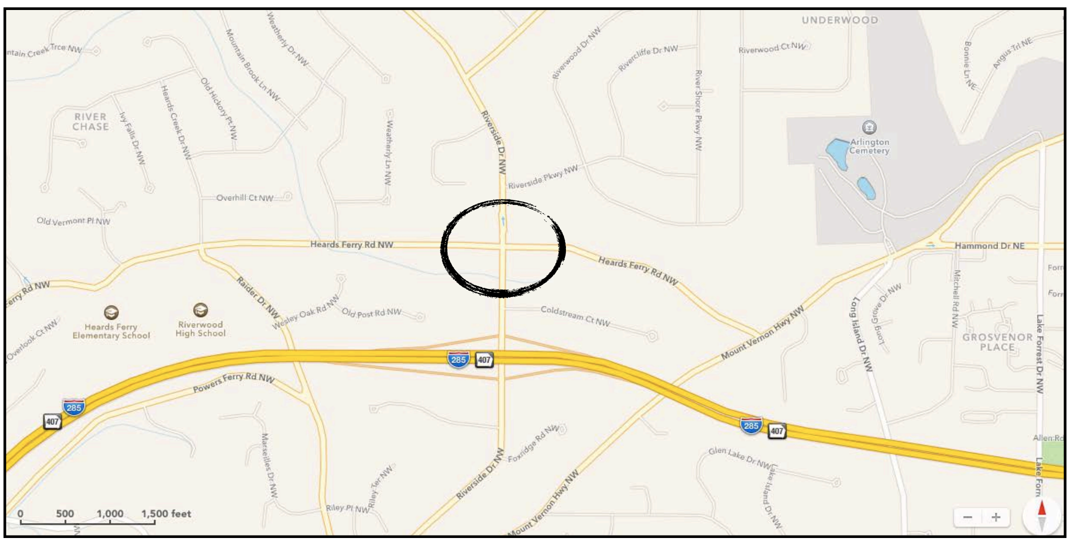


Figure 11: Sandy Springs DBTB data collection intersection location *(27)*.

3.2.1.3. Midtown

A DBTB data collection location in Midtown Atlanta was proposed because of its close proximity to Georgia Tech and high volume levels. Several intersection were examined, including Peachtree Road & 17th Street, Ponce de Leon Avenue & Piedmont Road, North Avenue & West Peachtree Street, and 10th Street & Williams Street. The same process and criteria used in selecting BCID intersection locations were used at the Midtown location. After several site visits and monitoring on GDOT PTZ cameras, if applicable, it was determined that the intersection of 10th Street & Williams Street was the best choice.

The reason this intersection was selected was the high volume of blocking observed during each site visit. Also, since this intersection is located along the interstate of 75/85, it presented a unique safety concern. The blocking that occurred blocked the approach of the 75/85 Southbound off ramps, causing vehicles to queue back into the interstate, presenting potential safety issues. A disadvantage of this intersection is that it did not have a PTZ camera. However, in this case, the benefits outweighed this disadvantage. It must be noted that the other intersections considered, excluding Ponce de Leon & Piedmont Road, displayed a great deal of blocking. Figure 12 below shows the location of the intersection circled in Midtown Atlanta.

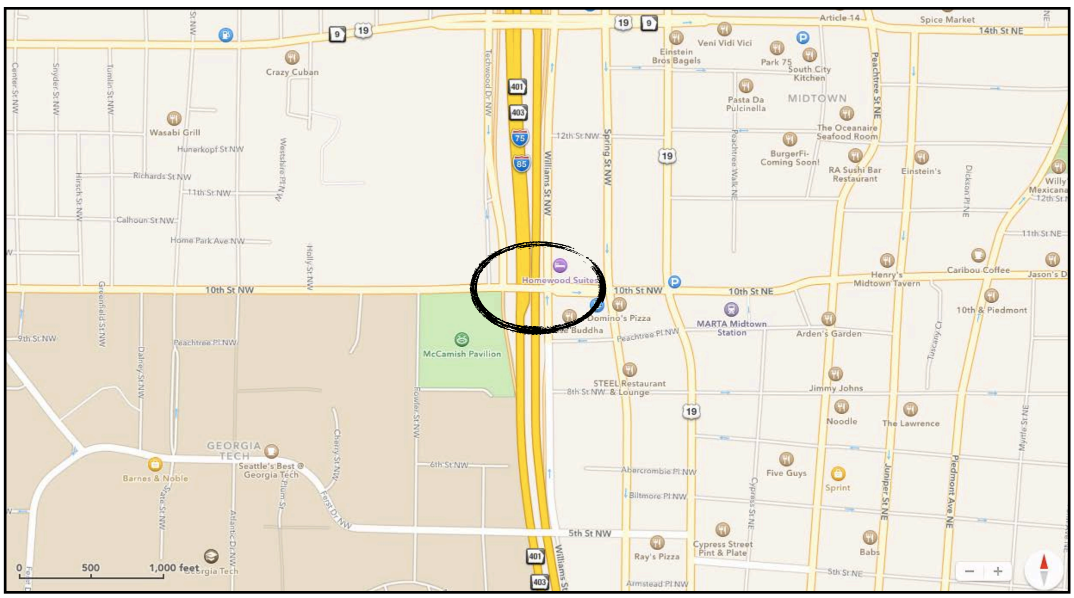


Figure 12: Midtown Atlanta DBTB data collection intersection location *(27)*.

3.2.2. Don't Block the Box Data to be Collected

Once the intersections were chosen for each location, the type of data needed was then determined. Initial data collection was concerned with the number of blocking events, movements blocked in each event, and the length of time of each blocking event over the data collection period, for instance, at peak hour. For this collection, the entry and exit location of each blocker are recorded. A timestamp for the beginning and end of the blocking event are also needed to determine how long the block occurred and how much green time is potentially being wasted. The movement being blocked was also recorded. Another important piece of data is the signal timing data for each data collection session.

3.2.3. Data Collection Time Frame

During the traffic pattern observations conducted throughout the intersection selection process, it was observed that the evening peak hour had the most blocking activity. Through site visits and monitoring of the PTZ cameras, this time frame was set to 4:30 P.M. to 6:30 P.M. as this period was observed to have the highest likelihood of blocking.

3.2.4. How Don't Block the Box Data will be Collected

DBTB data was collected by either high definition cameras onsite or PTZ cameras on existing infrastructure. PTZ cameras were considered the first choice for data collection because multiple intersections could be recorded at the same time. Due to the absence of PTZ cameras at the intersections in Midtown and Sandy Springs, high definition cameras were used to collect blocking data. The intersections within the BCID used PTZ cameras. Once the two hour video clips were recorded for each intersection, they were stored on a data server at Georgia Tech. Each video was then processed to extract essential blocking data components. Details on the data processing is presented in Chapter 4 - Data Processing Methodology.

3.2.5. Deployment Procedures

3.2.5.1. Buckhead Improvement District’s Intersections

As stated previously, the BCID’s intersection used GDOT PTZ cameras to record DBTB data. The GDOT PTZ cameras were accessed using the Geogria Navigator system on a virtual client on a secure Georgia Tech server. Figure 13 below shows a screenshot from the Georgia Navigator system. Once the virtual client was accessed each intersection within the BCID could be viewed. Twenty minutes before 4:30 P.M. the cameras at each intersection were moved. However, since these cameras are also being used by the GDOT’s Traffic Management Center (TMC) and the BCID maintaining the appropriate views throughout the data collection period was difficult in some instances. Cameras could be moved during data collection by GDOT personnel, resulting in a loss of data for that day. At 6:30 P.M., the end of data collection, the cameras were moved back to their original setting.

During the last two weeks of the data collection, the project received permission to move the cameras with limited movement by the other transportation agencies. Presets for each intersection's PTZ were also created to make the process of data collection easier.

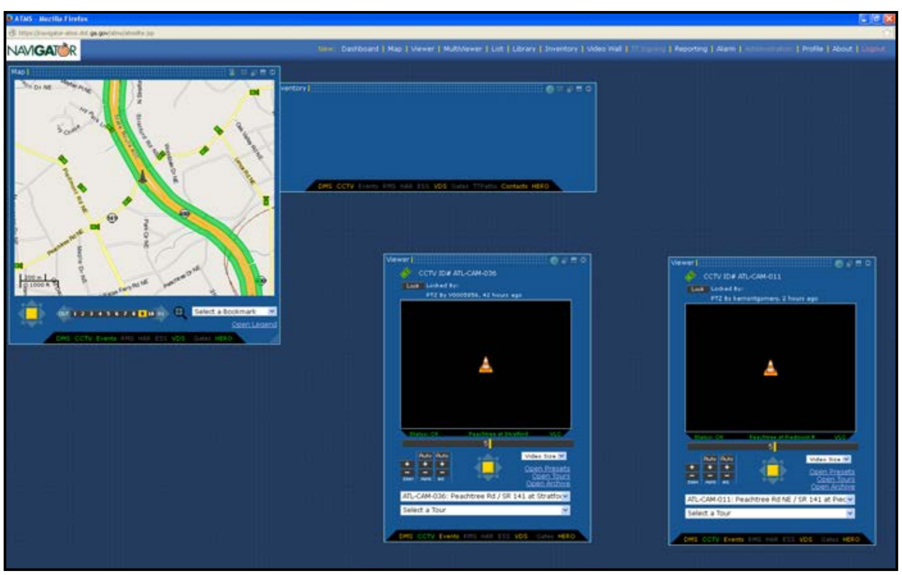


Figure 13: Georgia Navigator program.

3.2.5.2. Riverside Drive & Heards Ferry Road

High definition cameras were used at the intersection of Riverside Drive & Heards Ferry Road in Sandy Springs, Georgia. The cameras were placed on opposite sides of the intersection during the data collection time frame to capture the signal heads and the queues for the Northbound and Westbound approaches. The exact placement for each camera can be seen in Figure 14 below.

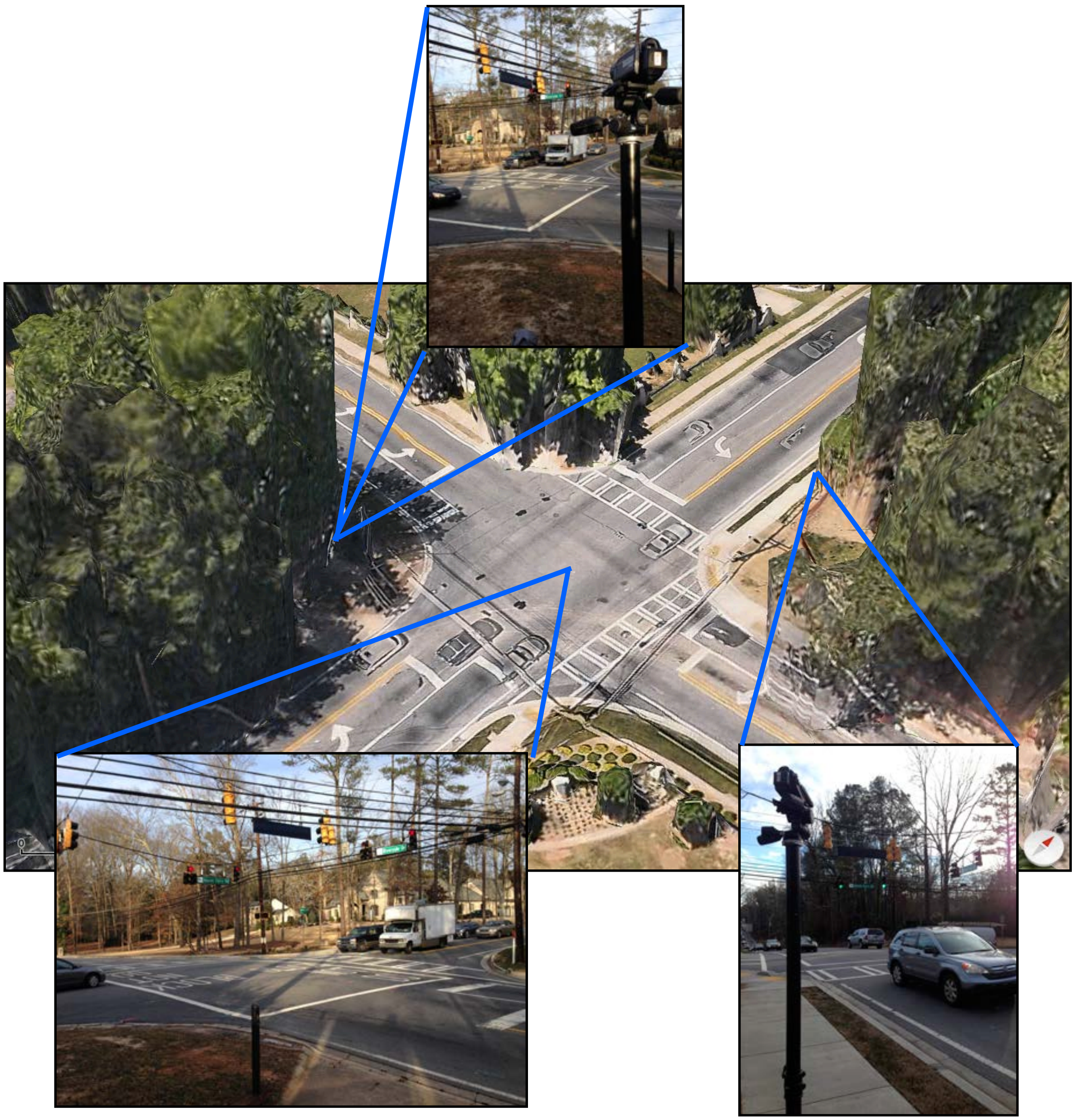


Figure 14: Sandy Springs's camera placements *(27 and 51)*.

3.2.5.3. 10th Street & Williams Street

High definition cameras were also used at the intersection of 10th Street and Williams Street. There was two deployment strategies taken for this intersection, video was recorded on the sidewalk at the intersection and in a window on the top floors of the Homewood Suites Hotel that is located in the Northeast quadrant of the intersection. The exact placement of the cameras at this intersection can be seen in Figure 15 below.

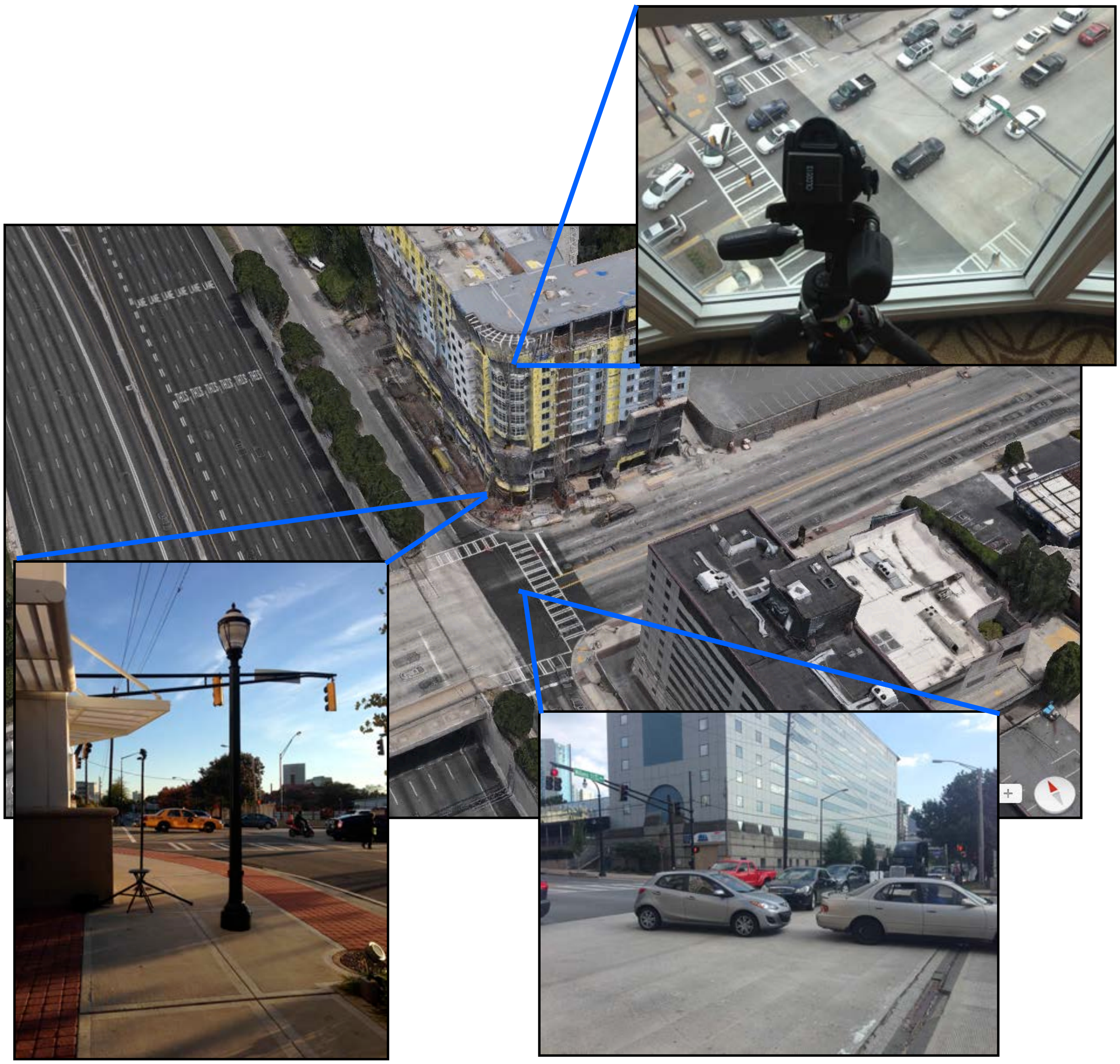


Figure 15: Midtowns's camera placements *(27 and 51)*.

3.3. Don’t Block the Box Survey Development

The DBTB survey attempted to determine the current level implementation of DBTB throughout the US, benefits and drawback as experienced by other agencies and potential barriers and lessons learned. If DBTB campaigns are proven to be a cost effective traffic management tool then cities around the nation can consider using it to reduce congestion.

3.3.1. Initial Framework

The DBTB survey started as a phone interview survey. Representatives from Miami, Boston, Sandy Springs, and Virginia Beach were contacted by phone and were asked a short list of questions. The introduction and questions used in the phone interviews are listed below.

3.3.1.1. Phone Interview Questions

Mr. or Mrs. XXXX,

My name is Samuel Harris. I am a transportation engineering graduate student at Georgia Tech and I was wondering if you could spare a couple of minutes to answer some questions I have. I am currently researching "Don't block the box campaigns around the United States and it would be helpful if you answer some questions I have regarding the "Don't block the box" campaign around the City of XXXX.

1. When did the campaign start?
2. What and who caused this campaign to start?
3. How hard was it to implement?
4. If so, how did you over come the hurdle?
5. What types of enforcement is in place?
    5.1. Cameras?
    5.2. Officers on foot or patrol car?
    5.3. Can parking enforcement give tickets (is it a non moving violation in Boston?

6. Are there tickets given out to violators?

    6.1. If so, how much is the fine and are points taken off drivers license?

7. Have you seen an improvement since the campaign started?

    7.1. If so, how much?

    7.2. If not, what can be done to make it better?

Based on the answers given by the participants new questions were developed. The questions are discussed more in the following section.

3.3.2. Drafting the Don't Block the Box Survey

After the literature review, additional research, and information learned from the phone interviews the DBTB survey was created. A survey by Maddox et al. was used as the primary template for the modified DBTB survey *(1)*. Maddox's survey was used to help organize the structure of the survey and formulate multiple questions. When possible, the questions within the survey were set up as yes or no questions. However, some questions required additional information, such as budgetary information and public education campaigns. In most cases, these questions were set as a conditional question based on the participant's previous answer. These questions always provided the option "Don't know".

3.4. Final Don't Block the Box Survey

The questions within the survey created in the previous section went through multiple drafts to create the final draft of the survey to ensure the questions were worded clearly to avoid confusion by participants. The duration of the final survey was designed to be between 5 and 15 minutes to encourage more participants to take the survey.

The final survey is divided into three sections: the first section collects information on organizations that currently have a DBTB campaign, the second section is for organizations that have considered implementing a DBTB campaign and chosen not to proceed, and last section of the survey is for organizations currently considering a DBTB campaign. The first section collected general information about the participants DBTB campaign, such as organization classification, expenditures, help establish potential benefits in traffic operations and safety, implementation challenges, partnerships, and which pavement makings were installed. If an organization considered implementing a DBTB campaign and stopped their pursuit the second part of the survey collects information on the reasons why the participant stopped their pursuit. The final part of the survey collected information, such as anticipated benefits and concerns, about participants interested in starting a DBTB survey. Data from the second and last part will support future improvements in DBTB campaigns for cities that do not currently take advantage of this cost effect traffic management tool.

The survey was created on SurveyMonkey to take advantage of their easy to use platform. The survey was tested multiple times to ensure the conditional questions worked correctly and that there were no issues with the survey. The study population inclusion for this survey was based on occupation. The occupations targeted were traffic engineers, public works employees, police officers, and city planners. These occupation were chosen because people in these occupations are expected to be the best informed regarding whether their city, company, or organization has interest in a DBTB Campaign. Once the target population was established, the survey was then sent out to variety of different organization classifications, including, city public works departments, police departments, TMAs, BIDs, and the phone survey participants. Multiple follow up surveys and emails were sent out to encourage participants to complete the survey. The organizations contacted to take the survey are listed in Appendix A. A copy of the final DBTB survey can be found in Appendix B.

CHAPTER 4

DATA PROCESSING METHODOLOGY

This chapter discusses the data processing methodology for the recorded videos that were collected for each intersection. The computer software program that was used in the initial analysis of the DBTB videos was a program developed in the School of Civil and Environmental Engineering at Georgia Tech called VideoAnalyzer. VideoAnalyzer was used to extract the entry point of blockers, exit point of blockers, start time of blocking, end time of blocking, and signal indication timestamps for each day of data collection.

4.1. Blocking the Box Defined

Vehicles that were considered blockers had to match the following requirements:

1. The vehicle must enter a predefined box within the intersection,
2. The vehicle must be stopped (or nearly stopped),
3. The vehicle must be blocking a conflicting approach (vehicle presence in the conflicting approach is not required), and
4. The conflicting approach that is being blocked must have a green indication.

4.2. VideoAnalyzer

The DBTB analysis consisted of two video data reduction phases and the data analysis. Initial video data reduction was conducted using the VideoAnalyzer tool, this was followed by video reduction for data that was unable to be obtained directly with the Video Analyzer tool, and finally analysis of the data. This section starts off by describing how the VideoAnalyzer tool was used to extract the initial blocking data, such as signal interval timestamps, entry cell of the blocker, start time of the block, exit cell of the blocker, and exit time of the block. After the collection of the initial data additional manual video reduction (phase two of data reduction) was conducted to assign the block ID, determine which approaches were blocked (if there was more than one lane on an approach a lane analysis was also conducted), verify the degree of each block, calculate the duration of each blocking session, process signal data, and fill in any missing information not produced by the VideoAnalyzer tool. These additional analyses were conducted by manually reviewing the videos processed by the VideoAnalyzer tool. Once this additional data was collected final analysis of the data such as temporal distribution of blocks, distribution of conflicting lane blocks, partial and full blocking analysis, pedestrian safety analysis, probability of a blocker changing lanes to stop blocking, driver characteristics (i.e. decisions on a driver either stopping at a stop bar and deciding whether to or not to enter an intersection to block), percent of green time with blocking, and lost capacity was completed.

4.2.1. Initial Data Extracted from VideoAnalyzer

This section describes, step-by-step, how to use the VideoAnalyzer program. The VideoAnalyzer was a custom program developed for this project by a separate graduate student team. The VideoAnalyzer software was used to extract the initial blocking data, such as signal interval timestamps, entry cell of the blocker, start time of the block, exit cell of blocker, and exit time of the block. Listed below are the steps that should be used to properly run the VideoAnalyzer program.

4.2.1.1. Step 1: Open the Program

Double click the VideoAnalyzer icon to start the program. A screenshot of this step is shown in Figure 16 below.

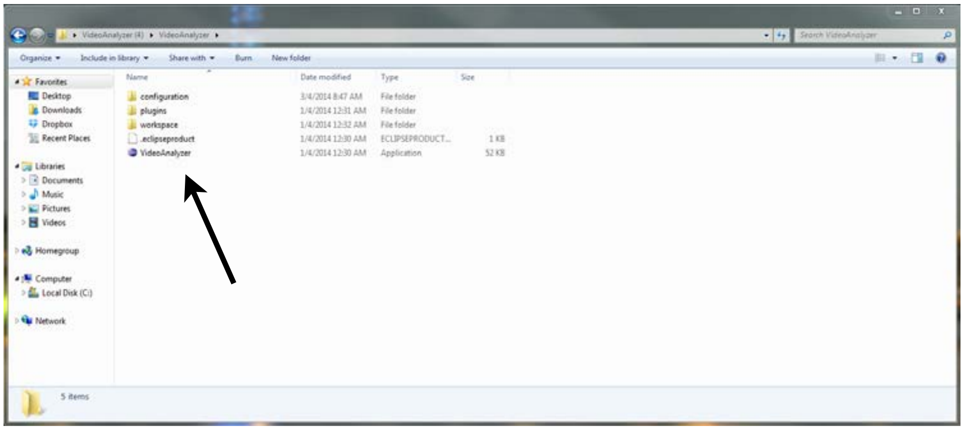


Figure 16: VideoAnalyzer icon.

4.2.1.2. Step 2: Select a Video File

Click the file select button on the VideoAnalyzer interface to select a video file. A screenshot of this step is shown in Figure 17 below.

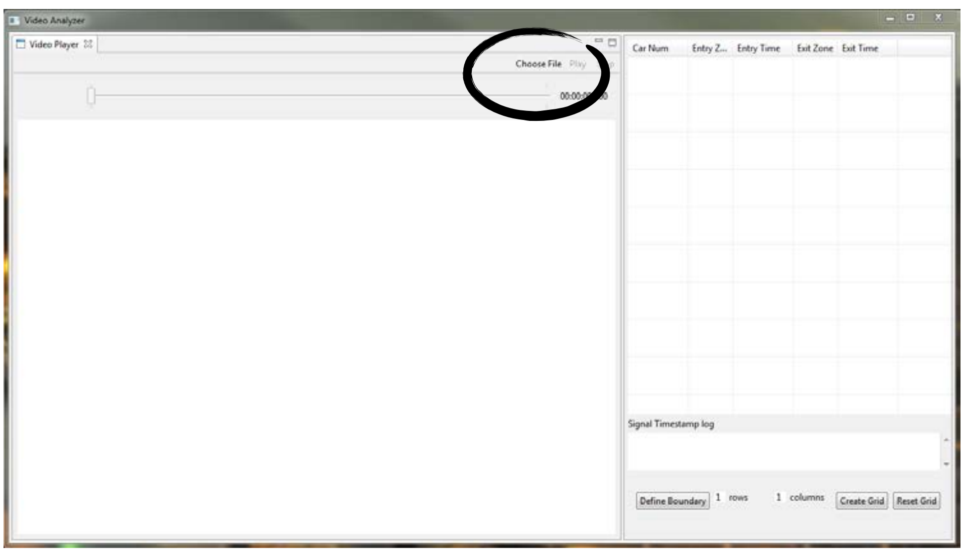


Figure 17: Selection of video file in VideoAnalyzer.

4.2.1.3. Step 3: Create the Grid

Once the video has loaded into the program, the grid for data collection should be created. The purpose of the grid is to make the collection of DBTB data more manageable by allowing a user to easily record one or multiple blocking vehicles during a blocking session. The following steps must be taken to create a grid:

1. First click the button labeled “define boundaries” on the VideoAnalyzer interface.

2. Next, click four locations within the video screen to outline the grid boundary points, these points will act as the four corners of the grid box. It is important to note that the first two points serve as the top of the grid (i.e. the border of the first row which will be labeled a row “1” in the data collection).

3. Once these four points are created, number of columns and rows needed must be entered into the VideoAnalyzer interface. The number of rows and columns needed for the grid depends on the intersection geometry and PTZ camera angle. Generally the grid is set up to allow for the columns to correspond to the number of major lanes and the rows to correspond to the number minor lanes, however, the geometry and location of the PTZ camera will ultimately dictate the grid’s layout. For instance, intersections with a better aerial view usually have larger grids (i.e. more columns and rows) because more approaches can be seen. In other cases where all approaches cannot be seen the grids will be smaller. For example, because of the restrictions of the PTZ camera angle in Figure 18 below only the northbound and southbound can be seen. This means the minor lanes cannot be fully analyzed at this intersection, thus, only 2 rows will be needed for the collection of entry and exit points and 7 columns will be required to collect data for each lane within the southbound and northbound approaches. If the camera angle had a better view on the intersection the rows in the grid layout could have been expanded to account for all the lanes within the minor approaches at this intersection.

4. After the number of columns and rows are inserted the “create grid button” can be selected on the VideoAnalyzer interface. A screenshot of these steps is shown in Figures 18 and 19 below. Once the grid is created a layout file is saved in the same locations as the video file being used.

5. If the correct grid is not created steps 1 through 4 can be repeated to create a new grid. To clear the previous grid the video must be played for a few seconds.

6. Lastly, the grid cells and their corresponding labels must be documented for each intersection for future reference subsequent data collection or analysis. This process can be done by either drawing the grid, along with its orientation, cell numbers, and corresponding lane labels in a notebook or within a computer program, such as a word processing software.

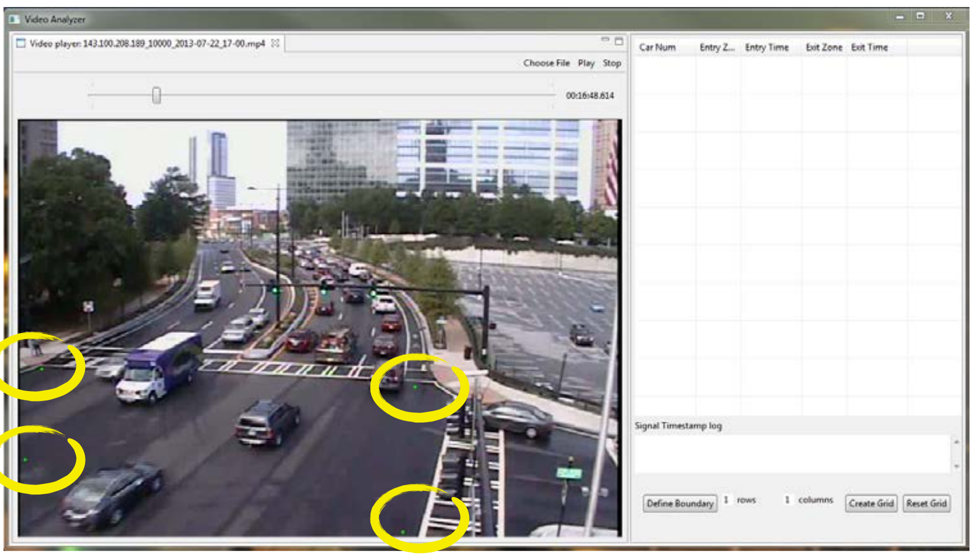


Figure 18: Selecting grid boundary points in Video Analyzer.

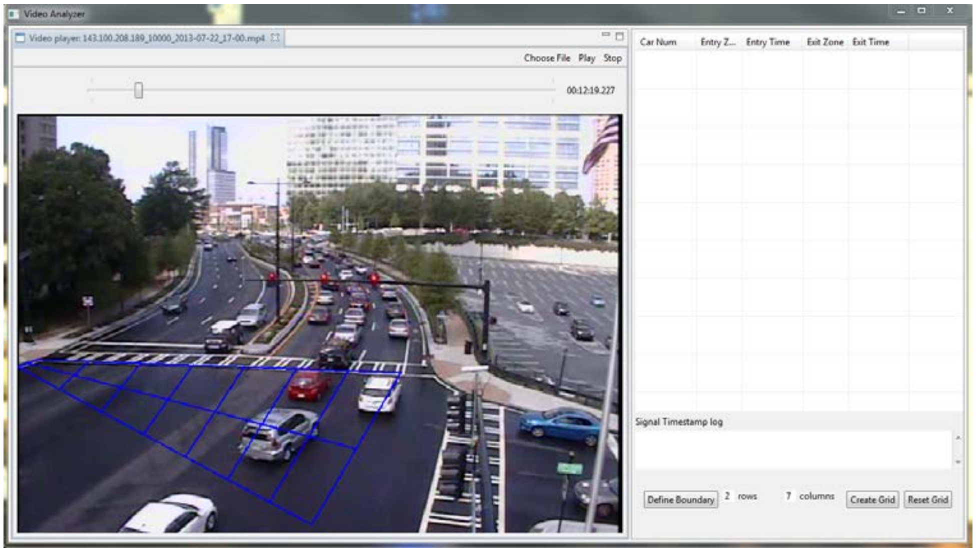


Figure 19: Grid created in VideoAnalyzer.

<u>4.2.1.4. Step 4: Process the Blocking Data</u>

The screenshots in Figure 20 and 21 should be consulted in this data processing step. It should be noted that when a user observes a blocking session it is helpful to watch the entire blocking session, then return to the beginning of the blocking session in the video, before he or she starts to record the blocking data. This allows the user to understand the order of events prior to recording data, reducing potential errors.

To collect blocking data with the VideoAnalyzer when a blocking session starts the video should be paused by pressing the space bar. When the video is paused the following actions must take place: first use the click-and-drag selector over the vehicle that is blocking a conflicting approach and click “Box 1” in the open panel located on the right side of the VideoAnalyzer interface. This will create an image of the vehicle to aid in data collection and review. In the development of the VideoAnalyzer it was found that recording an image of the vehicle was helpful to the data collector in tracking events and returning to review data at a later period. Next, click the grid cell that represents the blocking vehicle entry lane and then click “Box 2”, this will enter the entry cell location of the blocking vehicle. It must be noted at this point that the VideoAnalyzer tool is not intended to provide as visual for lane assignment. For instance, in Figure 20 below it can be seen that the lines within the grid do not line up with their respective lanes. That is, in this image the gray SUV enters in the grid box for lane 1 (lanes are numbered from median to curb) although it is in lane 2 in the intersection. The user must classify the vehicle as entering lane 2 by clicking on the correct cell within the grid, in this case grid box for lane 2.

Next, double click "Box 3", this records the time stamp for the start of blocking for the vehicle. The video can now be resumed (by pressing the space bar) until the vehicle finishes the blocking session and exits the grid. When the vehicle exits the grid, the video should be paused again and the following actions must be performed: click the grid cell that represents the exit lane of the blocking vehicle and then click "Box 4", recording the exit lane of the blocking vehicle. Next, double click "Box 5", recording the time stamp for end-of-the-block for a vehicle.

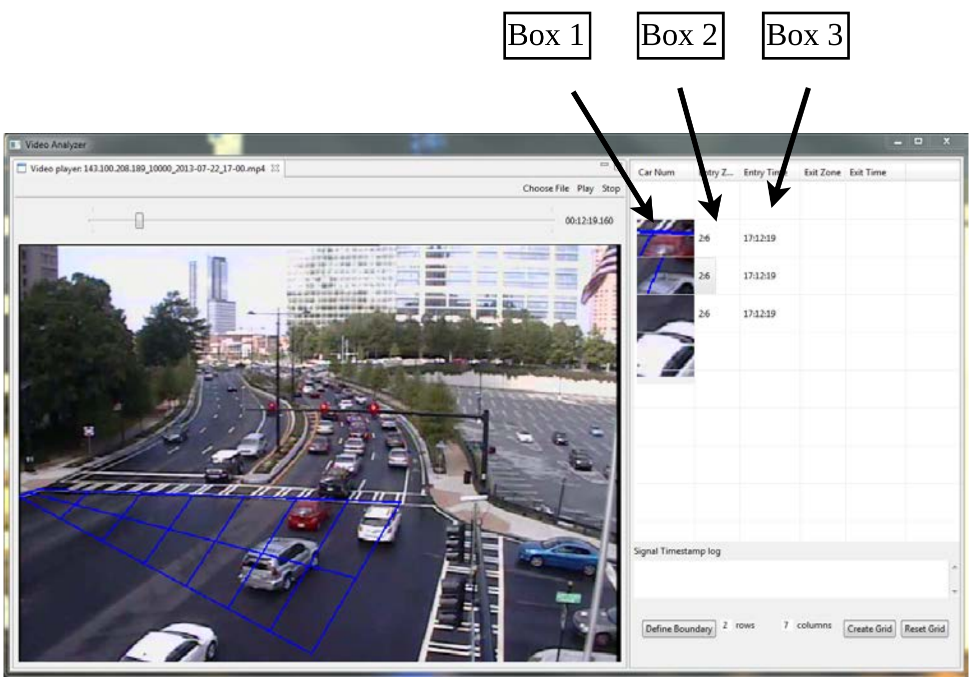


Figure 20: Creating screenshots, entry zones, and entry time stamps in VideoAnalyzer.

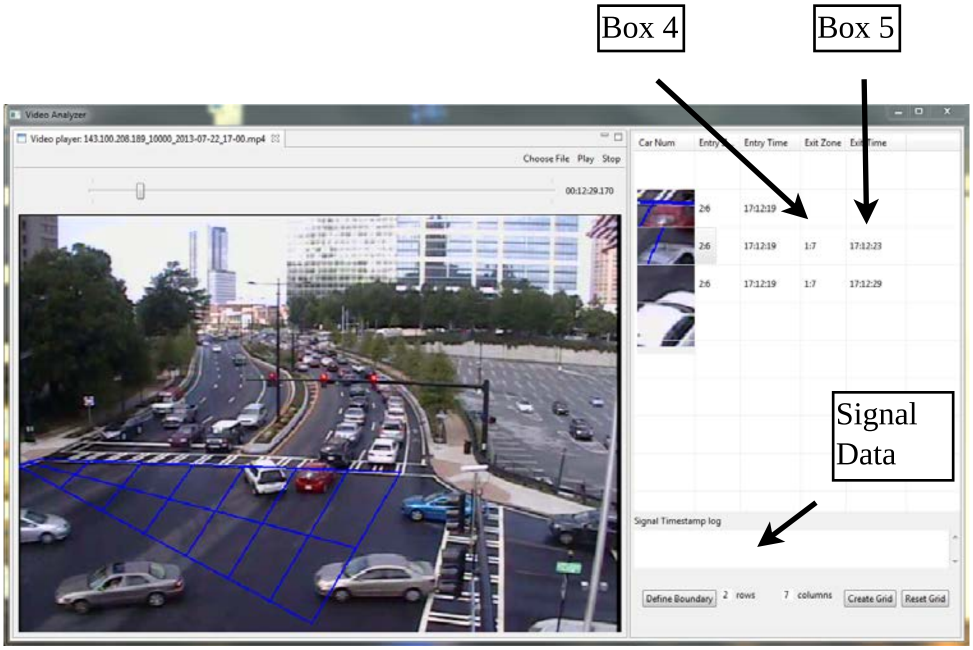


Figure 21: Creating exit zones and exit time stamps in VideoAnalyzer.

4.2.1.5. Step 5: Collecting the Signal Data

In addition to the DBTB data the VideoAnalzyer can collect signal timing data. To collect signal data the following hot keys should be used: press “G” when the signal head turns green, press “A” when the signal head turns yellow, and press “R” when the signal head turns red. It should be noted that when the signal interval timestamps are collected in the VideoAnalzyer program an approach label is not recorded. Thus, the user must make take a note indicating the approach for the recorded signal indication to allow for later analysis.

4.2.1.6. Step 6: Exit the program

The program saves the blocking and signal data to two separate csv files in the same folder as the video that is being processed. It should also be noted that the data is recorded throughout the video data reduction process. Knowing this, when the user finishes collecting data they can exit the program by clicking the “x” in the top right corner of the program at any point. The naming convention selected for the blocking data is “_(camera IP address, port number)_(Date of recording)_(Start time of recording).csv" and the naming convention for the signal data is "_(camera IP address.port number)_(Date of recording)_(Start time of recording)_signals.csv. An example of these naming conventions for the intersection of Peachtree Road & Lenox Mall entrance recorded on December 11th, 2013 is "_1XX.XXX.XXX.XXX.XXXXX_2013-12-11_16-30.csv" and "_1XX.XXX.XXX.XXX.XXXXX_2013-12-11_16-30_signals.csv"

4.2.2. Labeling of Lanes within the Intersections

When the grid was constructed for the intersections within this project, each lane was given a label for its placement within the grid layout. For example, referring back to Figure 19 in the previous section, a 2x7 grid was created and each approach was labeled in reference to the grid layout (i.e. the lane 1 on the northbound approach was NB - 1, etc.). Within each intersection, each approach that had more than one lane was given a label of "(approach acronym) – (lane number)". If an approach had one lane only the approach acronym was used. Figures 22 - 28 show the labeling schemes that were used for each intersection in this project. The lane labels used for this project are as follows:

- NB - #: Northbound Lane #
- NBT: Northbound Through
- NBL - #: Northbound Left Lane #
- NBR: Northbound Right
- SB - #: Southbound Lane #
- SBT: Southbound Through
- SBL - #: Southbound Left Lane #
- EB - #: Eastbound Lane #
- EBT: Eastbound Through
- EBL - #: Eastbound Left Lane #
- EBR: Eastbound Right
- WB - #: Westbound Lane #
- WBT: Westbound Through
- WBL - #: Westbound Left Lane #

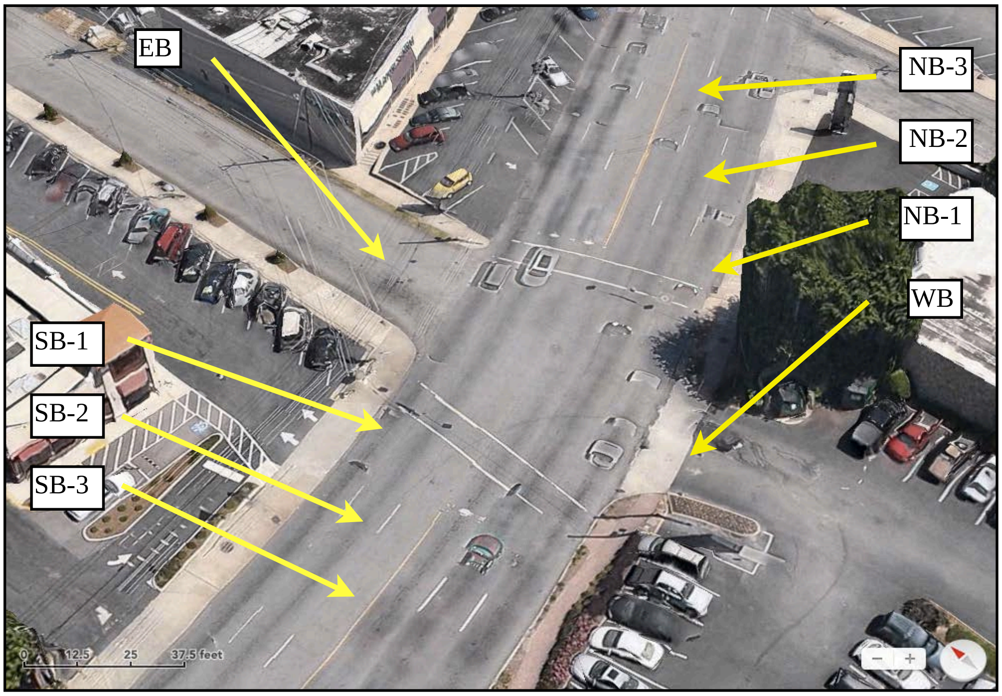


Figure 22: Labeling scheme for Peachtree Road & Mathieson Drive *(27)*

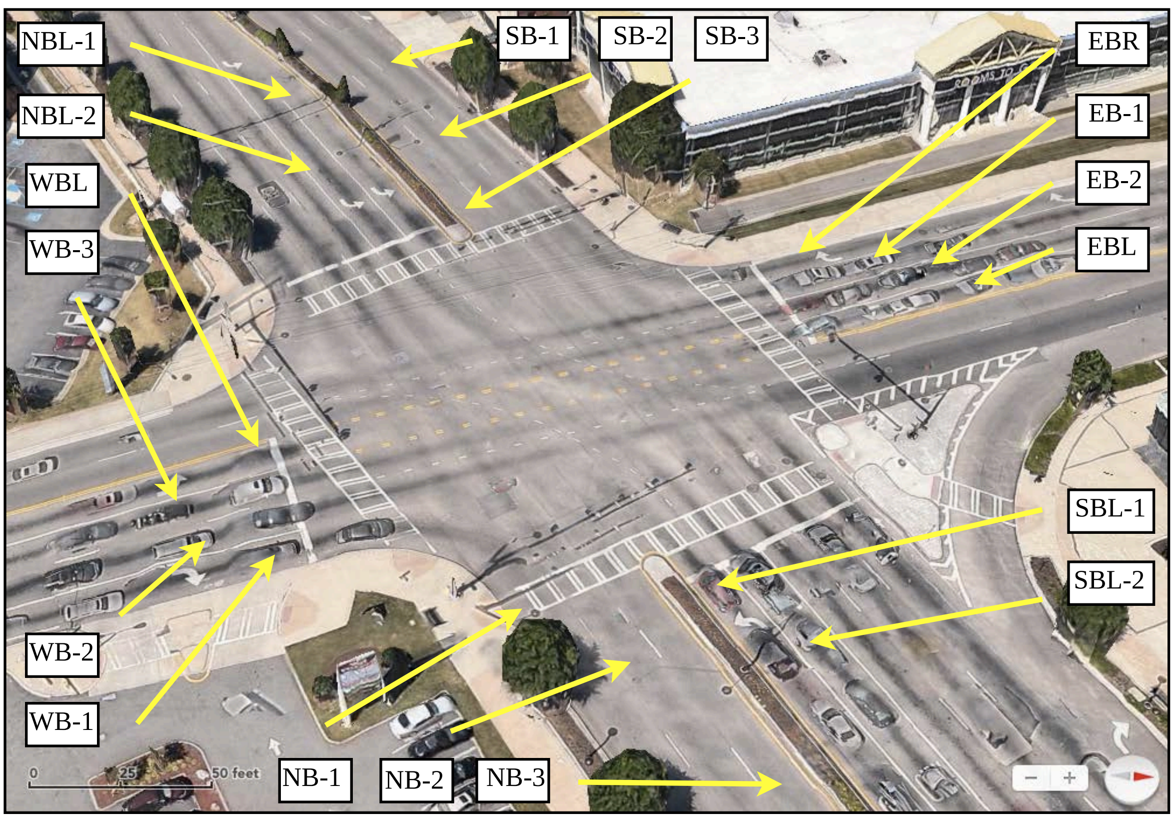


Figure 23: Labeling scheme for Peachtree Road & Piedmont Road *(27)*.

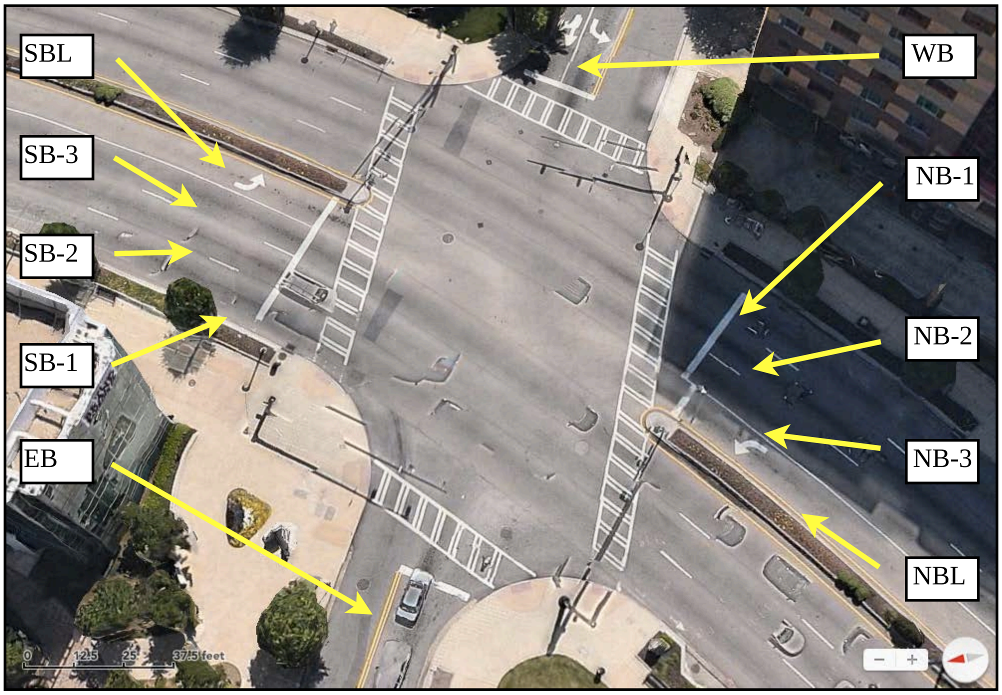


Figure 24: Labeling scheme for Peachtree Road & Highland Drive *(27)*.

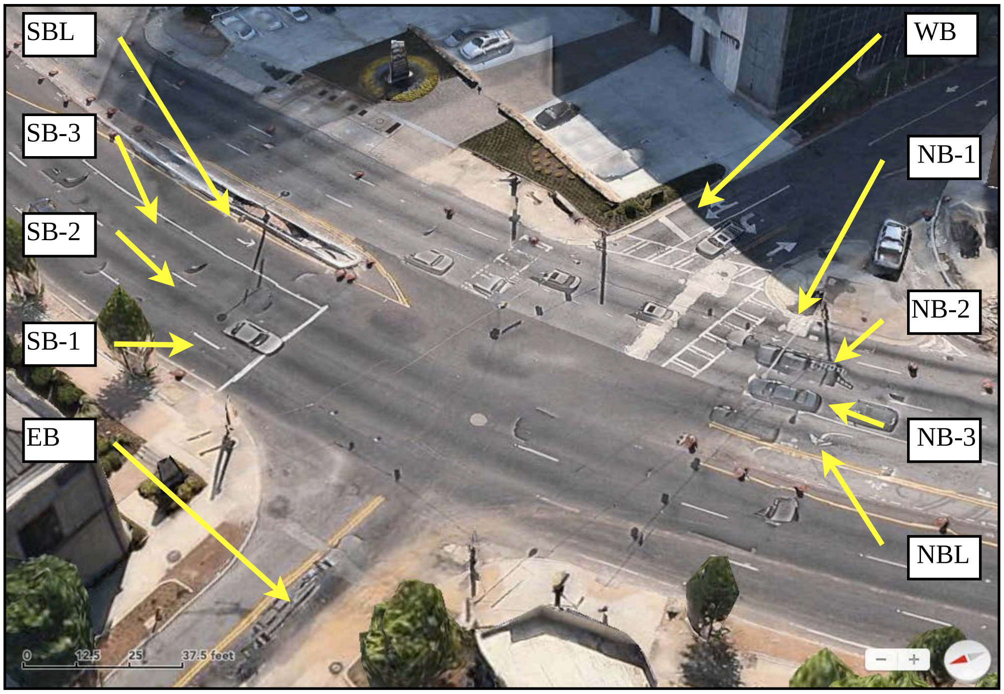


Figure 25: Labeling scheme for Peachtree Road & Stratford Road *(27)*.

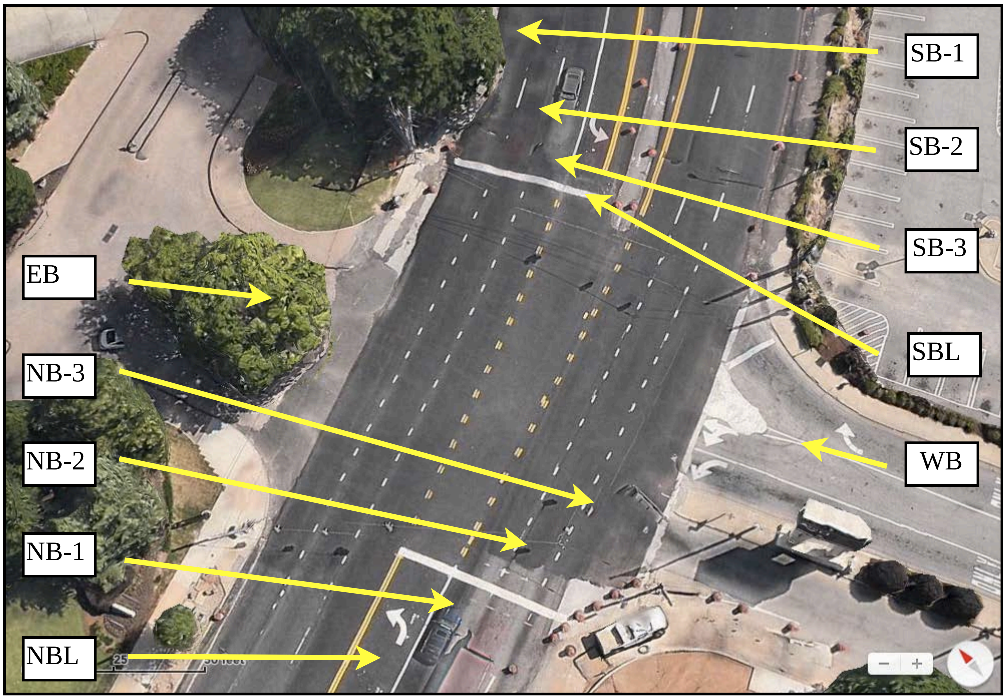


Figure 26: Labeling scheme for Peachtree Road & Lenox Mall Entrance *(27)*.

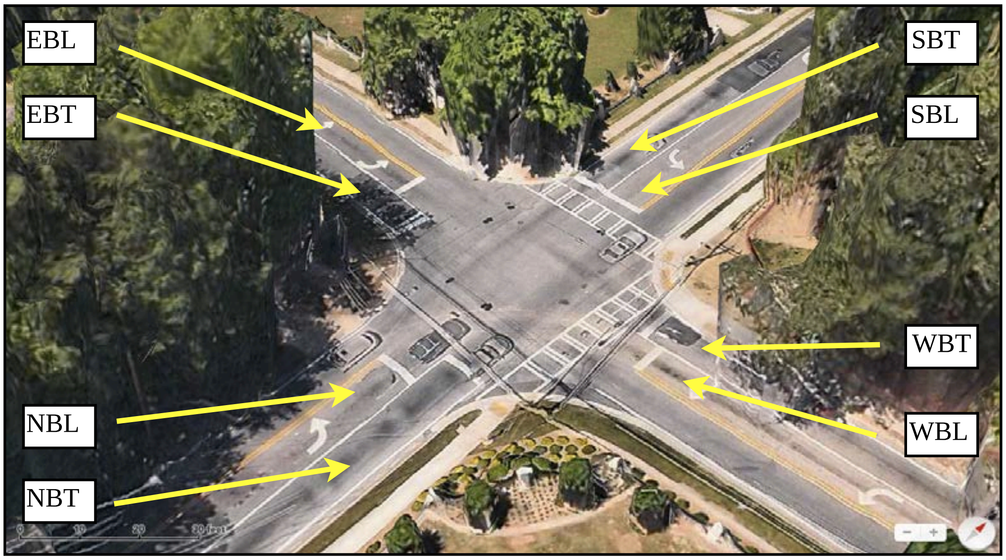


Figure 27: Labeling scheme for Riverside Drive & Heards Ferry Road *(27)*.

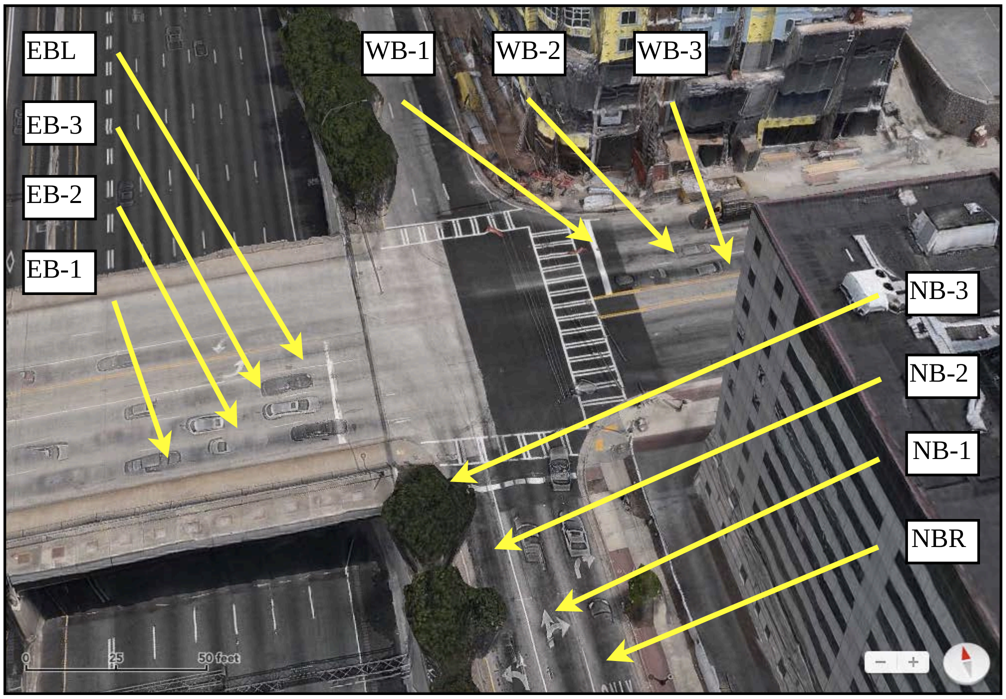


Figure 28: Labeling scheme for 10th Street & Williams Street *(27)*.

4.2.3. First Data Reduction Phase: Initial Data Extracted from VideoAnalyzer Tool

The raw data that was extracted from the VideoAnalyzer tool was as follows:

- Start time of block
- Entry cell of a blocker
- Exit cell of a blocker
- End time of block
- Signal interval timestamp

The start time of a block is defined as the start of a blocking event associated with conflicting approach's green interval. The entry cell of a blocker is defined as the approach, or lane where an approach has more than one lane, from which the blocking vehicle originated. The exit cell of a blocker is defined as the approach, or lane where an approach has more than one lane, the blocker departed at the end of the blocking session. The end time of a block is defined as the end of a blocking session event associated with conflicting approach's green interval. An example of the raw data can be seen in Figure 29 below. The raw data seen in Figure 29 will continue to be used to show examples for the next steps in the DBTB data processing.

Entry Cell	Blocking Start Time	Exit Cell	Blocking End Time
	18:13:53	1:05	18:14:16
	18:03:30	1:05	18:04:15
	18:03:19	1:05	18:03:35
	18:03:16	1:06	18:03:35
2:07	17:49:28	1:07	17:49:36
	17:47:46	1:06	17:48:16
1:04	17:39:37	1:07	17:40:18
	17:36:39	1:05	17:37:43
	17:36:38	1:05	17:37:43
	17:36:37	1:05	17:37:14
	17:34:04	1:07	17:34:19
	17:25:41	1:05	17:25:50
1:02	17:25:31	2:02	17:26:00
2:05	17:25:31	1:06	17:25:38
	17:20:57	1:06	17:21:26
	17:20:41	1:05	17:21:11
	17:17:55	1:06	17:19:07
	17:17:51	1:07	17:19:04
	17:17:51	1:07	17:19:02
	17:17:46	1:07	17:19:00
	17:17:46	1:07	17:18:57
1:04	17:12:53	1:06	17:13:36
	17:12:36	1:07	17:13:10
2:07	17:12:11	1:07	17:12:18
	17:10:00	1:06	17:10:58
	17:09:54	1:07	17:10:58
	17:09:50	1:07	17:10:58
	17:09:43	1:06	17:10:58
2:07	16:58:44	1:07	16:58:51
2:07	16:34:53	1:07	16:35:06
2:06	16:34:53	1:06	16:35:06
2:06	16:34:53	1:06	16:35:05
2:06	16:34:53	1:06	16:35:02
2:05	16:34:53	1:05	16:35:02

Figure 29: Example of raw blocking data from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

The data for the entry and exit of the blocker are formatted as [row: column] in reference to the grid layout selected by the user. It is seen that in the raw data that the start and end time are in reverse order in Figure 29 (i.e. last blocked recorded can be seen in the top row). This format results from the process of recording blocking information within the VideoAnalyzer program, where the most recent data was placed at the top of the data entry form. It should also be noted that some of the cells within the entry column are blank in Figure 29. This is related to the grid set up. Where a minor approach lane could not be seen instances occurred where a grid cell represented both and a major and minor entry. To avoid this ambiguity it was then decided that VideoAnalyzer tool would be used to collect the entry cell data for the major lanes only and the minor lanes would be recorded in the second data reduction process. Thus, in the raw data after phase 1 (i.e. VideoAnalyzer) data collection blank cells indicate the blocker entered from a minor approach. Lastly, an example of the raw signal data can be seen in Figure 30 below. The column titled “Time Stamp” shows the exact time the signal indication was recorded and the column titled “Signal Color” shows the corresponding signal indication to the time stamp. Where multiple approaches could be observed a note would be added by typing in the approach acronym within the signal timestamp log inside the VideoAnalyzer interface while the program was being used. The additional analysis of the extracted data can be found in the next section.

Time Stamp	Signal Color
16:34:37	Amber
16:34:41	Red
16:35:45	Green
16:37:17	Amber
16:37:21	Red
16:38:28	Green
16:39:57	Amber
16:40:01	Red
16:41:01	Green
16:42:37	Amber
16:42:41	Red
16:43:45	Green
16:45:17	Amber
16:45:21	Red
16:46:06	Green
16:47:57	Amber
16:48:01	Red
16:49:09	Green

Figure 30: Example of raw signal data from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

4.2.4. Second Data Reduction Phase: Additional Analysis of Initial Data

Once the initial data was extracted using the VideoAnalyzer tool the second step of video reduction was conducted by reviewing the PTZ videos for each intersection and day. The video reduction conducted while reviewing the video data was as follows:

- Fill in any missing information that was not completed with the VideoAnalyzer tool
- Assign Block ID
- Duration of blocking session
- Conflicting approaches and lanes
- Verify the degree of block
- Process signal data

The following sections discuss the additional video reduction.

4.2.4.1. Fill in Missing Data

In some instances there was missing data that was not captured using the VideoAnalyzer tool. Typically this was a result of a grid layout that did not allow the user to input the entry data for blockers on the approaches that could not been seen by the PTZ camera. For instances, it was seen in section 4.2.1.3-Step 3: Create the Grid that there were only 2 rows and 7 columns in the grid at the intersection of Peachtree Road & Lenox Mall entrance (Figure 19). The 7 columns allow the major approach data to be collected across all lanes, however, this is not true for the minor approaches as there were four minor lanes but only two rows in the grid. If the cell near the entrance of the minor approach was used, for example cell “2:02”, it could have been mistaken for a blocker on the major approach entering in cell “2:02”. This confusion was eliminated at this intersection by only collecting major road entry data with VideoAnalyzer. When the video was reviewed the minor approach entry locations were inserted manually in a different format as seen in the Figure 31 below. Future iterations of VideoAnalyzer will be modified to allow a user to directly distinguish between major and minor movements.

Entry Cell	Blocking Start Time	Exit Cell	Blocking End Time
EB	18:13:53	1:05	18:14:16
WB	18:03:30	1:05	18:04:15
EB	18:03:19	1:05	18:03:35
EB	18:03:16	1:06	18:03:35
2:07	17:49:28	1:07	17:49:36
WB	17:47:46	1:06	17:48:16
1:04	17:39:37	1:07	17:40:18
EB	17:36:39	1:05	17:37:43
EB	17:36:38	1:05	17:37:43
EB	17:36:37	1:05	17:37:14
EB	17:34:04	1:07	17:34:19
EB	17:25:41	1:05	17:25:50
1:02	17:25:31	2:02	17:26:00
2:05	17:25:31	1:06	17:25:38
WB	17:20:57	1:06	17:21:26
EB	17:20:41	1:05	17:21:11
WB	17:17:55	1:06	17:19:07
WB	17:17:51	1:07	17:19:04
EB	17:17:51	1:07	17:19:02
EB	17:17:46	1:07	17:19:00
EB	17:17:46	1:07	17:18:57
1:04	17:12:53	1:06	17:13:36
WB	17:12:36	1:07	17:13:10
2:07	17:12:11	1:07	17:12:18
EB	17:10:00	1:06	17:10:58
EB	17:09:54	1:07	17:10:58
EB	17:09:50	1:07	17:10:58
EB	17:09:43	1:06	17:10:58
2:07	16:58:44	1:07	16:58:51
2:07	16:34:53	1:07	16:35:06
2:06	16:34:53	1:06	16:35:06
2:06	16:34:53	1:06	16:35:05
2:06	16:34:53	1:06	16:35:02
2:05	16:34:53	1:05	16:35:02

Figure 31: Filled in data from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

It should also be noted in this example that the direction can be derived from the entry and exit cell data and the second review was not critical (although allowed for error checking and quality control). For instance, the northbound approach enters the grid on the second row and exits the grid on the first row (Figure 19). A minor approach vehicle would not have this pattern. Another piece of information that can be extracted from Figure 31 is the direction the minor approach exited. In this example if the minor lane took a right to go northbound the exit cell would be [1:0X].

4.2.4.2. Assign Block ID

The total number of blockers per two hour session was determined for each intersection within the project. The number of blockers was found by consecutively numbering the blockers for a given day. An example of how the blocker numbering is seen in Figure 32. Each row in Figure 32 represents a blocker and as the rows progress downward the number of blockers increases. As the raw data has the latest block start time in the first row block number 1 refers to the last block recorded, with block number increasing in a last-out format.

Block Number	Entry Cell	Blocking Start Time	Exit Cell	Blocking End Time
1	EB	18:13:53	1:05	18:14:16
2	WB	18:03:30	1:05	18:04:15
3	EB	18:03:19	1:05	18:03:35
4	EB	18:03:16	1:06	18:03:35
5	2:07	17:49:28	1:07	17:49:36
6	WB	17:47:46	1:06	17:48:16
7	1:04	17:39:37	1:07	17:40:18
8	EB	17:36:39	1:05	17:37:43
9	EB	17:36:38	1:05	17:37:43
10	EB	17:36:37	1:05	17:37:14
11	EB	17:34:04	1:07	17:34:19
12	EB	17:25:41	1:05	17:25:50
13	1:02	17:25:31	2:02	17:26:00
14	2:05	17:25:31	1:06	17:25:38
15	WB	17:20:57	1:06	17:21:26
16	EB	17:20:41	1:05	17:21:11
17	WB	17:17:55	1:06	17:19:07
18	WB	17:17:51	1:07	17:19:04
19	EB	17:17:51	1:07	17:19:02
20	EB	17:17:46	1:07	17:19:00
21	EB	17:17:46	1:07	17:18:57
22	1:04	17:12:53	1:06	17:13:36
23	WB	17:12:36	1:07	17:13:10
24	2:07	17:12:11	1:07	17:12:18
25	EB	17:10:00	1:06	17:10:58
26	EB	17:09:54	1:07	17:10:58
27	EB	17:09:50	1:07	17:10:58
28	EB	17:09:43	1:06	17:10:58
29	2:07	16:58:44	1:07	16:58:51
30	2:07	16:34:53	1:07	16:35:06
31	2:06	16:34:53	1:06	16:35:06
32	2:06	16:34:53	1:06	16:35:05
33	2:06	16:34:53	1:06	16:35:02
34	2:05	16:34:53	1:05	16:35:02

Figure 32: Number of blocks from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

4.2.4.3. Duration of Blocking Sessions

The duration of a blocking session for an approach is defined as the difference between the last blocker's end time and the first blockers start time that are in a continuous time frame, i.e. the block times overlap. For instance, in Figure 33 blocks numbers 22 and 23 occurred during the continuous time frame of 17:12:36 to 17:13:36, making a blocking session, and once that continuous time frame was broken by the next block (block 21) that occurred at 17:17:46 a new blocking session began. It should be noted that the bold line between some of the rows signify the start or end of a blocking session. Additionally, the rows in the columns titled "Entry Cell", "Blocking Start time", "Exit Cell", and "Blocking End time" in Figure 33 are outlined to help visualize the different blocking sessions occurred on February 4th, 2014 at the intersection of Peachtree Road & Lenox Mall entrance.

Block Number	Entry Cell	Blocking Start Time	Exit Cell	Blocking End Time		Duration of Blocking Session
1	EB	18:13:53	1:05	18:14:16		0:00:23
2	WB	18:03:30	1:05	18:04:15		
3	EB	18:03:19	1:05	18:03:35		
4	EB	18:03:16	1:06	18:03:35		0:00:59
5	2:07	17:49:28	1:07	17:49:36		0:00:08
6	WB	17:47:46	1:06	17:48:16		0:00:30
7	1:04	17:39:37	1:07	17:40:18		0:00:41
8	EB	17:36:39	1:05	17:37:43		
9	EB	17:36:38	1:05	17:37:43		
10	EB	17:36:37	1:05	17:37:14		0:01:06
11	EB	17:34:04	1:07	17:34:19		0:00:15
12	EB	17:25:41	1:05	17:25:50		
13	1:02	17:25:31	2:02	17:26:00		
14	2:05	17:25:31	1:06	17:25:38		0:00:29
15	WB	17:20:57	1:06	17:21:26		
16	EB	17:20:41	1:05	17:21:11		0:00:45
17	WB	17:17:55	1:06	17:19:07		
18	WB	17:17:51	1:07	17:19:04		
19	EB	17:17:51	1:07	17:19:02		
20	EB	17:17:46	1:07	17:19:00		
21	EB	17:17:46	1:07	17:18:57		0:01:21
22	1:04	17:12:53	1:06	17:13:36		
23	WB	17:12:36	1:07	17:13:10		0:01:00
24	2:07	17:12:11	1:07	17:12:18		0:00:07
25	EB	17:10:00	1:06	17:10:58		
26	EB	17:09:54	1:07	17:10:58		
27	EB	17:09:50	1:07	17:10:58		
28	EB	17:09:43	1:06	17:10:58		0:01:15
29	2:07	16:58:44	1:07	16:58:51		0:00:07
30	2:07	16:34:53	1:07	16:35:06		
31	2:06	16:34:53	1:06	16:35:06		
32	2:06	16:34:53	1:06	16:35:05		
33	2:06	16:34:53	1:06	16:35:02		
34	2:05	16:34:53	1:05	16:35:02		0:00:13
					Total Blocking Time:	0:09:19

Figure 33: Duration of blocking sessions from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

4.2.4.4. Conflicting Approaches and Lanes

Blocking the box was defined as when a vehicle enters an intersection and blocks the conflicting approach that has a green indication. Base analysis was completed at the approach level and in addition at the lane level for multi-lane approaches. A manual process for finding which lanes were being blocked was used. The blocking session times (based on video analysis data) for every intersection were visually reviewed to determine which approaches and lanes were being blocked. “Approach Blocked” in Figure 34, indicates which approach, or approaches, are blocked throughout a blocking session. All approaches listed within a blocking session are assumed blocked over the entire session. (Please note, in the raw data of “Approach Blocked” the approach listed in the same row as a Block number does not indicate that vehicle is blocking the given approach. Instead, listed approaches are for one or a combination of vehicles within the session.) For example, Block vehicles 17 through 21 (individually or in combination) are blocking the approaches NBT, SBL, WB, and EB from 17:17:46 through 17:19:07.“Lane Blocked” (Figure 34) indicates the blocked lanes for approach listed in “Approach Blocked” by the blocking vehicle. Blank cells within “Lane Blocked” by default indicate a single lane approach.

Block Number	Entry Cell	Blocking Start Time	Exit Cell	Blocking End Time	Lane Blocked	Duration of Blocking Session		Number of Blockers:	34		Approach Blocked
1	EB	18:13:53	1:05	18:14:1		0:00:23					WB/SBL
2	WB	18:03:30	1:05	18:04:1							
3	EB	18:03:19	1:05	18:03:3	3						NBT
4	EB	18:03:16	1:06	18:03:3		0:00:59					SBL
5	2:07	17:49:28	1:07	17:49:3		0:00:08					EB/WB
6	WB	17:47:46	1:06	17:48:1	3	0:00:30					NBT
7	1:04	17:39:37	1:07	17:40:1	3	0:00:41					SBL/NBT
8	EB	17:36:39	1:05	17:37:4							
9	EB	17:36:38	1:05	17:37:4							
10	EB	17:36:37	1:05	17:37:1		0:01:06					SBL
11	EB	17:34:04	1:07	17:34:1		0:00:15					SBL
12	EB	17:25:41	1:05	17:25:5							
13	1:02	17:25:31	2:02	17:26:0							WB
14	2:05	17:25:31	1:06	17:25:3		0:00:29					EB
15	WB	17:20:57	1:06	17:21:2	2,3						NBT
16	EB	17:20:41	1:05	17:21:1		0:00:45					SBL
17	WB	17:17:55	1:06	17:19:0							
18	WB	17:17:51	1:07	17:19:0	1,2						NBT
19	EB	17:17:51	1:07	17:19:0							SBL
20	EB	17:17:46	1:07	17:19:0							WB
21	EB	17:17:46	1:07	17:18:5		0:01:21					EB
22	1:04	17:12:53	1:06	17:13:3	1						NBT
23	WB	17:12:36	1:07	17:13:1		0:01:00					SBL
24	2:07	17:12:11	1:07	17:12:1		0:00:07					EB/WB
25	EB	17:10:00	1:06	17:10:5	1						NBT
26	EB	17:09:54	1:07	17:10:5							SBL
27	EB	17:09:50	1:07	17:10:5							WB
28	EB	17:09:43	1:06	17:10:5		0:01:15					
29	2:07	16:58:44	1:07	16:58:5		0:00:07					EB
30	2:07	16:34:53	1:07	16:35:0							
31	2:06	16:34:53	1:06	16:35:0							
32	2:06	16:34:53	1:06	16:35:0							
33	2:06	16:34:53	1:06	16:35:0							WB
34	2:05	16:34:53	1:05	16:35:0		0:00:13					EB

Figure 34: Example of the conflicting approach and lane data from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

4.2.4.5. Verify the Degree of Block

This project classified a block as being either full or partial. A full block is when the vehicle on the conflicting approach cannot pass the vehicle that is blocking their approach. An example of a full block can be seen in Figure 35 below, the vehicle in NB-1 was fully blocked by the truck and white SUV in lane WB-3. This vehicle could not bypass this block. It should be noted that the vehicles in NB-2 were partially blocked. A partial block is when a vehicle on the conflicting approach can bypass the blocking vehicle by entering another lane to go around the blocking vehicle. An example of a partial block can be seen in Figure 36 below. The silver car decided there was sufficient room to bypass the block (i.e. truck), thus resulting in a partial block. The potential hazards of bypassing a block can also be seen in Figure 36. The silver car can be seen encroaching into the lane of the black vehicle to navigate around the blocking vehicle.

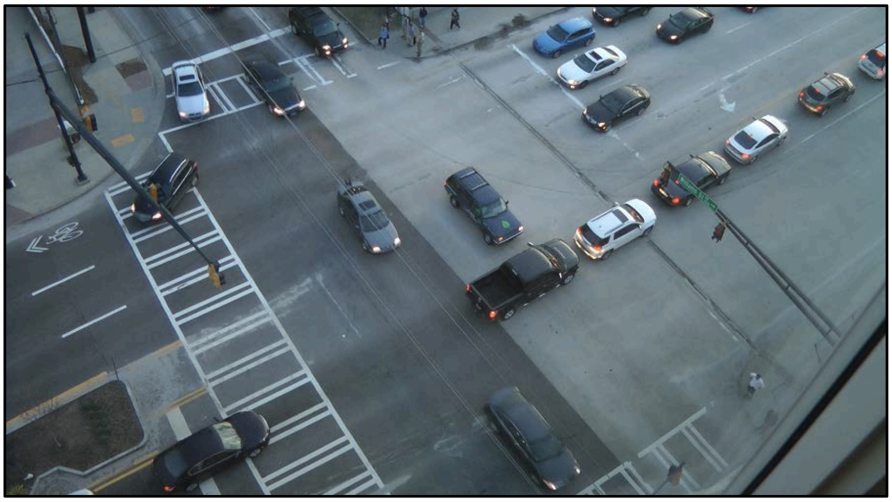


Figure 35: Example of full block at the 10th Street & Williams Street intersection *(51)*.

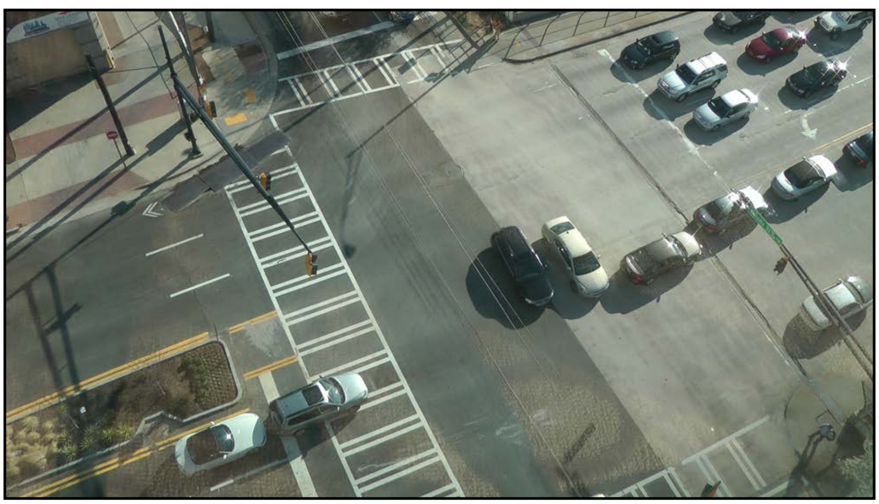


Figure 36: Example of partial block at the 10th Street & Williams Street intersection *(51)*.

An example of partial and full blocking data can be seen outlined in Figure 37 below. There are three columns labeled “Degree of Block” to account for approaches with more than one lane. It should also be noted that some of the “Degree of Block” columns have two classifications (i.e. “P/F). This indicates that there was only one row in which the blocking data could be entered (i.e. signifying a single blocker) and the single blocking vehicle blocked two or more approaches. An example of this can be seen in row one, P/P means that the WB and SBL approaches were both partially blocked. When there was enough space to record the degree of block (i.e. more blockers within a blocking session) the degree of block was aligned in the same row as the approach in the “Approach Block” column it coincided with. An example of this can be seen in rows 18 through 21. It should also be noted that the number of blockers within a blocking session does not equal the number of approaches blocked under the column “Approach Blocked”. For instance, blocks 17 through 21, a total of five blocks, only blocked four approaches, signifying that any combination of the five blocks blocked the corresponding four approaches. The collected data does not allow for a one-to-one mapping of blocked approaches to the blocking vehicle within a blocking session.

Block Number	Entry Cell	Blocking Start Time	Exit Cell	Blocking End Time	Lane Blocked	Duration of Blocking Session	Number of Blockers:	34	Approach Blocked	Degree of Block	Degree of Block	Degree of Block
1	EB	18:13:53	1:05	18:14:16		0:00:23			WB/SBL	P/P		
2	WB	18:03:30	1:05	18:04:15								
3	EB	18:03:19	1:05	18:03:35	3				NBT	F		
4	EB	18:03:16	1:06	18:03:35		0:00:59			SBL	P		
5	2:07	17:49:28	1:07	17:49:36		0:00:08			EB/WB	P/F		
6	WB	17:47:46	1:06	17:48:16	3	0:00:30			NBT	P		
7	1:04	17:39:37	1:07	17:40:18	3	0:00:41			SBL/NBT	P/F		
8	EB	17:36:39	1:05	17:37:43								
9	EB	17:36:38	1:05	17:37:43								
10	EB	17:36:37	1:05	17:37:14		0:01:06			SBL	F		
11	EB	17:34:04	1:07	17:34:19		0:00:15			SBL	P		
12	EB	17:25:41	1:05	17:25:50								
13	1:02	17:25:31	2:02	17:26:00					WB	P		
14	2:05	17:25:31	1:06	17:25:38		0:00:29			EB	P		
15	WB	17:20:57	1:06	17:21:26	2,3				NBT	F	F	
16	EB	17:20:41	1:05	17:21:11		0:00:45			SBL	P		
17	WB	17:17:55	1:06	17:19:07								
18	WB	17:17:51	1:07	17:19:04	1,2				NBT	F	F	
19	EB	17:17:51	1:07	17:19:02					SBL	P		
20	EB	17:17:46	1:07	17:19:00					WB	F	F	
21	EB	17:17:46	1:07	17:18:57		0:01:21			EB	P		
22	1:04	17:12:53	1:06	17:13:36	1				NBT	F		
23	WB	17:12:36	1:07	17:13:10		0:01:00			SBL	P		
24	2:07	17:12:11	1:07	17:12:18		0:00:07			EB/WB	F/P		
25	EB	17:10:00	1:06	17:10:58	1				NBT	P		
26	EB	17:09:54	1:07	17:10:58					SBL	P		
27	EB	17:09:50	1:07	17:10:58					WB	P		
28	EB	17:09:43	1:06	17:10:58		0:01:15						
29	2:07	16:58:44	1:07	16:58:51		0:00:07			EB	F		
30	2:07	16:34:53	1:07	16:35:06								
31	2:06	16:34:53	1:06	16:35:06								
32	2:06	16:34:53	1:06	16:35:05								
33	2:06	16:34:53	1:06	16:35:02					WB	P		
34	2:05	16:34:53	1:05	16:35:02		0:00:13			EB	F	F	P

Figure 37: Example of degree of partial and full blocking data that was recorded from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

It should be noted that the status of a block was not change once determined. This means if a block was classified as full it is treated as a full block throughout the blocking session for the analysis.

4.2.4.6. Processing Signal Data

After the time stamps for the signal intervals were recorded there was need for additional analysis to find parameters such as overall green time, green time that was blocked, and the percent of green time that was blocked. These parameters were found by processing the signal data found by the VideoAnalzyer program. For this analysis total green time refers to the total green time on the observed approach and the overall green time at the intersection is defined as the sum of any time that any approach has a green indication. Where an approach could not be observed it was assumed that approach had similar yellow times to the observed. Thus, overall green time is the total observation time (i.e. 2 hours) less the sum of the approximate clearance intervals. For all intersections this is generally on the order of 110 to 115 minutes of green time. The duration of the blocking session from the blocking data was then summed to find the green time that was blocked. The percentage of green time that was blocked was then determined as the ratio between the total blocked time and the overall green time. An example of a section of this data can be found in Figure 38 below. It should be noted that Figure 38 only shows a section of the signal data because of data within the first two columns was extensive. The data from the final analysis can be found in the next section.

Difference Between Indications	Signal Color		Total Green Time	Total Yellow Time	Total Red Time	Overall Green Time	Green Time that was Blocked	% of Green Time that was Blocked
0:01:02	Red		1:14:31	0:02:55	0:42:02	1:53:38	0:09:19	8.2
0:00:58	Red							
0:01:03	Red							
0:00:58	Red							
0:00:27	Red							
0:01:04	Red							
0:01:07	Red							
0:01:01	Red							
0:01:06	Red							
0:01:01	Red							
0:00:55	Red							
0:00:48	Red							
0:01:07	Red							
0:01:07	Red							
0:01:07	Red							
0:00:59	Red							
0:01:00	Red							
0:01:03	Red							
0:00:55	Red							
0:01:03	Red							
0:00:56	Red							
0:00:54	Red							
0:00:57	Red							
0:01:12	Red							
0:01:07	Red							
0:01:00	Red							
0:00:44	Red							

Figure 38: Example of processed signal data that was recorded from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

4.2.5. Final Analysis of Data

After the data collection was completed operations performance was evaluated for the following:

- Temporal analysis
- Distribution of conflicting lane blocks
- Partial and full blocking analysis
- Percent of green time with full and partial blocking
- Lost capacity
- Pedestrian safety analysis

- Probability of a blocker changing lanes to stop blocking
- Driver characteristics

4.2.5.1. Temporal Analysis of Blocking

The temporal analysis of blocking seeks to determine when (or if) the blocking is the most problematic during the two hour peak analysis. The peak two hour time frame, in which each intersection was recorded, is divided into eight 15 minute periods to analyze the variability in blocking over a session. Blocks are grouped into a 15 minute period based on the block start time. When all the blocking sessions were categorized for each day of data collection, the number of blocks that occurred in each 15 minute period of the two hour analysis could be observed. An example of the how the temporal analysis was calculated can be seen in Figure 39 below. Each 15 minute period was highlighted by a different color shade that corresponded to its entry time.

Blocking Start Time
18:13:53
18:03:30
18:03:19
18:03:16
17:49:28
17:47:46
17:39:37
17:36:39
17:36:38
17:36:37
17:34:04
17:25:41
17:25:31
17:25:31
17:20:57
17:20:41
17:17:55
17:17:51
17:17:51
17:17:46
17:17:46
17:12:53
17:12:36
17:12:11
17:10:00
17:09:54
17:09:50
17:09:43
16:58:44
16:34:53
16:34:53
16:34:53
16:34:53
16:34:53

Standard Time	24 Hour Clock	Number of Blocks
4:30 PM to 4:45 PM	16:30 to 16:45	5
4:45 PM to 5:00 PM	16:45 to 17:00	1
5:00 PM to 5:15 PM	17:00 to 17:15	7
5:15 PM to 5:30 PM	17:15 to 17:30	10
5:30 PM to 5:45 PM	17:30 to 17:45	5
5:45 PM to 6:00 PM	17:45 to 18:00	2
6:00 PM to 6:15 PM	18:00 to 18:15	4
6:15 PM to 6:30 PM	18:15 to 18:30	0

Figure 39: Example of how the temporal analysis was calculated from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

Again, it should be noted that the times within the "Blocking Start Time" column are in reverse chronological order while the times shown to the left are shown in the proper chronological order.

4.2.5.2. Distribution of Conflicting Approach and Lane Blocks

The distribution of conflicting approach and lane blocks can be defined as the process of determining the allocation of which approaches, and in some case lanes, were being blocked. The distribution of conflicting approach blocks for the intersection of Peachtree Road & Lenox Mall entrance on February 4th, 2014 can be found in Figure 40 below. The process in determining each percentage for each conflicting approach was first found by taking the sum of blocks for each approach and then dividing that number by the intersection total (total number blocks recorded over all approaches) to determine the percentage of the total blocks that blocked each approach. In this analysis if two vehicles are blocking the same lane (may occur where street containing the blocking traffic is multi-lane) at the same time this would be counted as two separate blocks.

Conflicting Approach		Who Was Getting Blocked	Number	Percent
EB		EB	6	20.7
EB		NBT	7	24.1
EB		SBL	9	31.0
EB		WB	7	24.1
EB				
EB		Total:	29	
EB				
EB				
NBT				
NBT				
NBT				
NBT				
NBT				
NBT				
NBT				
SBL				
SBL				
SBL				
SBL				
SBL				
SBL				
SBL				
SBL				
SBL				
WB				
WB				
WB				
WB				
WB				
WB				
WB				

Figure 40: Example of determining the percentage of total blocks that blocked an approach for the two hour data collection period from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

In addition to the distribution of conflicting approach blocks the distribution of conflicting lane blocks was also found for the approaches with more than one lane. Example results of this analysis can be seen in Figure 41 below.

Lane Blocked		Approach:	NBT	Lane Number	Number of Blocks per Lane	Percentage (%)
1				1	3	33.3
1				2	2	22.2
3				3	4	44.4
3						
3				Total:	9	
1						
2						
2						
3						

Figure 41: Example of determining the percentage of total blocks that blocked a lane from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

4.2.5.3. Full or Partial Block

The degree of blocking data was extracted and analyzed to find the percent of partial blocks and full blocks for each blocked approach. The percent of partial and full blocks for each approach was found by first summing the total number of partial and full blocks for each approach, adding them together to get the total number of blocks for each approach, and then dividing the sum of partial and full blocks by the total number of blocks for each approach to find the percentage. As stated previously each column that states “Degree of block” represents a lane (i.e. the first “Degree of Block” column for the first NBT approach represents NB-1 and the second “Degree of Block” column for the first NBT approach represents NB-2). An example of this analysis can be seen in Figure 42 below.

Conflicting Approach	Degree of Block	Degree of Block	Degree of Block
WB	P		
WB	F		
WB	P		
WB	P		
WB	F	F	
WB	P		
WB	P		
SBL	P		
SBL	P		
SBL	P		
SBL	F		
SBL	P		
SBL	P		
SBL	P		
SBL	P		
SBL	P		
NBT	F		
NBT	P		
NBT	F		
NBT	F	F	
NBT	F	F	
NBT	F		
NBT	P		
EB	P		
EB	P		
EB	P		
EB	P		
EB	F		
EB	P		
EB	F		
EB	F	F	P

Conflicting Approach	Number of Partial Blocks	Number of Full Blocks	TOTAL	Percent of Partial Blocks	Percent of Full Blocks
WB	5	3	8	62.5	37.5
SBL	8	1	9	88.9	11.1
NBT	2	7	9	22.2	77.8
EB	6	4	10	60.0	40.0

Figure 42: Example of percent of partial and full blocks data from the intersection of Peachtree Road & Lenox Mall entrance for February 4th, 2014.

4.2.5.4. Percent Green with Full and Partial Blocking

The percent of green with blocking is the amount of time that the green phase on an approach was blocked. The percent of green time that experienced blocking was determined using the signal timing data and blocking data found in the data reduction sections of this thesis. The following steps for finding the percent green time that experienced blocking were performed for each intersection within the project:

1. First, data found in the first and second phase of data reduction (the date of analysis, day of week, the Total Green Time that experienced blocking (TGB_{ial}), the Percentage of Green Time with blocking ($PTGB_i$), where i indicates the intersection, a indicates the approach, and l the lane) were copied into a new analysis worksheet.

2. Next, the Percentage of Partial Block Time ($PPBT_i$), and Percentage of Full Block Time ($PFBT_i$) were calculated by summing the the duration of blocking sessions for partial blocking (DBS_p), and full blocking (DBS_f), where p indicates a partial block and f indicates a full block.

$$PPBT_i = DBS_p / TGB$$

$$PFBT_i = DBS_f / TGB$$

Figure 43 below shows an example of step 2 described above. It can be seen that when the duration of blocking sessions is summed for the partial time of green time with blocking it is 8 minutes and 6 seconds and when the duration of blocking sessions is summed for the full time of green time with blocking it is 6 minutes and 27 seconds for the single two hour period on February 4th, 2014. It should be noted that these times may not sum to the total green time with blocking as a blocking session can have more than one approach blocked at the same time, which can result in more than one classification of block. For instance, in the second blocking session of 59 seconds there was two degree of blocks recorded, full and partial. Each degree of block corresponds to an approach, which in this case was the NBT and SBL approaches.

Duration of Blocking Session	Degree of Block	Degree of Block	Degree of Block		Partial Time of Green Time with Blocking	Full Time of Green Time with Blocking	Partial Block %	Full Block %		Total Green Time with Blocking
0:00:23	P/P				0:08:06	0:06:27	0.9	0.7		0:09:19
	F									
0:00:59	P									
0:00:08	P/F									
0:00:30	P									
0:00:41	P/F									
0:01:06	F									
0:00:15	P									
	P									
0:00:29	P									
	F	F								
0:00:45	P									
	F	F								
	P									
	F	F								
0:01:21	P									
	F									
0:01:00	P									
0:00:07	F/P									
	P									
	P									
	P									
0:01:15	P									
0:00:07	F									
	P									
0:00:13	F	F	P							
0:09:19										

Figure 43: Example of percent of partial and full blocks data from the intersection of Peachtree Road & Lenox Mall entrance on February 4th, 2014.

An example of this analysis can be found in Figure 44 below.

Date	Day of the Week	Total Green Time with Blocking	% of Green Time with Blocking	Partial Block %	Full Block %	Partial Time of Green Time with Blocking	Full Time of Green Time with Blocking
7/22/2013	Saturday	0:15:44	14.0	1.0	0.5	0:14:59	0:08:20
7/23/2013	Sunday	0:15:13	13.6	1.0	0.6	0:14:59	0:09:09
12/8/2013	Sunday	0:24:48	22.0	1.0	0.5	0:23:37	0:11:50
12/9/2013	Monday	0:06:54	9.1	0.8	0.9	0:05:40	0:06:04
12/11/2013	Wednesday	0:06:58	7.2	1.0	0.5	0:06:58	0:03:14
12/15/2013	Sunday	0:05:36	8.0	0.6	0.6	0:03:20	0:03:36
12/16/2013	Monday	0:10:51	9.6	1.0	0.3	0:10:33	0:03:38
12/17/2013	Tuesday	0:19:20	17.1	0.9	0.4	0:17:47	0:08:39
12/27/2013	Friday	0:25:40	22.7	0.6	0.8	0:15:35	0:19:40
12/28/2013	Saturday	0:40:50	36.1	0.5	0.8	0:20:40	0:31:09
12/29/2013	Sunday	0:08:47	7.9	0.8	0.7	0:07:15	0:06:19
12/30/2013	Monday	0:19:16	16.8	0.8	0.8	0:14:28	0:15:22
1/3/2014	Friday	0:08:13	7.3	0.9	0.8	0:07:32	0:06:30
1/4/2014	Saturday	0:42:27	38.0	0.9	0.7	0:39:06	0:30:29
1/6/2014	Monday	0:01:34	1.4	0.5	0.5	0:00:50	0:00:44
1/7/2014	Tuesday	0:01:52	1.6	1.0	0.0	0:01:52	0:00:00
1/8/2014	Wednesday	0:01:06	1.0	1.0	0.0	0:01:06	0:00:00
1/9/2014	Thursday	0:07:33	6.7	0.8	0.3	0:06:24	0:01:58
1/10/2014	Friday	0:09:03	8.0	0.8	0.4	0:07:32	0:03:33
1/13/2014	Monday	0:07:07	6.8	0.9	0.3	0:06:08	0:02:22
1/14/2014	Tuesday	0:07:30	10.2	0.9	0.6	0:07:02	0:04:09
1/15/2014	Wednesday	0:08:11	7.2	0.9	0.3	0:07:46	0:02:05
1/16/2014	Thursday	0:02:05	1.8	0.9	0.2	0:01:51	0:00:26
1/17/2014	Friday	0:03:08	3.3	1.0	0.3	0:03:08	0:00:50
1/20/2014	Monday	0:02:48	2.5	1.0	0.2	0:02:40	0:00:34
1/23/2014	Tuesday	0:10:20	9.5	1.0	0.5	0:10:20	0:04:39
1/31/2014	Friday	0:10:45	9.4	1.0	0.6	0:10:45	0:06:33
2/3/2014	Monday	0:01:10	1.0	1.0	0.3	0:01:10	0:00:20
2/4/2014	Tuesday	0:09:19	8.2	0.9	0.7	0:08:06	0:06:27
2/5/2014	Wednesday	0:05:46	5.1	1.0	0.2	0:05:46	0:01:17
2/6/2014	Thursday	0:15:08	13.2	1.0	0.3	0:15:08	0:05:02
2/7/2014	Friday	0:09:30	8.4	1.0	0.4	0:09:30	0:04:06

Figure 44: Example of the analysis for percent green with blocking from the intersection of Peachtree Road & Lenox Mall entrance.

4.2.5.5. Lost Capacity

The lost capacity analysis can be defined as the capacity that was lost due to the percent of green time with blocking. The percent of capacity lost was also was found by processing the signal timing data along with the blocking data for each intersection. The following steps were used to find the percent of capacity lost:

1. First, a new Excel spreadsheet was created with the following already known variables: Overall Green Time (OGT_i), Total Green Time with Blocking (TGB_{ial}), Percentage of Partial Block Total ($PPBT_i$), Percentage of Full Block Total ($PFBT_i$), Total Partial Blocking Time (TPBT_i), and Total Full Blocking Time (TFBT_i). The Total Green Time Not Blocked ($TGNB_i$) was then calculated as:

$TGNB_i = TGT_i - TGB_i$

2. Next, the Total Overlap Time (TOT_i), Total Partial Blocking Only Time ($TPBOT_i$), and Total Full Blocking Only Time ($TFBOT_i$) were calculated as:

$TOT_i = (TPBT_i + TFBT_i) - TGB_i$

$TPBOT_i = TPBT_i - TOT_i$

$TFBOT_i = TFBT_i - TOT_i$

3. The next step in determining the lost capacity percentage was calculating the Percentage of Partial Blocking Only ($PPBO_i$), Percentage of Full Blocking Only ($PFBO_i$), Percentage of Total Time Not Blocked ($PTTNB_i$), and Percentage of Overlap (PO_i,). These variables were calculated as:

$PPBO_i = TPBOT_i \ / OGT_i$

$PFBO_i = TFBOT_i \ / OGT_i$

$PTTNB_i = TGNB_i \ / OGT_i$

$PO_i = TOT_i \ / OGT_i$

4. Lastly, to determine Percent Lost Capacity for intersection *i* ($LCAP_i$) it is necessary to determine the Intersection specific Saturation flow ($ISAT_i$). The following equation was utilized:

$ISAT_i = PTTNB_i * IdealSAT + PFBO_i * .5 + PPBO_i * (IdealSAT * 0.75) + PO_i * .25$

In this equation it is assumed when an intersection is not blocked it would operate at ideal saturation flow (*IdealSAT*, assumed at 1800 vehicles per hour in this study), when the intersection is fully block only half of the vehicles would be processed (the assumption is that only one lane out of two is fully blocked on a two lane approach), and when the intersection is partially blocked it would operate a 75% of ideal saturation flow (the assumption is that one lane out of two is partially blocked on a two lane approach , meaning some vehicles will be able to bypass the partially blocked lane). The overlap percentage assumes only 25% of saturation flow as both a full block and partial block are being experience. Currently these percent decreases in saturation flow are based on judgment. While these values should be field calibrated the given equation should provide at least reasonable relative approximation of the aggregate saturation flow experienced at the intersection.

5.Finally the percent capacity lost was determined by:

$$LCAP_i = 100 - (ISAT_i / IdealSAT)* 100$$

An example of this analysis can be found in Figure 45 below.

Date	Day of the Week	Overall Green Time	Total Green Time with Blocking	Partial Block %	Full Block %	Total Partial Blocking Time	Total Full Blocking Time	Total Time Not Blocked	Total Overlap Time	Total Partial Blocking Only Time	Total Full Blocking Only Time	% Partial Blocking Only	% Full Blocking Only	% Total Time not Blocked	% Overlap	Saturation Flow for Two Hours	New Saturation Flow	% Capacity Lost
7/22/2013	Saturday	1:52:16	0:15:44	1.0	0.5	0:14:59	0:08:20	1:36:32	0:07:35	0:07:24	0:00:45	0.066	0.007	0.860	0.068	3600	3096	14.0
7/23/2013	Sunday	1:52:13	0:15:13	1.0	0.6	0:14:59	0:09:09	1:37:00	0:08:55	0:06:04	0:00:14	0.054	0.002	0.864	0.079	3600	3112	13.6
12/8/2013	Sunday	1:52:30	0:24:48	1.0	0.5	0:23:37	0:11:50	1:27:42	0:10:38	0:12:58	0:01:11	0.115	0.011	0.780	0.095	3600	2807	22.0
12/9/2013	Monday	1:16:07	0:06:54	0.8	0.9	0:05:40	0:06:04	1:09:13	0:04:50	0:00:50	0:01:14	0.011	0.016	0.909	0.063	3600	3274	9.1
12/11/2013	Wednesday	1:36:34	0:06:58	1.0	0.5	0:06:58	0:03:14	1:29:36	0:03:14	0:03:44	0:00:00	0.039	0.000	0.928	0.033	3600	3340	7.2
12/15/2013	Sunday	1:52:56	0:05:36	0.6	0.6	0:03:20	0:03:36	1:47:20	0:01:20	0:02:00	0:02:16	0.018	0.020	0.950	0.012	3600	3422	5.0
12/16/2013	Monday	1:53:22	0:10:51	1.0	0.3	0:10:33	0:03:38	1:42:31	0:03:20	0:07:13	0:00:18	0.064	0.003	0.904	0.029	3600	3256	9.6
12/17/2013	Tuesday	1:53:02	0:19:20	0.9	0.4	0:17:47	0:08:39	1:33:42	0:07:06	0:10:41	0:01:33	0.095	0.014	0.829	0.063	3600	2984	17.1
12/27/2013	Friday	1:53:04	0:25:40	0.6	0.8	0:15:35	0:19:40	1:27:24	0:09:34	0:06:00	0:10:05	0.053	0.089	0.773	0.085	3600	2783	22.7
12/28/2013	Saturday	1:53:04	0:40:50	0.5	0.8	0:20:40	0:31:09	1:12:14	0:10:59	0:09:41	0:20:10	0.086	0.178	0.639	0.097	3600	2300	36.1
12/29/2013	Sunday	1:51:09	0:08:47	0.8	0.7	0:07:15	0:06:19	1:42:22	0:04:47	0:02:28	0:01:32	0.022	0.014	0.921	0.043	3600	3316	7.9
12/30/2013	Monday	1:54:22	0:19:16	0.8	0.8	0:14:28	0:15:22	1:35:06	0:10:35	0:03:54	0:04:48	0.034	0.042	0.832	0.092	3600	2994	16.8
1/3/2014	Friday	1:53:16	0:08:13	0.9	0.8	0:07:32	0:06:30	1:45:03	0:05:49	0:01:43	0:00:41	0.015	0.006	0.927	0.051	3600	3339	7.3
1/4/2014	Saturday	1:51:33	0:42:27	0.9	0.7	0:39:06	0:30:29	1:09:06	0:27:08	0:11:58	0:03:21	0.107	0.030	0.619	0.243	3600	2230	38.1
1/6/2014	Monday	1:52:49	0:01:34	0.5	0.5	0:00:50	0:00:44	1:51:15	0:00:00	0:00:50	0:00:44	0.007	0.006	0.986	0.000	3600	3550	1.4
1/7/2014	Tuesday	1:53:21	0:01:52	1.0	0.0	0:01:52	0:00:00	1:51:29	0:00:00	0:01:52	0:00:00	0.016	0.000	0.984	0.000	3600	3541	1.6
1/8/2014	Wednesday	1:52:47	0:01:06	1.0	0.0	0:01:06	0:00:00	1:51:41	0:00:00	0:01:06	0:00:00	0.010	0.000	0.990	0.000	3600	3565	1.0
1/9/2014	Thursday	1:52:47	0:07:33	0.8	0.3	0:06:24	0:01:58	1:45:14	0:00:49	0:05:35	0:01:09	0.050	0.010	0.933	0.007	3600	3359	6.7
1/10/2014	Friday	1:53:04	0:09:03	0.8	0.4	0:07:32	0:03:33	1:44:01	0:02:02	0:05:30	0:01:31	0.049	0.013	0.920	0.018	3600	3312	8.0
1/13/2014	Monday	1:44:24	0:07:07	0.9	0.3	0:06:08	0:02:22	1:37:17	0:01:23	0:04:45	0:00:59	0.045	0.009	0.932	0.013	3600	3355	6.8
1/14/2014	Tuesday	1:13:26	0:07:30	0.9	0.6	0:07:02	0:04:09	1:05:56	0:03:41	0:03:21	0:00:28	0.046	0.006	0.898	0.050	3600	3232	10.2
1/15/2014	Wednesday	1:53:17	0:08:11	0.9	0.3	0:07:46	0:02:05	1:45:06	0:01:40	0:06:06	0:00:25	0.054	0.004	0.928	0.015	3600	3340	7.2
1/16/2014	Thursday	1:53:22	0:02:05	0.9	0.2	0:01:51	0:00:26	1:51:17	0:00:12	0:01:39	0:00:14	0.015	0.002	0.982	0.002	3600	3534	1.8
1/17/2014	Friday	1:33:47	0:03:08	1.0	0.3	0:03:08	0:00:50	1:30:39	0:00:50	0:02:18	0:00:00	0.025	0.000	0.967	0.009	3600	3480	3.3
1/20/2014	Monday	1:53:41	0:02:48	1.0	0.2	0:02:40	0:00:34	1:50:53	0:00:26	0:02:14	0:00:08	0.020	0.001	0.975	0.004	3600	3511	2.5
1/23/2014	Tuesday	1:48:52	0:10:20	1.0	0.5	0:10:20	0:04:39	1:38:32	0:04:39	0:05:41	0:00:00	0.052	0.000	0.905	0.043	3600	3258	9.5
1/31/2014	Friday	1:54:12	0:10:45	1.0	0.6	0:10:45	0:06:33	1:43:27	0:06:33	0:04:12	0:00:00	0.037	0.000	0.906	0.057	3600	3261	9.4
2/3/2014	Monday	1:53:01	0:01:10	1.0	0.3	0:01:10	0:00:20	1:51:51	0:00:20	0:00:50	0:00:00	0.007	0.000	0.990	0.003	3600	3563	1.0
2/4/2014	Tuesday	1:53:38	0:09:19	0.9	0.7	0:08:06	0:06:27	1:44:19	0:05:14	0:02:52	0:01:13	0.025	0.011	0.918	0.046	3600	3305	8.2
2/5/2014	Wednesday	1:53:06	0:05:46	1.0	0.2	0:05:46	0:01:17	1:47:20	0:01:17	0:04:29	0:00:00	0.040	0.000	0.949	0.011	3600	3416	5.1
2/6/2014	Thursday	1:54:20	0:15:08	1.0	0.3	0:15:08	0:05:02	1:39:12	0:05:02	0:10:06	0:00:00	0.088	0.000	0.868	0.044	3600	3124	13.2
2/7/2014	Friday	1:53:12	0:09:30	1.0	0.4	0:09:30	0:04:06	1:43:42	0:04:06	0:05:24	0:00:00	0.048	0.000	0.916	0.036	3600	3298	8.4

Figure 45: Example of the analysis for capacity lost from the intersection of Peachtree Road & Lenox Mall entrance.

4.2.5.6. Pedestrian Safety Analysis

A pedestrian safety analysis was conducted for the intersections of Lenox Mall entrance, Highland Drive, and Stratford Road. The Lenox Mall entrance intersection was selected because it is in close proximity to Lenox Mall where significant pedestrian activity observed. The intersections of Stratford Road and Highland Drive were chosen because of the high density of work related pedestrian traffic. Blocking sessions for each video for these intersections were reviewed for potential pedestrian hazards.

When a pedestrian was considered in a potentially hazardous situation they were recorded. After each day the sum of pedestrians in potentially hazardous situations were summed to give an outlook of how many pedestrians were put in an potentially unsafe situation by a blocking vehicle. A pedestrian was considered in a potentially unsafe situation when they had the right of way to cross the intersection and a vehicle was in the process of blocking the intersection. This situation is considered potentially dangerous because a vehicle blocking the intersection can present blind spots to both drivers and pedestrians, increasing the likelihood of a collision. An example of this situation can be seen in Figure 46 and 47 below. Several blocking vehicles and two pedestrians with a baby stroller can be seen crossing Peachtree Road at the Lenox Mall entrance intersection in Figure 46. This is a potentially dangerous situation because the sliver car in NB-3 cannot see the pedestrians because of the black SUV. Figure 47 shows that when the silver car accelerated to stop blocking it almost hit the pedestrians.

Figure 46: Pedestrians crossing Peachtree Road with several vehicles blocking the intersection.

Figure 47: Pedestrians almost being hit by a blocking vehicle that was vacating the intersection.

4.2.5.7. Probability Blocker will Change Lanes to End Block

When a blocker was in the act of blocking and moved out of the way to stop blocking the intersection (i.e. vehicles that changed lanes and did not stop blocking were not counted), it was defined as a blocker changing lanes while within a block. The potential that a blocking vehicle stopped blocking by changing lanes was tentatively identified when a blocking vehicle had different entry and exit lanes. For each identified instance of a vehicle with different entry and exit lanes the intersection video was revisited to evaluate when and where blockers decided to change lanes while blocking to end the block. Once the number of blockers that changed lanes and the total number of blockers was known, the probability of a blocker changing lanes could be calculated for each intersection.

4.2.5.8. Driver Characteristics

Driver characteristics, such as the tendency to block an intersection, were explored at the intersection of 10th Street & Williams Street. This analysis was important because by understanding different situations in which a driver could be in during actions of blocking and non-blocking a better understanding of how to stop potential blocking could be explored. Four vehicle behaviors were identified under the actions of blocking and non-blocking in the analysis of driver characteristics. Two behaviors were found related to blocking. The first behavior under the action of blocking was vehicles that enter on the green indication and stopped in the intersection. The second behavior under the action of blocking was vehicles that stop at the stop bar during the green indication, enter the intersection on the yellow indication, and blocked the intersection. To identify these behaviors the video for identified blocks was reviewed.

Two behaviors were also found for the action of non-blocking. The first behavior under the action of non-blocking was found for the vehicles that stop at the stop bar during the green indication, enter the intersection as the green or yellow indications elapses, and do not block the intersection. That is, vehicles that stopped at the stop bar to avoid potential blocking but where able to enter during the same green phase due to clearing of the intersection. The second behavior under the action of non-blocking was found for the vehicles that stop at the stop bar, do not enter the intersection during the current cycle, and do not block the intersection. For this behavior the video was reviewed for all vehicles that stopped at the stop bar during a green phase.

4.3 Summary of Data Processing Methodology

How blocking the box was defined in this project was stated as the following:

1. The vehicle must enter a predefined box within the intersection,
2. The vehicle must be stopped (or nearly stopped),
3. There must be an conflicting approach for the vehicle to be blocking (vehicle presence in the conflicting approach is not required), and
4. The conflicting approach, that is being blocked, must have a green indication on its signal head.

Next, detailed steps on how to use the Video analyzer tool was described. These steps included how the grid was created and used to record the initial data. The initial data that came from the VideoAnalyzer program was the start time of the block, the end time of the block, the entry cell of the blocker, and the exit cell of the blocker. Signal interval timestamps were also recorded by the VideoAnalyzer tool during the first phase of data reduction. After the initial data was collected a second phase of data reduction was conducted by reviewing the video recording for each intersection and day. The second phase of data reduction consisted of finding the number of blocks, filling in missing data, determining the duration of each blocking session, concluding the conflicting approaches and lane, collecting signal data, and verifying the degree of each block. Lastly, a final analysis of data was conducted, which included a temporal analysis, distribution of conflicting approach and lane blocks, partial and full block analysis, percent of green time with blocking, lost capacity, pedestrian safety analysis, probability a blocker will change lanes to stop blocking, and driver characteristics.

CHAPTER 5

RESULTS

This chapter discusses the results of the DBTB study, including, the findings and analysis for each intersection, along with the survey results.

5.1. Don’t Block the Box Data

The impact that blocking an intersection can have on traffic operations becomes more prominent as the number of blocks increases, the percentage of green time with blocking increases, and the percent of capacity lost increases. The primary objectives of the DBTB study were the following:

1. Determine if the number of blocks increases during the peak hour and holiday season when compared to normal operations.

2. Establish if the percentage of green time with blocking increases during the holiday season when compared to normal operations.

3. Determine if the percentage of green time with blocking results in a substantial percentage of capacity lost.

The secondary objectives of the DBTB study were as follows:

1. Determine if the minor approach causes most of the blocking in any given intersection.

2. Conclude if certain approaches and lanes get blocked more often.

3. Check if there are more partial blocks when compared to the amount of full blocks

5.1.1. Data Collection Time Frame for Each Intersection

DBTB data was collected for each intersection within this project. The data collection dates for each intersection depended on the availability of preferred PTZ camera angles and data processing resources. The original presets of the GDOT PTZs restricted the amount of usable DBTB data and new presets had to be created with the permission of GDOT in order to obtain the optimal viewing angle (center of the intersection). The duration of DBTB data collection for each intersection within this project is listed below. Data collection days were typically not consecutive but split over a several month period (i.e. July 2013 to February 2014).

- Peachtree Road & Mathieson Drive (14 weekdays)
- Peachtree Road & Piedmont Road (9 weekdays)
- Peachtree Road & Highland Drive (7 weekdays)
- Peachtree Road & Stratford Road (7 weekdays)
- Peachtree Road & Lenox Mall entrance (31 weekdays)
- 10^{th} Street & Williams Street (3 weekdays)
- Riverside Drive & Heards Ferry Road (4 weekdays)

It should also be noted that during each day of data collection video was recorded for two hours (4:30 P.M. to 6:30 P.M.) during the peak for each day. Each weekday (Sunday through Saturday) was represented at least once during the collection of the DBTB data. Again, because of the PTZ restrictions most of the DBTB data was collected during the week (Monday through Friday) and in the time frame of 3 to 14 days. However, the intersection of Peachtree Road & Lenox Road's PTZ original preset allowed for more data to be collected, including weekend

(Saturday and Sunday) data. As for the other intersections, the GDOT preset was set at an angle to capture the queues on the major approaches (northbound and southbound) and not the center of the intersection. This resulted in new presets being created for these intersections and a lower number of days with data collection.

5.1.2. Number of Blockers

<u>5.1.2.1 Findings</u>

The total number of blocks for each intersection from 4:30 P.M. to 6:30 P.M. can be seen in Figure 48 below.

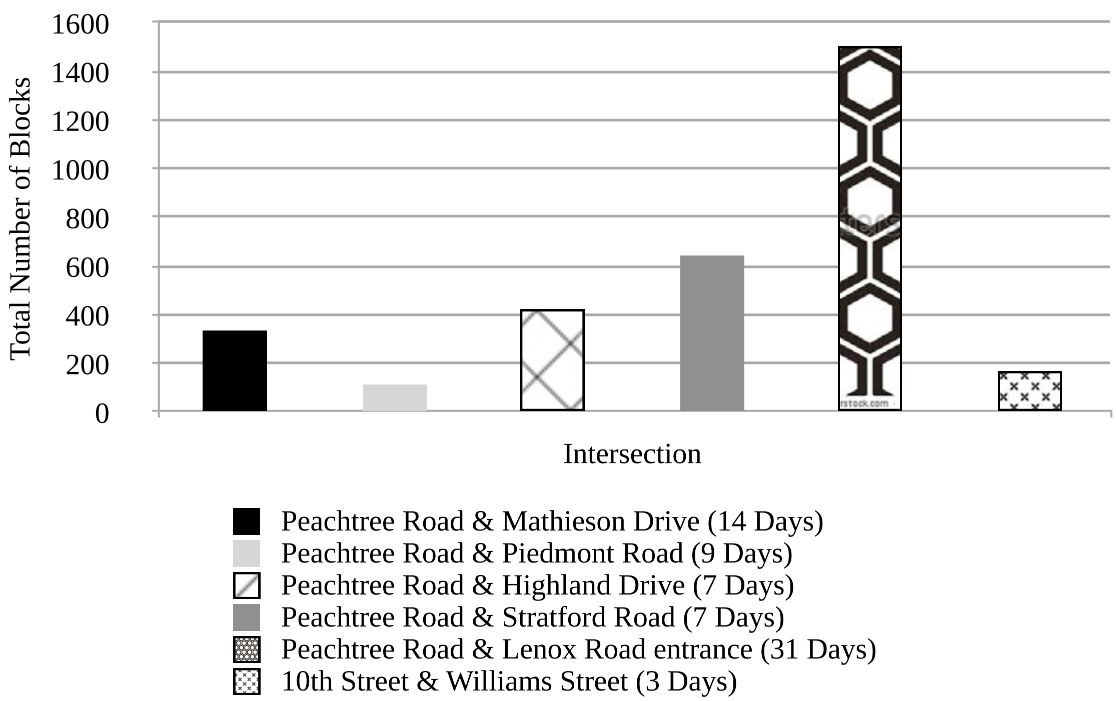


Figure 48: Total number of blocks for each intersection.

Figure 49 to 54 shows the number of blocks and the degree of block for each day of analysis for each intersection.

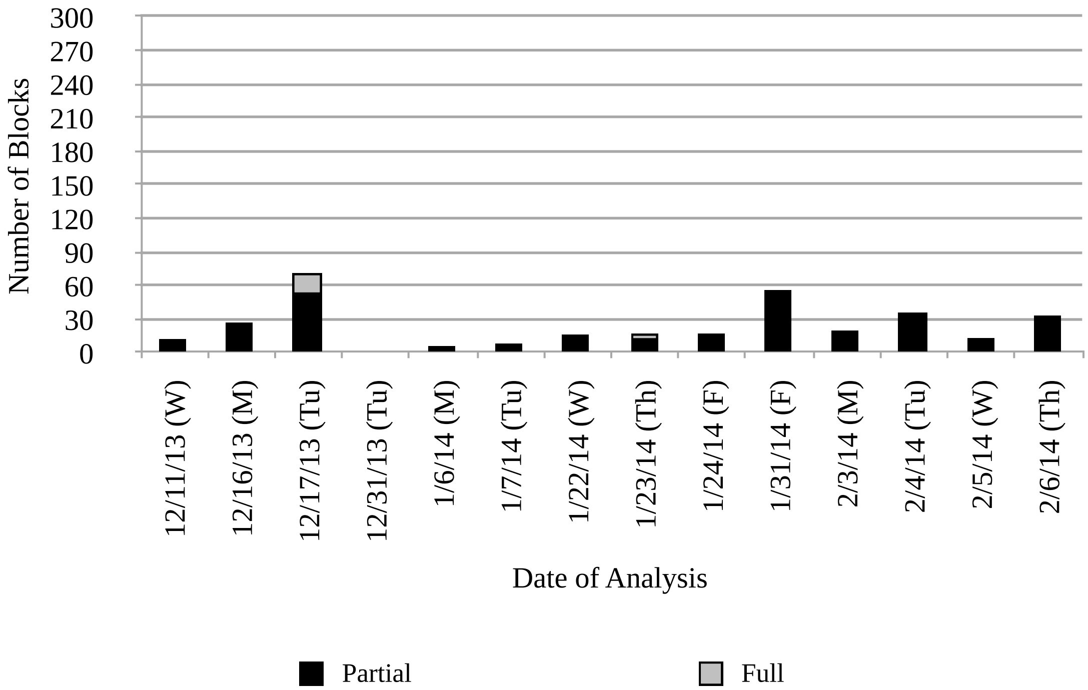


Figure 49: Number of blockers for each date of analysis at Peachtree Road & Mathieson Drive.

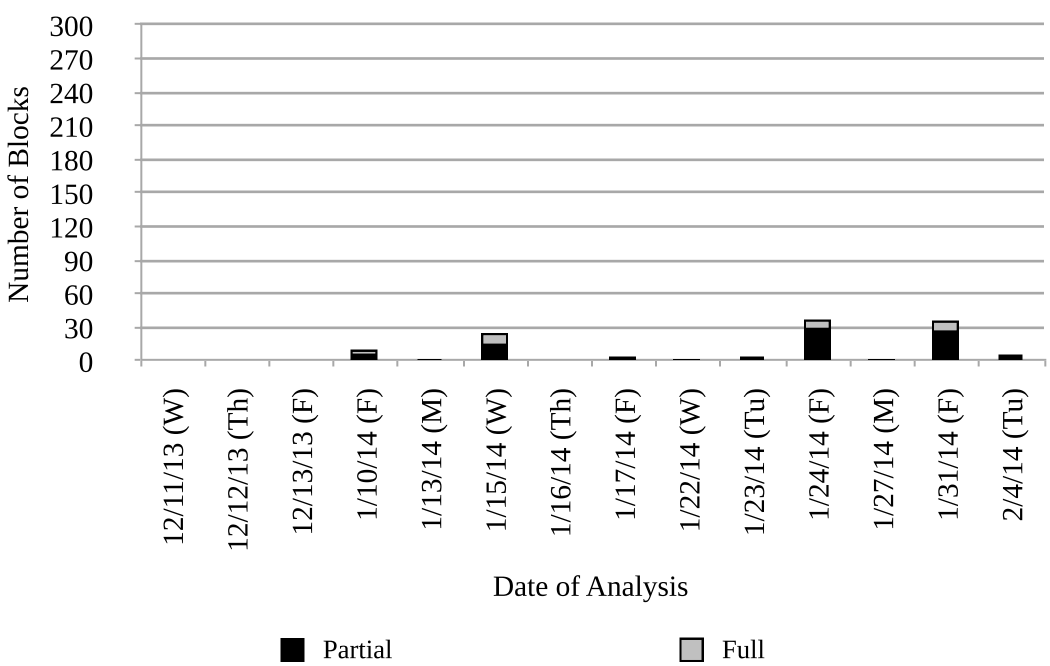


Figure 50: Number of blockers for each date of analysis for Peachtree Road & Piedmont Road.

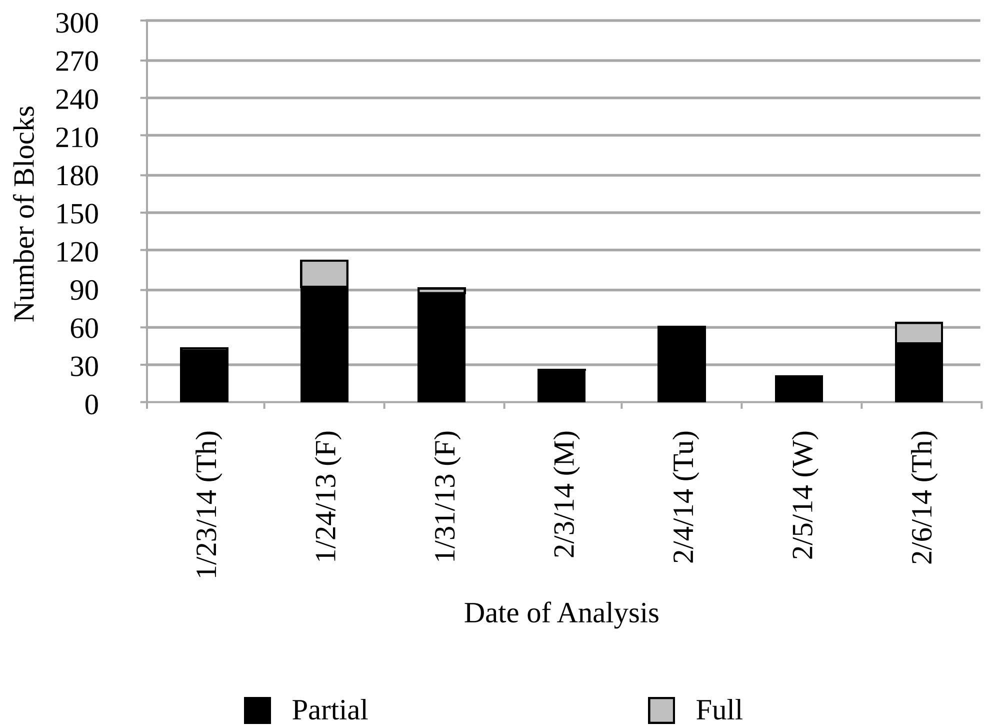


Figure 51: Number of blockers for each date of analysis for Peachtree Road & Highland Drive.

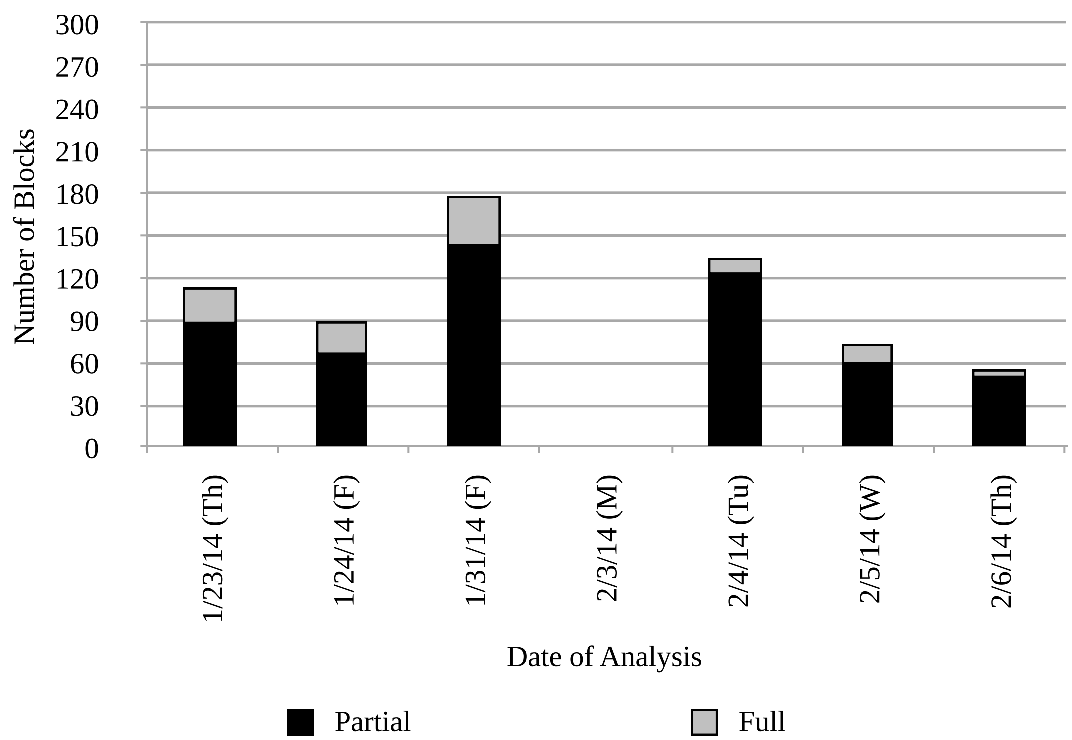


Figure 52: Number of blockers for each date of analysis for Peachtree Road & Stratford Road.

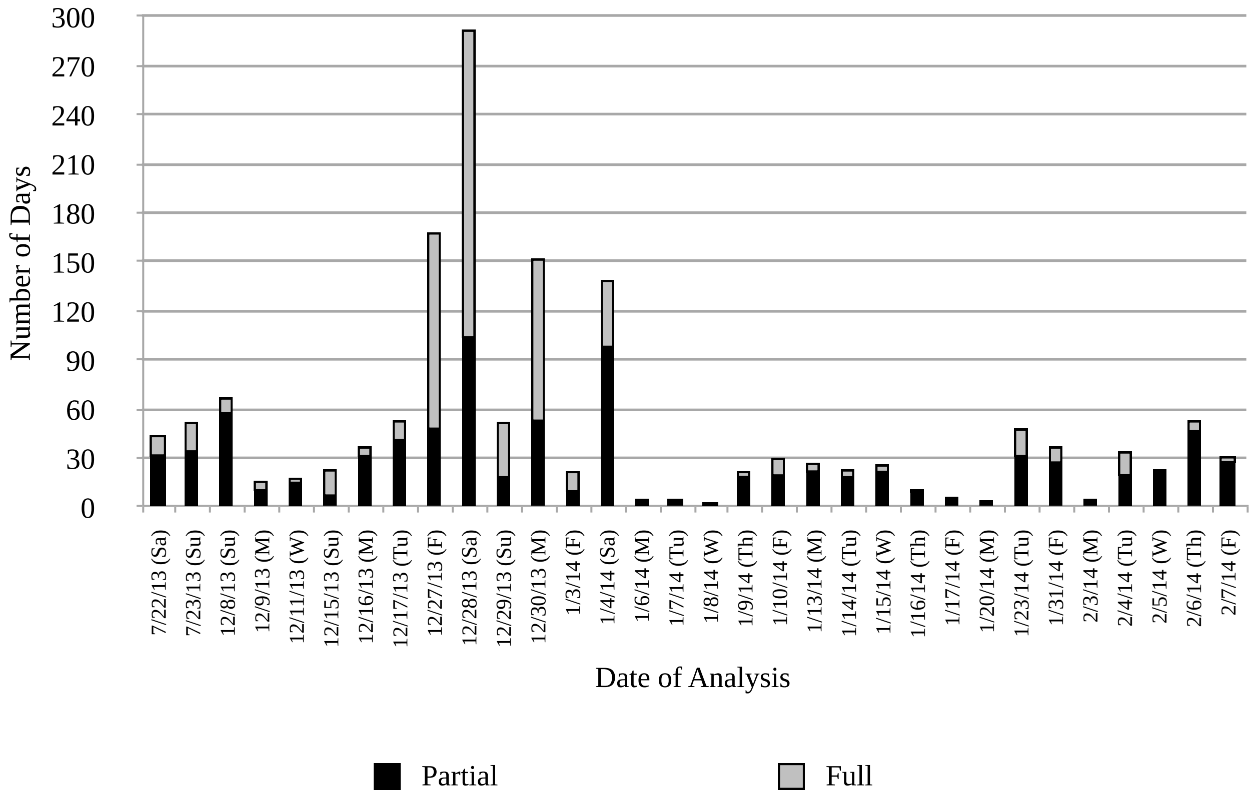


Figure 53: Number of blockers for each date of analysis for Peachtree Road & Lenox Mall entrance.

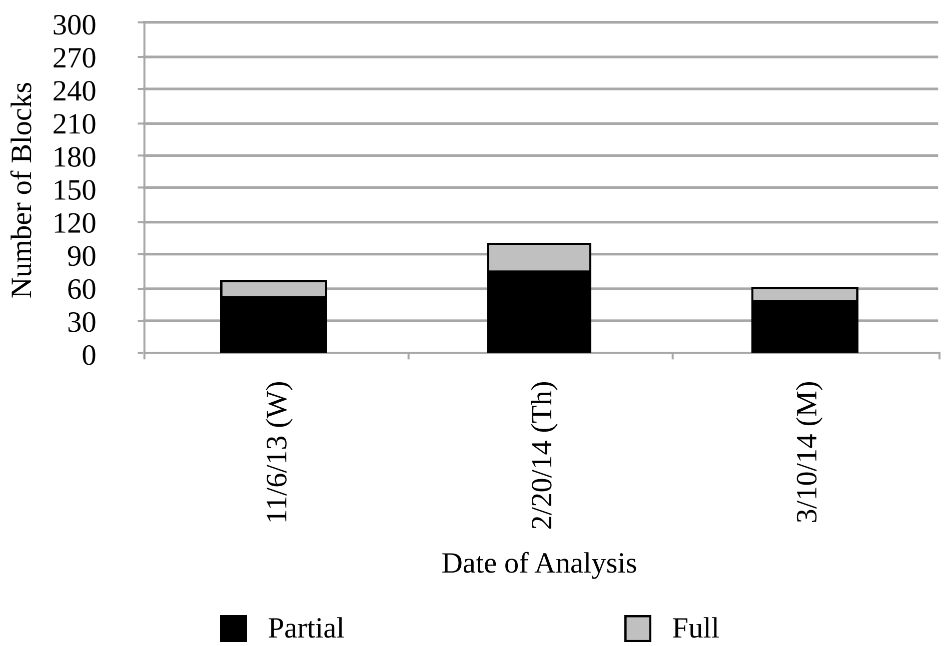


Figure 54: Number of blockers for each date of analysis for 10th Street & Williams Street.

5.1.2.2. Analysis

The main observation that can be taken away from this section was that different blocking behaviors were observed during the holiday season when compared to normal conditions. It must be noted that the increase in blocking during the holiday season could be tied to an increase in the traffic volume, however, volume data is needed to support this claim. The rest of this section will specify the details that led to this observation.

First and foremost, caution must be exercised as the data mixes before and after the Christmas and News Years holiday season, potentially biasing the daily data at the intersections of Peachtree Road & Mathieson Drive, Peachtree Road & Piedmont Road, and Peachtree Road & Lenox Mall entrance. Overall there was an increasing trend in the number of blocks from the beginning of December until Christmas Day for these intersections. The highest amount of total blocks for a given day was recorded during this span of time on December 28th, 2013 with 292 blocks at the intersection of Peachtree Road & Lenox Mall entrance. After Christmas day there were several days with high amount of blocks, however, generally there was a decline in the number of blocks until New Year's Day.

In Figures 49, 50, and 51, it is seen that after the New Year's holiday there was considerably lower number of blocks through the beginning of January. The assumption for this lower block total was that some people are still on holiday, including students, and traffic volumes tend to be lower on these days resulting in a lower amount of blocks. Later in January and the following month there was a rise in the number of blocks until what seemed to be normal traffic operations (i.e. no major holidays) for these intersections.

An important date to point out is January 31st, 2014. This date was two days after the snow storm that hit Atlanta, Georgia (SnowJam 14'). All the public schools and many workplaces were closed from January 28th, 2014 to January 30th, 2014 because of the storm. On January 31st a majority of businesses and some schools reopened. Several intersections had high number of blocks on this day which may be storm related.

The intersections that did not have data collected during the Christmas and New Year's holiday season had a limited amount of DBTB data because of the previously stated restrictions with the PTZ cameras. In the case of Peachtree Road & Highland Drive and Peachtree Road & Stratford Road the data was collected at the end of January and the beginning of February. The data that was collected at the beginning of February was during the span of an entire week and overall the days with the highest traffic volume and blocking sessions were on Tuesdays, Thursdays, and Fridays. Caution must also be exercised in drawing trends as the data collection days have a small sample size. These trends can be observed in Figures 51 and 52. When referring to Figure 54 it can be seen that February 20th, 2014 had the most blocks for the intersection of 10th Street and Williams Street with 101 blocks. However, because of the limited amount of data a better analysis of the number of blocks over an extended period of time could not be established.

In general most of the intersection's blocks (70% to 100%) were classified as partial. However, 16 days experienced a majority of full blocks (within the range of 28% to 100 %). Most of the previously stated 16 days were found to be during the Christmas holiday season at the Peachtree Road & Lenox Mall entrance intersection.

5.1.3. Temporal Analysis of Blocking

5.1.3.1 Findings

A temporal analysis of the average number of blocks was also conducted to determine when the highest number of blocks occurred during the two hour data collection period. Figures

55 through 60 below show the average number of blockers, during each intersection's respective analysis period, categorized into each 15 minute time period during the two hour peak.

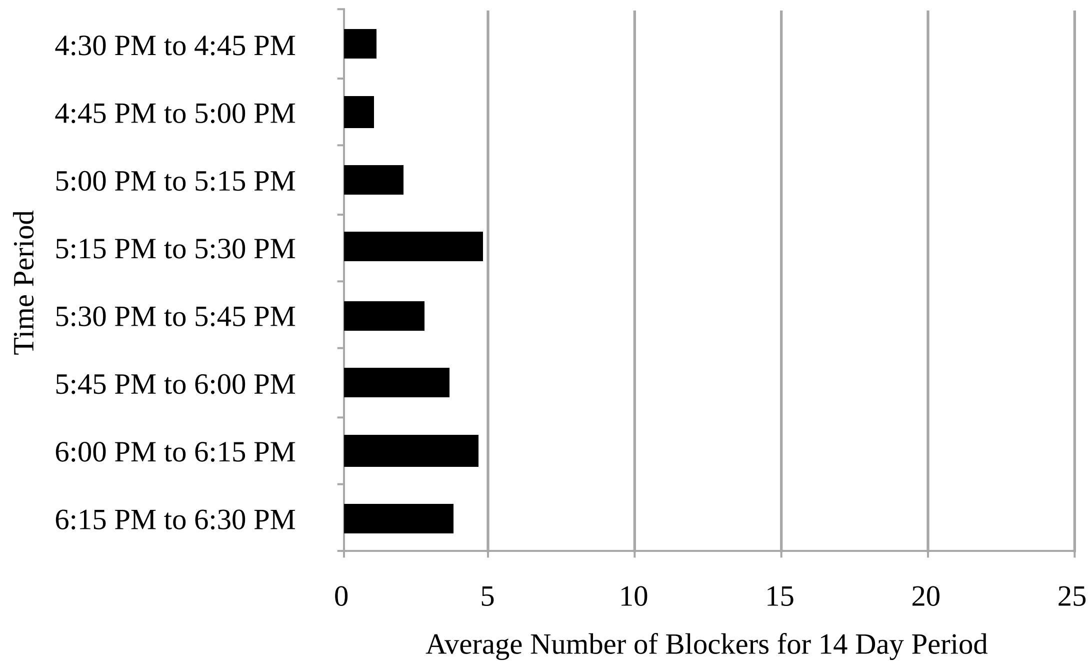


Figure 55: Temporal analysis for Peachtree Road & Mathieson Drive.

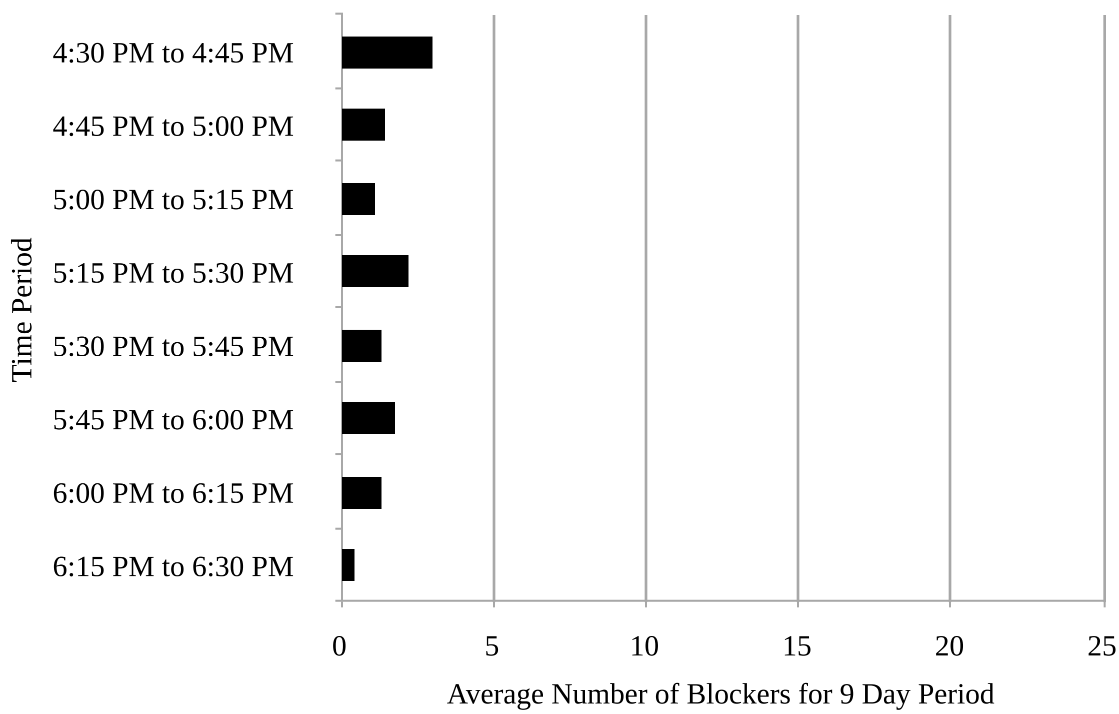


Figure 56: Temporal analysis for Peachtree Road & Piedmont Road.

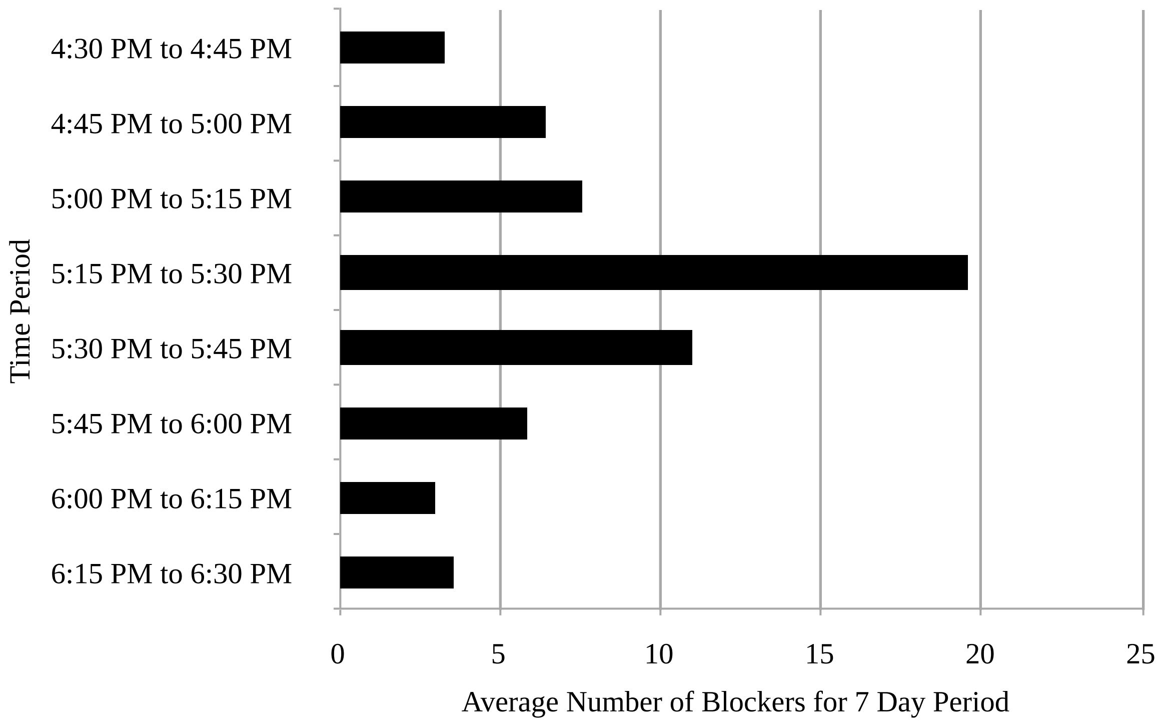


Figure 57: Temporal analysis for Peachtree Road & Highland Drive.

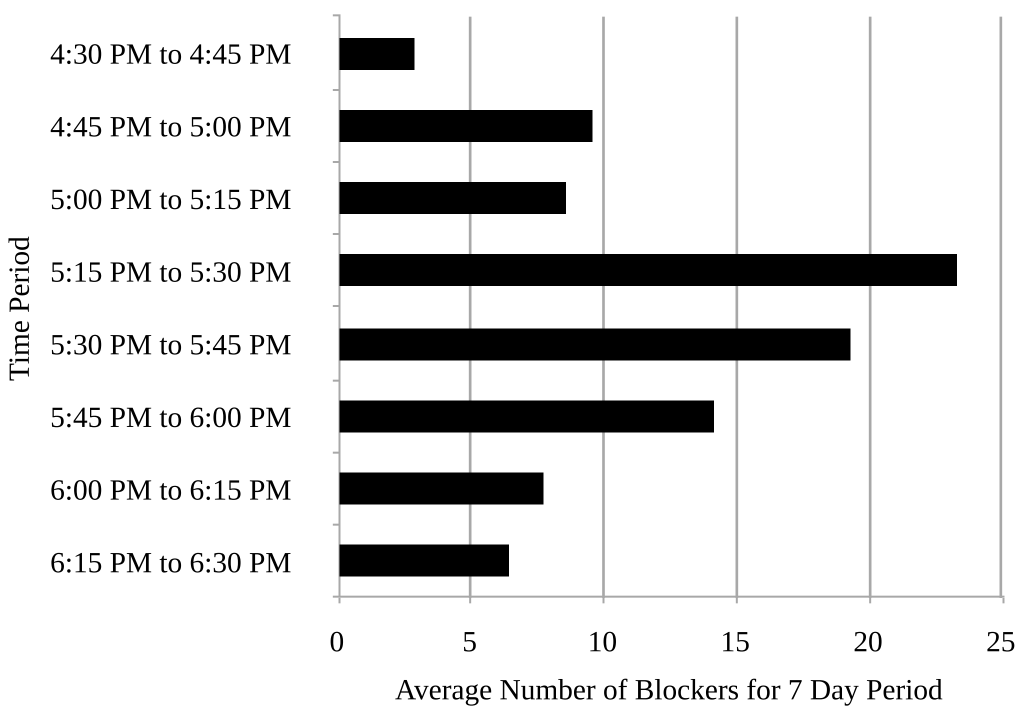


Figure 58: Temporal analysis for Peachtree Road & Stratford Road.

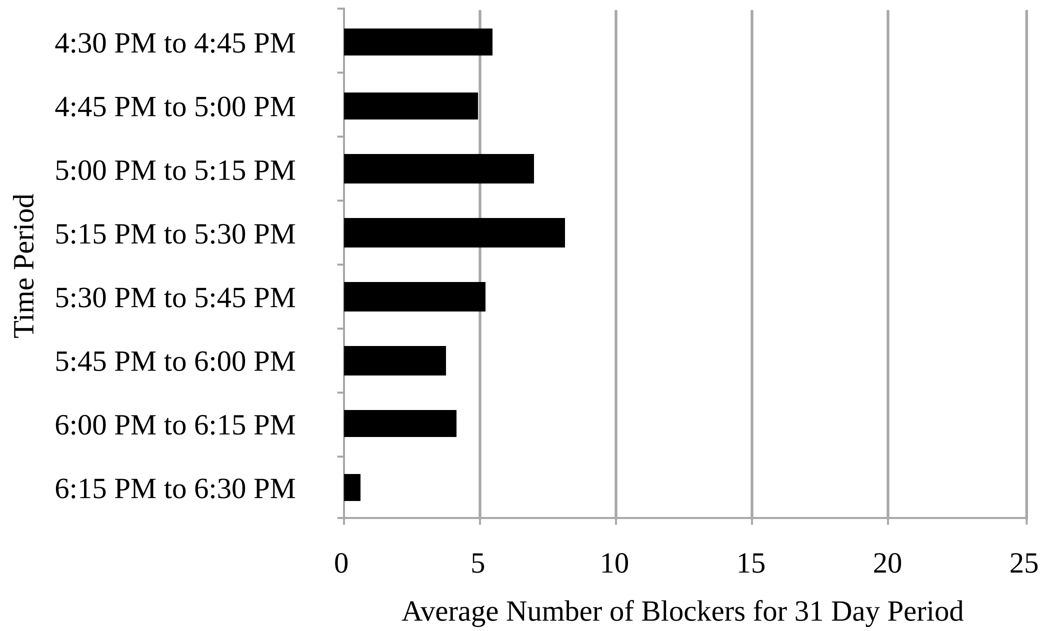


Figure 59: Temporal analysis for Peachtree Road & Lenox Mall entrance.

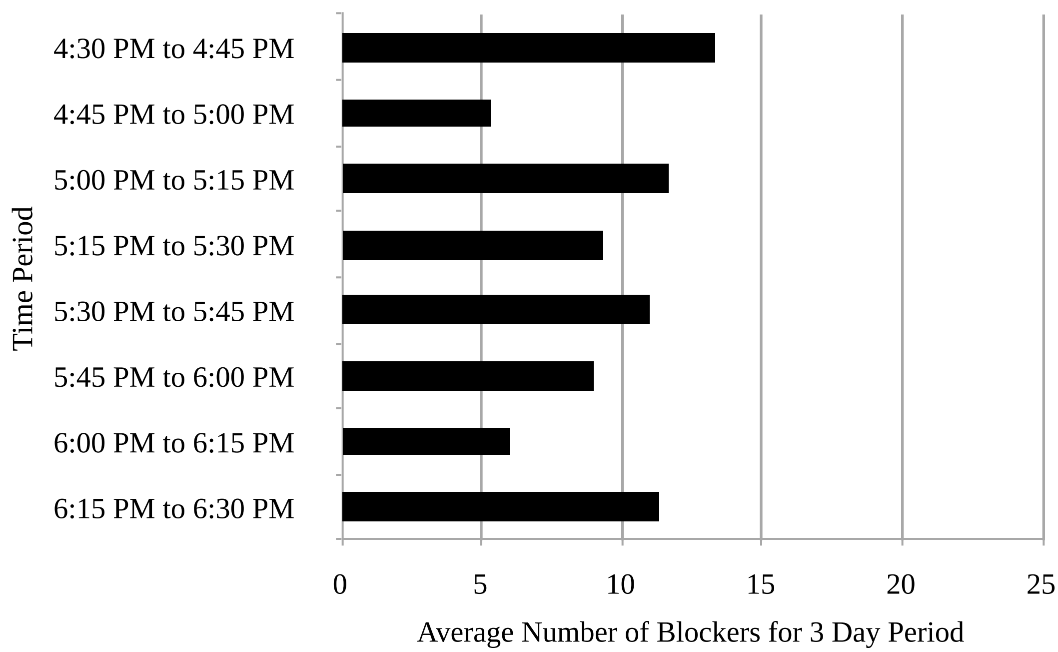


Figure 60: Temporal analysis for 10th Street & Williams Street.

5.1.3.2. Analysis

The main observation that can be taken away from this section was that there was a peaking of blockage during the middle of the two hour peak of 4:30 P.M. to 6:30 P.M.. The rest of this section will specify the details that led to this observation.

The time period with the highest average number of blocks, excluding the intersections of Peachtree Road & Piedmont Road and 10th Street & Williams Street, was between 5:15 and 5:30 P.M., with on average a range of 5 to 23 blocks. This trend can be observed in Figures 55, 57, 58, and 59. In general, also seen from Figures 55, 57, 58, and 59 it was observed that there was an increase in the average number of blocks from 4:30 to 5:30 P.M. and between 5:30 P.M and 6:30 P.M. the average number of blocks decreased. Generally, it would appear as traffic transitioned into the peak hour the likelihood of blocking increased with some consistency during the peak.

However, there were some intersections did not follow the general trend stated above. The intersection of Peachtree Road & Piedmont Road had the highest average number of blocks during its 9 day period between 4:30 and 4:45 P.M., with an average of 3 blocks, as seen in Figure 56. The intersection of 10th Street & Williams Street also had the highest average number of blocks during its 3 day analysis period was between 4:30 and 4:45 P.M., with an average of 13.3 blocks, as seen in Figure 60. Unfortunately, with the limited sample size for these intersections meaningful trends cannot be drawn for these particular intersections at this level of disaggregation.

5.1.4. Percent Green Time with Full and Partial Blocking

5.1.4.1 Findings

The amount of green time during which blocking occurred was also recorded. Table 2 below shows a summary of the total green time with blocking for each intersection within this project. Table 2 includes information on the total green time, the total green time that experienced blocking, the overall percentage of green time that experienced blocking, total time due to partial blocking, total time due to full blocking, average amount of green time due to partial blocking, and average amount of green time due full blocking that was experienced each day (i.e. each two hour peak).

Table 2: Summary of green time with blocking for each intersection within the project.

Intersection	Total Analysis Period (days/ minutes)	Total Green Time	Total Green Time that Experienced Blocking	Overall Percent of Green Time that Experienced Blocking	Total Partial Blocking Time	Total Full Blocking Time	Average Green time lost due to Partial Blocking Each 2 hr Period	Average Green time lost due to Full Blocking Each 2 hr Period
Peachtree Rd. & Mathieson Dr.	(14/ 20,160)	1468 minutes and 50 seconds	82 minutes and 48 seconds	5.6%	69 minutes and 1 second	13 minutes and 48 seconds	4 minutes and 56 seconds	0 minutes and 59 seconds
Peachtree Rd. & Piedmont Rd.	(11/ 15,840)	881 minutes and 24 seconds	22 minutes and 34 seconds	2.5 %	17 minutes and 41 seconds	4 minutes and 53 seconds	1 minute and 58 seconds	0 minutes and 33 seconds
Peachtree Rd. & Highland Dr.	(7/ 10,080)	671 minutes and 5 seconds	73 minutes and 14 seconds	10.9 %	67 minutes and 29 seconds	5 minutes and 45 seconds	9 minutes and 38 seconds	0 minutes and 49 seconds
Peachtree Rd. & Stratford Rd.	(7/ 10,080)	698 minutes and 57 seconds	120 minutes and 34 seconds	17.2 %	80 minutes and 15 seconds	40 minutes and 19 seconds	11 minutes and 28 seconds	5 minutes and 46 seconds
Peachtree Rd. & Lenox Mall entrance	(31/ 44,640)	3492 minutes and 34 seconds	360 minutes and 32 seconds	10.3 %	240 minutes and 55 seconds	109 minutes and 32 seconds	8 minutes and 13 seconds	3 minutes and 32 seconds
10th Street & Williams Street	(3/ 4,320)	319 minutes and 6 seconds	139 minutes and 9 seconds	43.6%	105 minutes	34 minutes and 9 seconds	35 minutes	11 minutes and 23 seconds

Figures 61 through 67 show the percent of green time that experienced blocking for each day of the analysis along with information regarding on the percentage of green time with blocking that was partial or fully blocked.

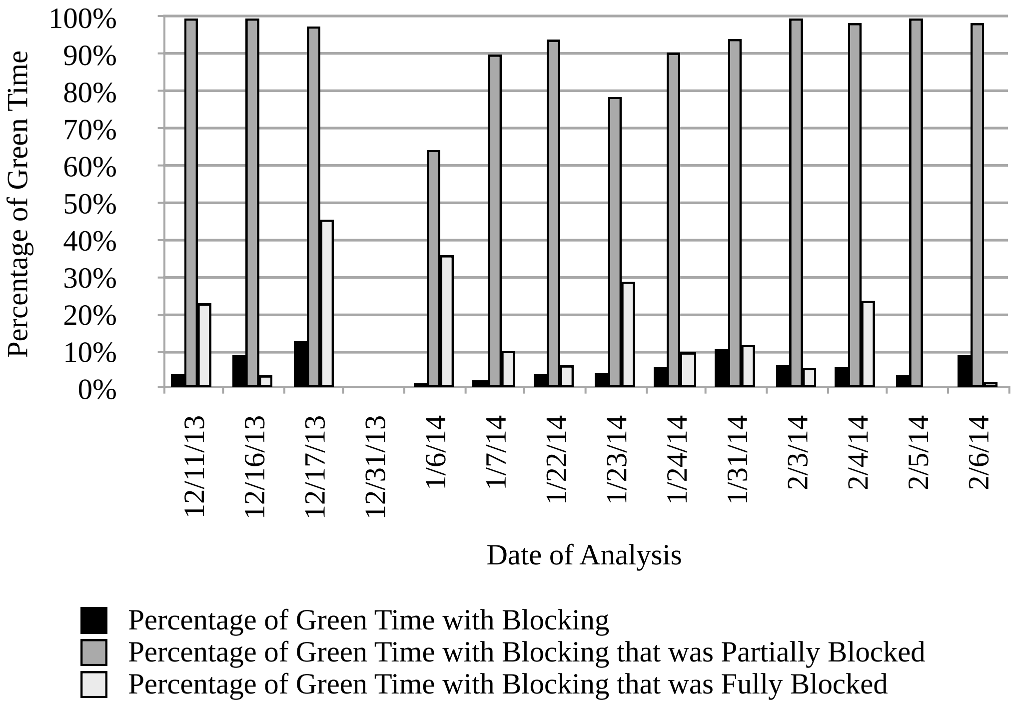


Figure 61: Percent of green time that experienced blocking for each day of analysis at Peachtree Road & Mathieson Drive.

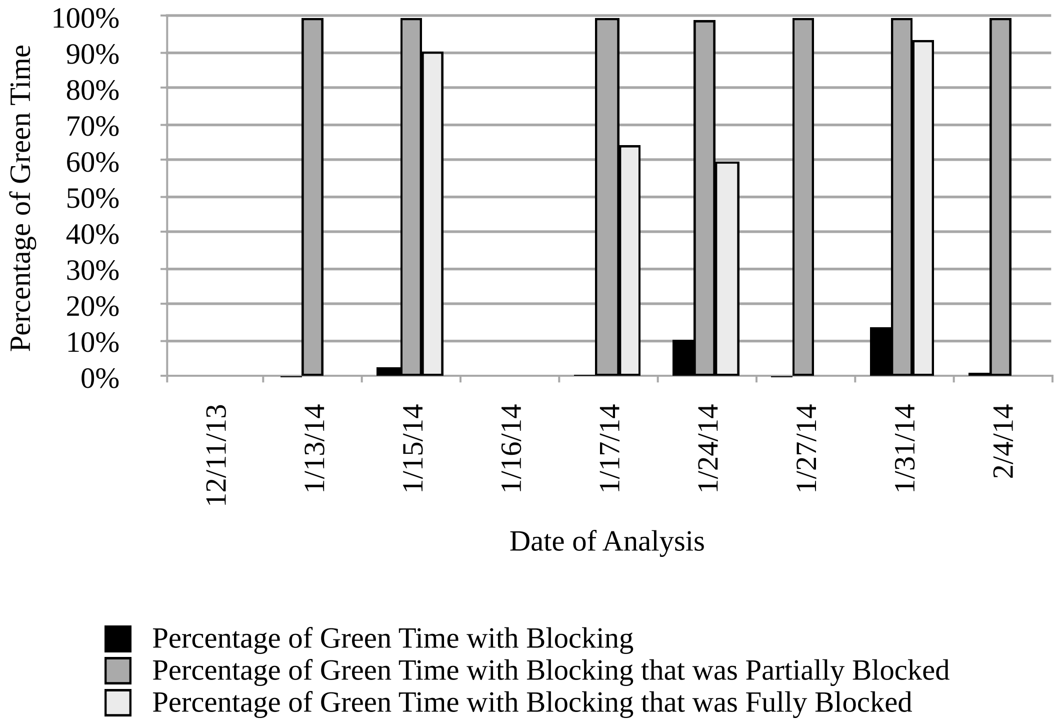


Figure 62: Percent of green time that experienced blocking for each day of analysis at Peachtree Road & Piedmont Road.

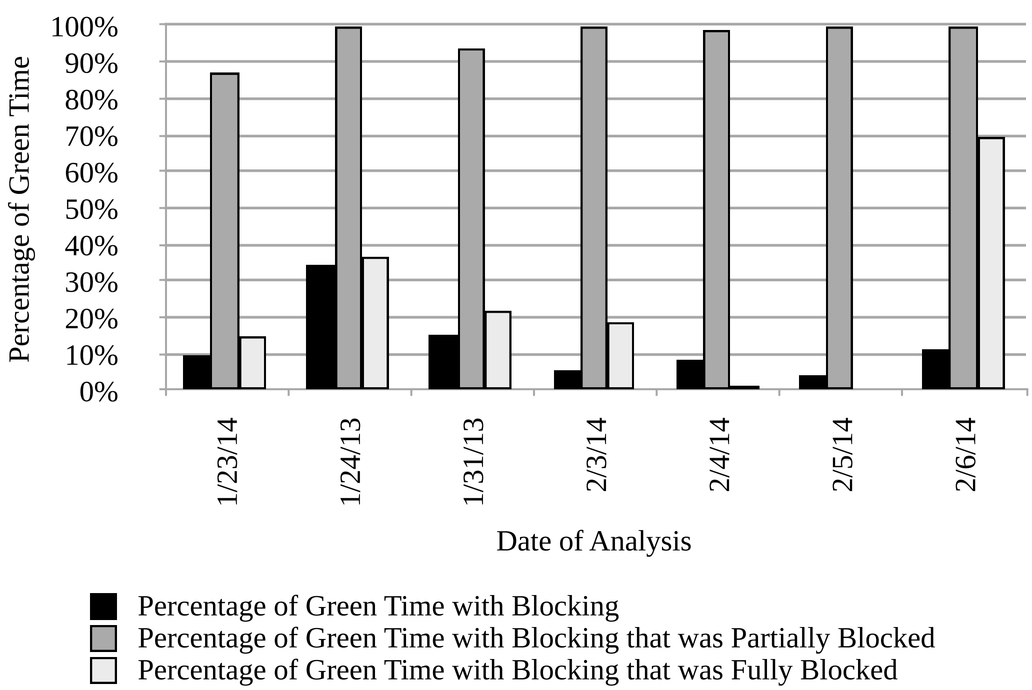


Figure 63: Percent of green time that experienced blocking for each day of analysis at Peachtree Road & Highland Drive.

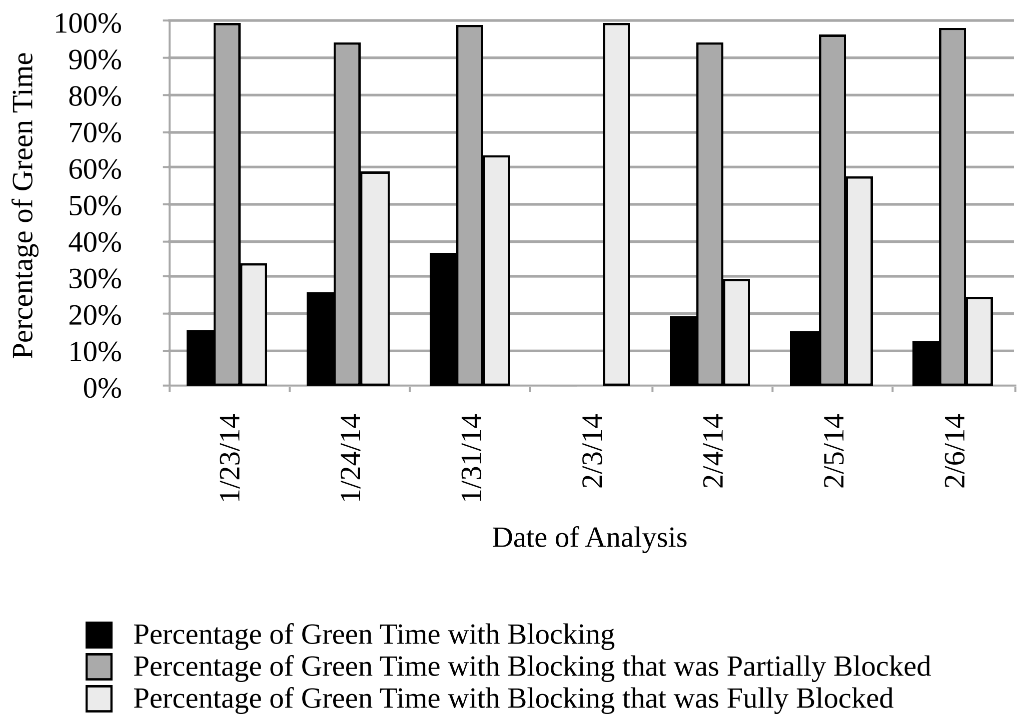


Figure 64: Percent of green time that experienced blocking for each day of analysis at Peachtree Road & Stratford Road.

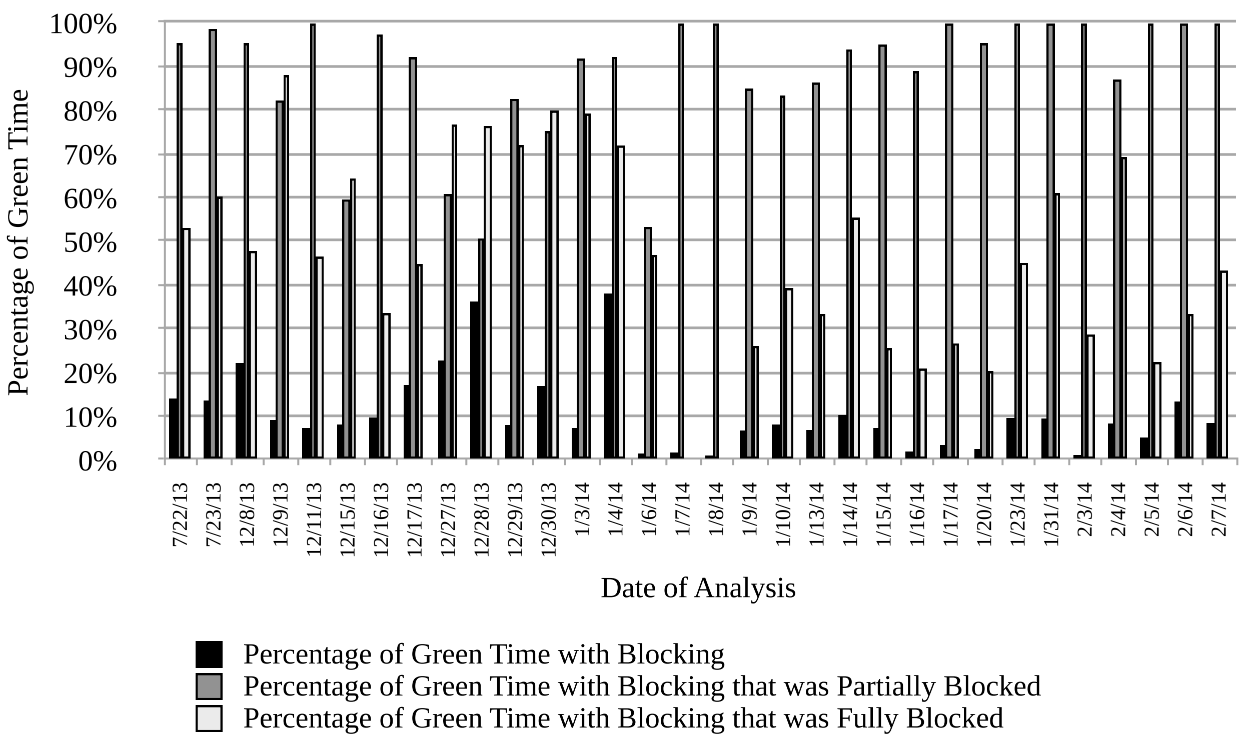


Figure 65: Percent of green time that experienced blocking for each day of analysis at Peachtree Road & Lenox Mall entrance.

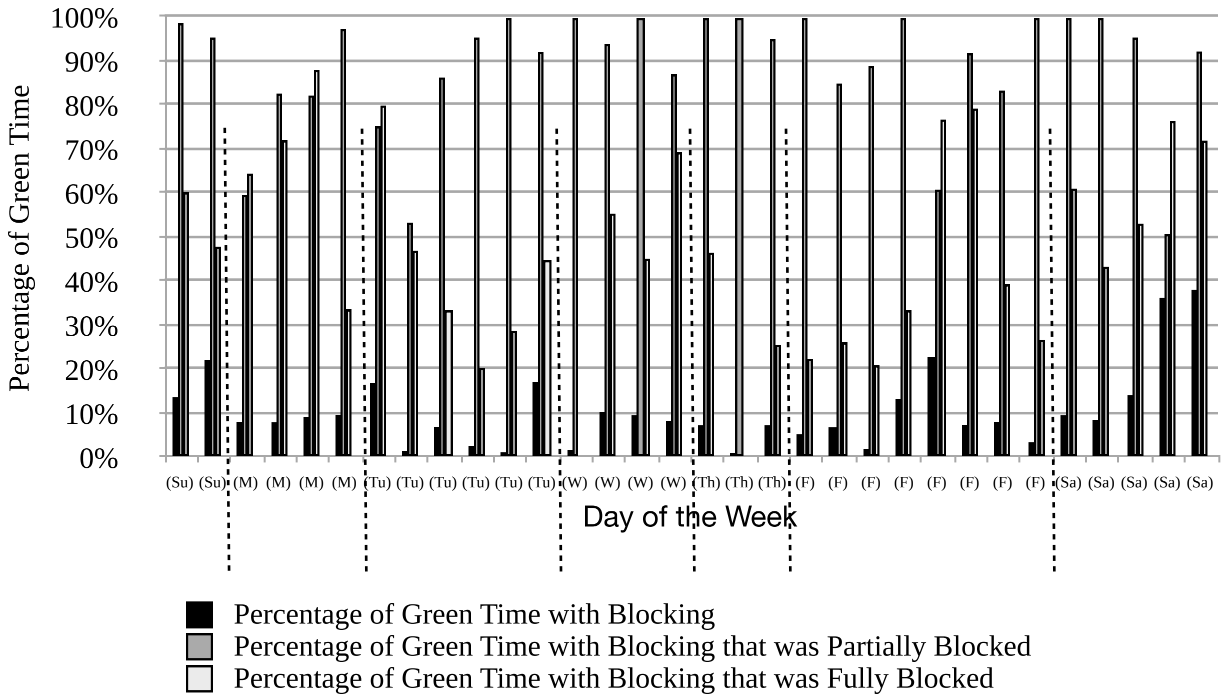


Figure 66: Weekday breakdown of percent of green time that experienced blocking for Peachtree Road & Lenox Mall entrance.

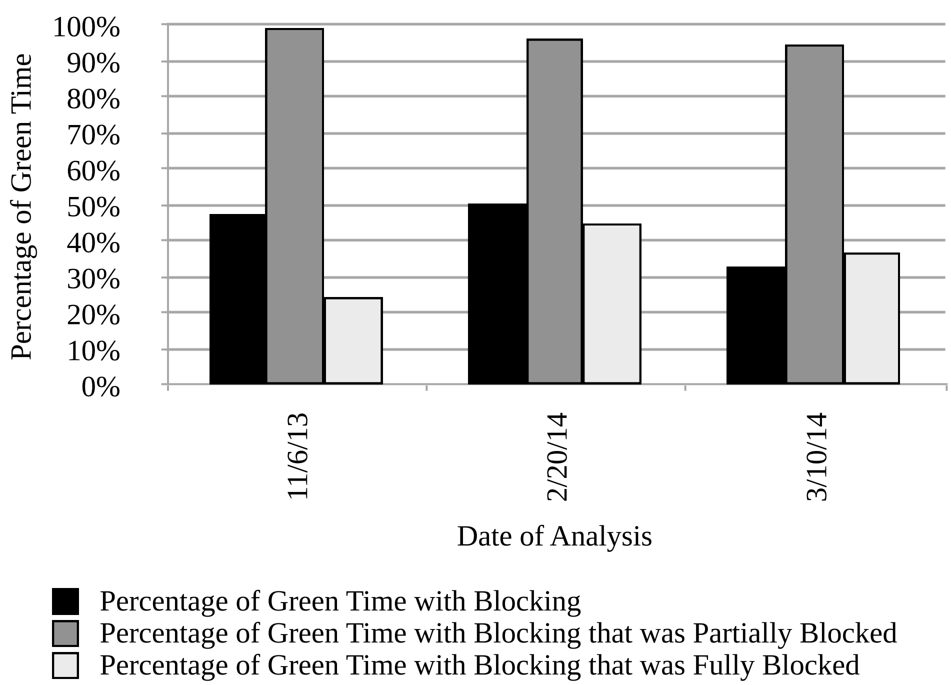


Figure 67: Percent of green time that experienced blocking for each day of analysis at 10th Street & Williams Drive.

5.1.4.2 Analysis

The main observation that can be taken away from this section was that there was a difference in the trend of blocking behavior over the holiday season when compared to the trends observed under normal conditions. Again, the increase in green time with blocking could be related to an increase in traffic volume during the holiday season, however, without the volume data this claim is just an assumption. Another important observation is that the percentage of green time with partial blocking was consistently in the range of 90% to 100% for each intersection, while the percentage of green time with full blocking showed greater variability (ranges from 0% to 100%). The rest of this section will specify the details that led to this observation.

Table 2 above shows that the intersection of 10th Street & Williams Street had the highest overall percentage (43.6%) of green time with blocking, with daily ranges from 33.1% to 50.6%. The next highest overall percentage of green time with blocking was 17.2% for the intersection of Peachtree Road & Stratford Road, with daily ranges from 0.1% to 36.7%. These results indicate that these intersections experienced the longest delays due to vehicles either partially or fully blocking the intersection. It should also be noted that the intersection with the highest average partial and full blocking times was 10th Street & Williams Street. This means that, on average, this intersection experienced the highest amount of partial and full blocking time out of the 2 hour peak when compared to the other intersections within this project. Generally, the trends discussed in the section 5.1.2 - Number of Blocks were also observed in this section (Figures 61 through 67).

Again, caution must be exercised as the data mixes before and after the Christmas and News Years holiday season, potential biasing the daily data at the intersections in Figures 61, 62, and 65. Overall there was an increasing trend in the percent green time that experienced blocking from the beginning of December until Christmas Day with percentages in the range of 0% to 32%. After Christmas Day to the beginning of January there were several intersections that saw a decline in the percent of green time with blocking (0% to 3%). However, after the beginning of January there was a rise in the green time with blocking until what seemed to be normal traffic operations (ranges from 2% to 13% with no major holiday basis) for the selected areas.

As stated in section 5.1.2. - Number of Blocks another important date to point out was January 31st , 2014 because this date was two days after the snow storm that hit Atlanta (SnowJam 14'). For the same reason stated in section 5.1.2 this day had a large amount of traffic volume observed which could have resulted in an increase in the percentage of green time with blocking. This can be seen in Figures 61 through 65. As stated at the beginning of this chapter weekend data was collected for the intersection of Peachtree Road & Lenox Mall entrance with ranges of green time with blocking from 7.9% to 38.0% (Figure 66). Caution must also be exercised when observing weekend trends in Figure 66 because the weekend data (Saturday and Sunday) was collected during the peak of the holiday season

5.1.5. Percent of Capacity Lost Due to Blocking

5.1.5.1 Findings

Figures 68 through 73 below show the percent of capacity lost due to the decrease in green time at each intersection for their respective analysis time.

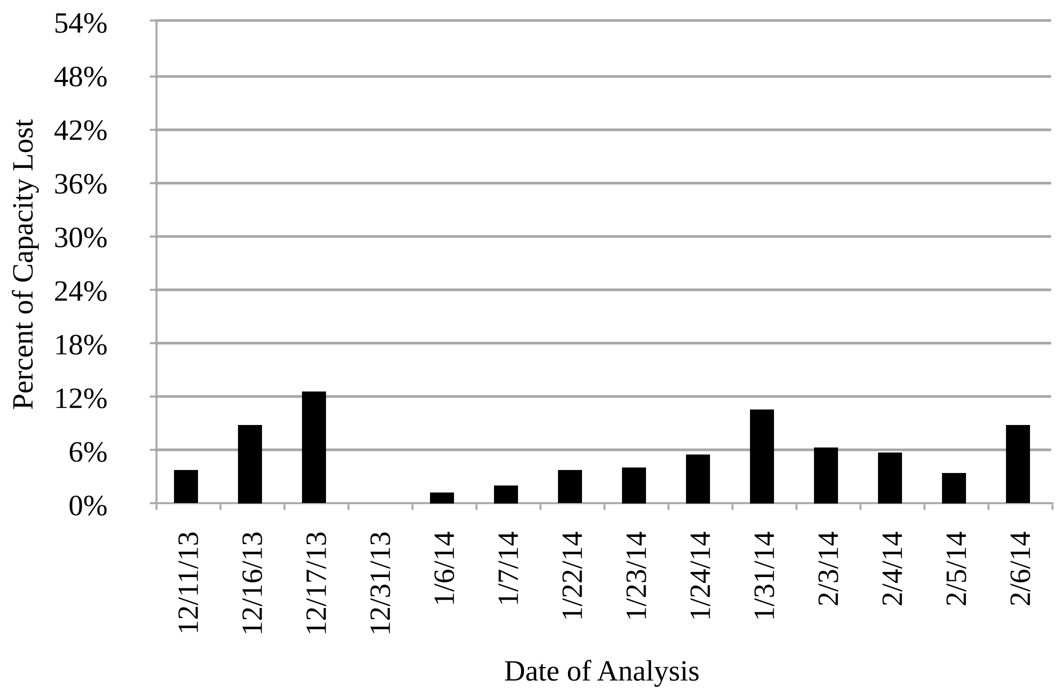


Figure 68: Percent of capacity lost due to blocking at Peachtree Road & Mathieson Drive.

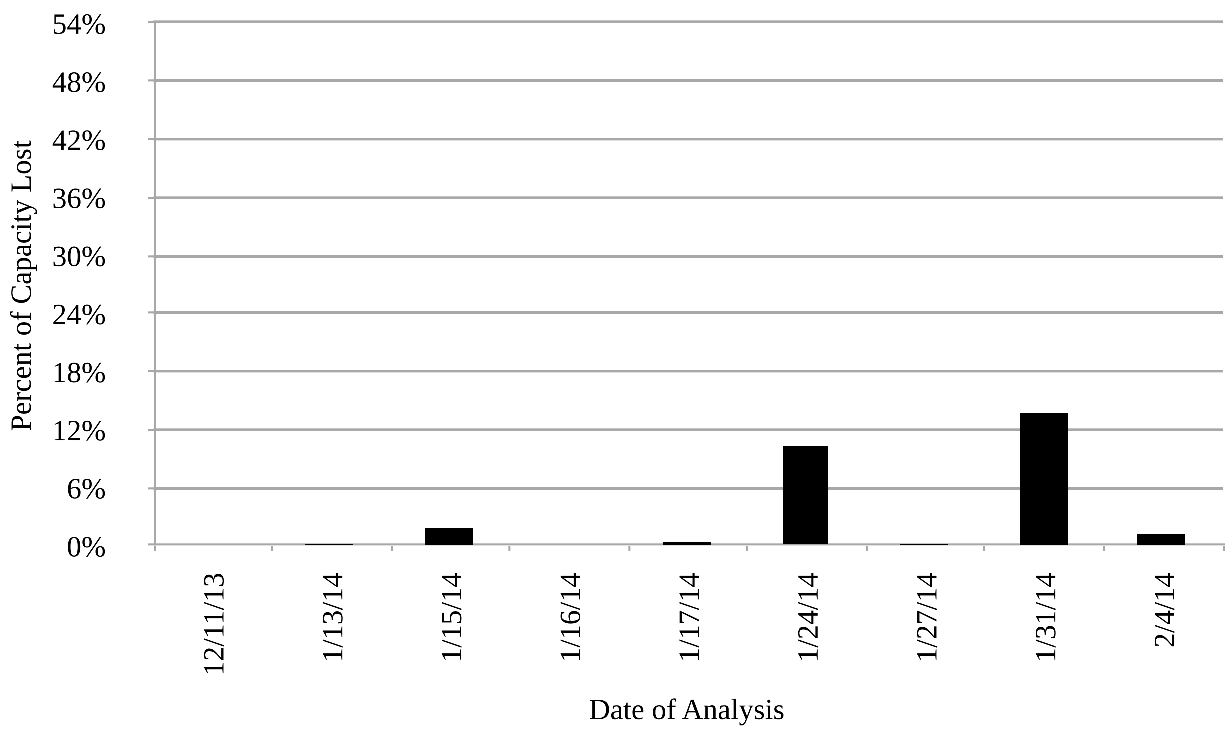


Figure 69: Percent of capacity lost due to blocking at Peachtree Road & Piedmont Road.

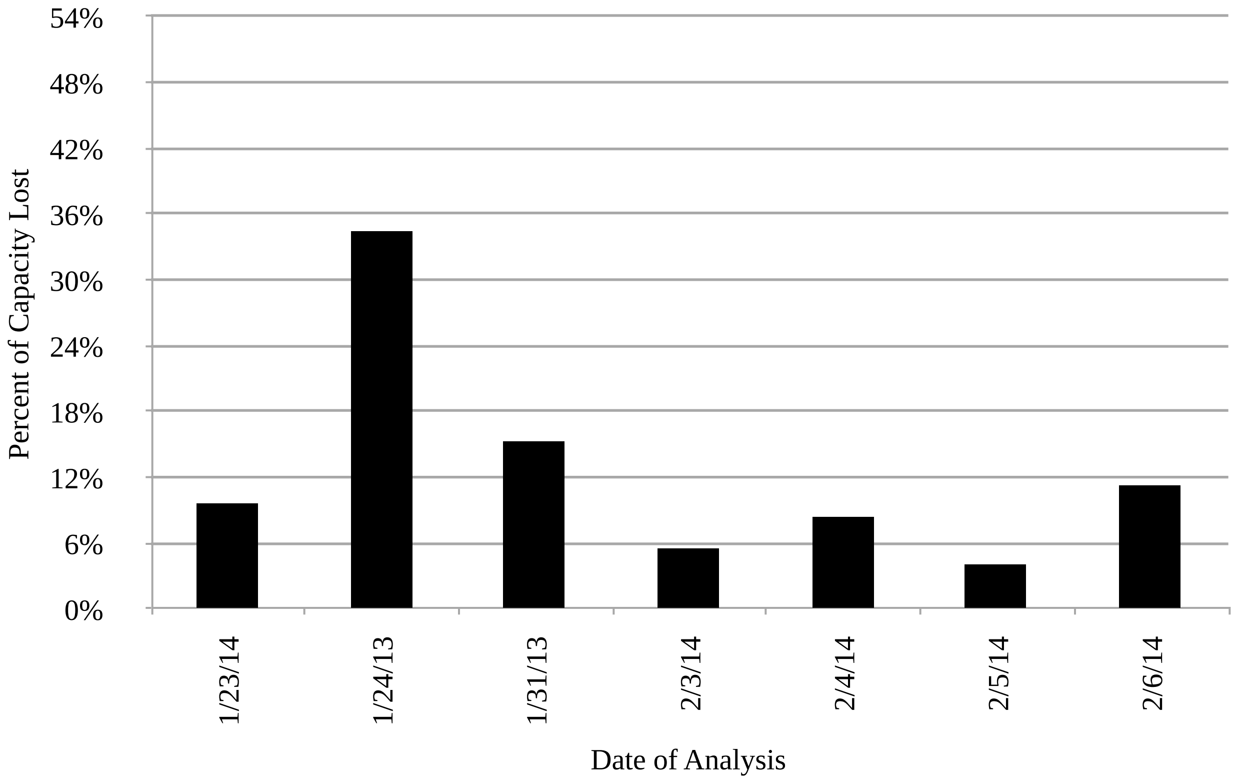


Figure 70: Percent of capacity lost due to blocking at Peachtree Road & Highland Drive.

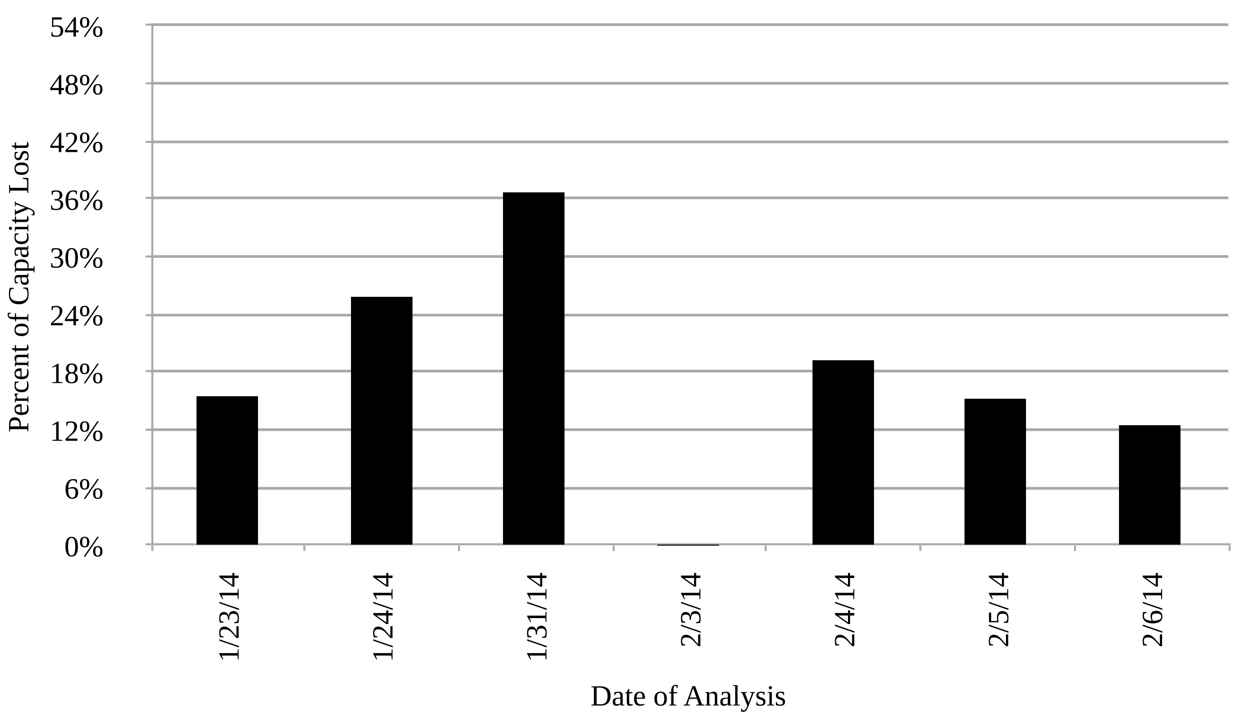


Figure 71: Percent of capacity lost due to blocking at Peachtree Road & Stratford Road.

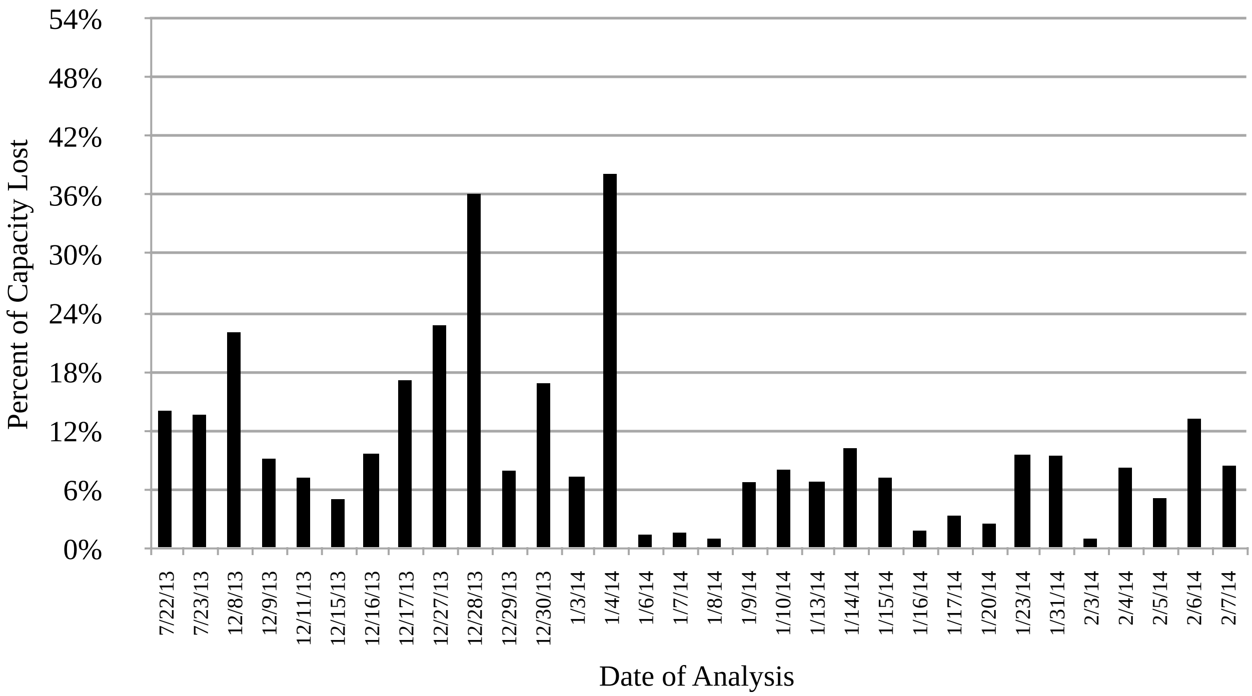


Figure 72: Percent of capacity lost due to blocking at Peachtree Road & Lenox Road entrance.

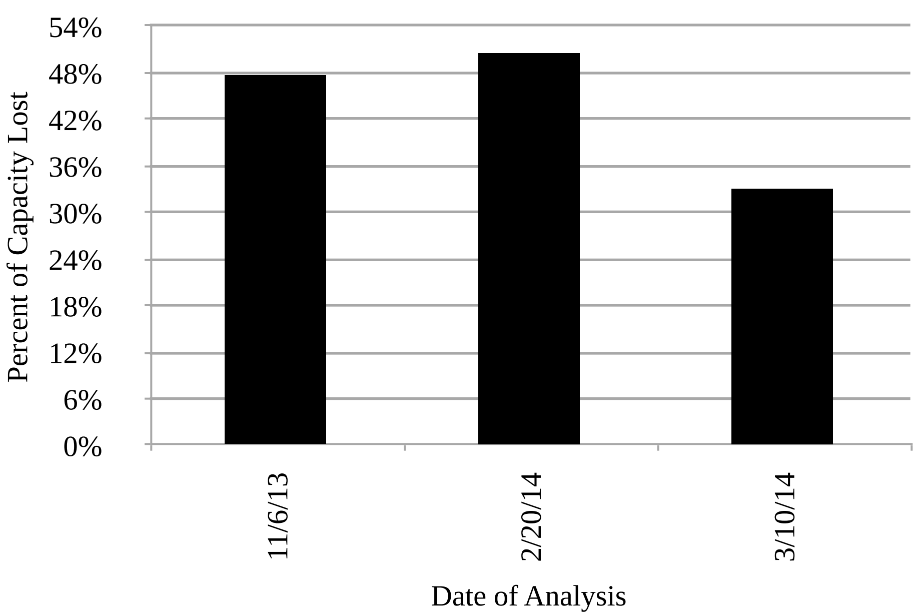


Figure 73: Percent of capacity lost due to blocking at 10th Street & Williams Street.

5.1.5.2 Analysis

The main observation that can be taken away from this section was that the percent of capacity lost observed was different during the holiday season when compared to normal conditions. Another key observation was that the range of percent capacity lost varies by intersection location (i.e. intersections in more dense locations were observed to have higher percentages of capacity lost). While the blocking that was observed at a selected intersection played the largest role in the percent of capacity lost, it must be noted that green time loss due to downstream congestion could have played a role at some intersections. The rest of this section will specify the details that led to these observations.

For the intersections in Figures 69, 71, and 73 there was a general increase in the percent of capacity lost due to blocking during the holiday season (the month of December). After Christmas Day there were a few days that showed to have a high percent of capacity lost due to blocking, however, there was generally a decrease in the percent of capacity lost due to blocking until the New Years and from New Years to the beginning of January there was a dead period where there was a low percent of capacity lost due to blocking. After the beginning of January there was an increase in the percent of capacity lost due to blocking until a steady state was achieved around the beginning of February. It must be stated again that caution must be taken when reviewing the data for these intersection because the data lies on days within the holiday session and on days not within the holiday season. Data within the holiday season tends to provide results higher than what should be expected under normal operating conditions.

The intersections with the highest percent of capacity lost due to blocking were Peachtree Road & Highland Drive (ranges from 4.1% to 34.4%), Peachtree Road & Stratford Road (ranges from 0.9% to 36.7%), Peachtree Road & Lenox Mall entrance (ranges from 1.0% to 38.1%), and 10th Street & Williams Street (ranges from 33.1% to 50.6%). The common theme between these intersections is they are located in dense environments when compared to the remaining intersections. These ranges also indicate that one some days that were observed had quarter to half of the total traffic was not able to be processed because of the blocking sessions, making congestion worst during the two hour peak period.

5.1.6. Entry and Exit of Blockers

5.1.6.1. Findings

The entrance and exit approach/lane of each blocker was recorded over the specified time period for each intersection. It should be noted that all approaches were able to be observed for all the intersections within this project, excluding the intersection of Peachtree Road & Lenox Mall entrance. Again, because of the angle of the PTZ only the northbound, westbound, and eastbound approaches could be observed for this intersection. Tables 3 to 8 below show the approach/lane, the number of blockers that came from and went to that approach/lane, and the aggregate percentage of the total number of blockers that came from and went to that approach/lane.

Table 3: Entry and exit points for blocks at Peachtree Road & Mathieson Drive.

Approach	Entry		Exit	
	Number of Blockers	Percent of the Total Number of Blockers	Number of Blockers	Percent of the Total Number of Blockers
EB	27	8.1 %	-	-
NB-1	5	1.5 %	8	2.4 %
NB-2	17	5.1 %	15	4.5 %
NB-3	18	5.4 %	26	7.8 %
SB-1	143	42.7 %	147	43.9 %
SB-2	102	30.4 %	119	35.5 %
SB-3	6	1.8 %	17	5.1 %
WB	17	5.1 %	3	0.9 %

Table 4: Entry and exit points for blocks at Peachtree Road & Piedmont Road.

Approach	Entry		Exit	
	Number of Blocks	Percent of Total Number of Blockers	Number of Blocks	Percent of Total Number of Blockers
SBL	3	2.7 %	-	-
SB-1	20	17.7 %	18	15.9 %
SB-2	25	22.1 %	27	23.9 %
SB-3	18	15.9 %	21	18.6 %
NBL	0	0.0 %	-	-
NB-1	-	-	5	4.4 %
NB-2	17	15.0 %	17	15.0 %
NB-3	18	15.9 %	19	16.8 %
EBL	12	10.6 %	-	-
EB-1	-	-	1	0.9 %
EB-2	-	-	2	1.8 %
WBL-1	-	-	3	2.7 %

Table 5: Entry and exit points for blocks at Peachtree Road & Highland Drive.

Approach	Entry		Exit	
	Number of Blocks	Percent of Total Number of Blockers	Number of Blocks	Percent of Total Number of Blockers
EB	40	9.5 %	3	0.7 %
NB-1	66	15.6 %	80	19.0 %
NB-2	72	17.1 %	81	19.2 %
NB-3	56	13.3 %	101	23.9 %
NBL	7	1.7 %	-	-
SB-1	18	4.3 %	35	8.3 %
SB-2	32	7.6 %	60	14.2 %
SB-3	17	4.0 %	57	13.5 %
SBL	15	3.6 %	-	-
WB	99	23.5 %	5	1.2 %

Table 6: Entry and exit points for blocks at Peachtree Road & Stratford Road.

Approach	Entry		Exit	
	Number of Blocks	Percent of Total Number of Blockers	Number of Blocks	Percent of Total Number of Blockers
WB	105	16.3 %	3	0.5 %
SBL	33	5.1 %	-	-
SB-1	37	5.8 %	48	7.5 %
SB-2	88	13.7 %	127	19.8 %
SB-3	37	5.8 %	71	11.0 %
NBL	5	0.8 %	-	-
NB-1	157	24.4 %	211	32.8 %
NB-2	-	-	113	17.6 %
NB-3	15	2.3 %	68	10.6 %
EB	166	25.8 %	2	0.3 %

Table 7: Entry and Exit points for blocks at Peachtree Road & Lenox Mall entrance.

Approach	Entry		Exit	
	Number of Blocks	Percent of Total Number of Blockers	Number of Blocks	Percent of Total Number of Blockers
NB-1	224	14.9 %	525	34.9 %
NB-2	102	6.8 %	254	16.9 %
NB-3	47	3.1 %	132	8.8 %
WB	345	23.0 %	-	-
EB	200	13.3 %	2	0.1 %
SBL	585	38.9 %	-	-
SB-1	-	-	9	0.6 %
SB-2	-	-	5	0.3 %
SB-3	-	-	2	0.1 %

Table 8: Entry and exit points for blocks at 10th Street & Williams Street.

Approach	Entry		Exit	
	Number of Blocks	Percent of Total Number of Blockers	Number of Blocks	Percent of Total Number of Blockers
WB-1	-	-	3	1.3 %
WB-2	-	-	16	6.9 %
WB-3	183	79.2 %	208	90.0 %
EBL	1	0.4 %	-	-
EB-1	2	0.9 %	2	0.9 %
EB-2	1	0.4 %	1	0.4 %
NB-1	-	-	1	0.4 %
NB-3	44	19.0 %	-	-

5.1.6.2. Analysis

The main observation that can be taken away from this section was vehicles that came from the minor approaches (eastbound or westbound) or turning approaches caused the most blocks. Another important observation was that generally blocking vehicles the originated from a major approach stayed on the major approaches (northbound and southbound). The rest of this section will specify the details that led to this observation.

The first stated observation can be observed at the intersections of Peachtree Road & Highland Drive, and Peachtree Road & Stratford Road, Peachtree Road & Lenox Mall Entrance (Tables 5, 6, and 7). An example of this trend can be seen with the blockers at the intersection of Peachtree Road & Lenox Mall entrance originating from the SBL lane (38.9%). As for the last three intersections, Peachtree Road & Piedmont Road and 10^{th} Street & Williams Street, they showed to have different intersection geometry when compared to the other intersection within this project and this affected the distribution of the blockers entry and exit.

In terms of the blockers that originated from the major approaches, the general trend observed within most of intersections was that the highest percentage of where the blockers originated from was found to be the same for where they exited. The intersections in Tables 3, 4, 6, and 8 all showed to follow this trend which indicates that the majority of the vehicles within these intersections came from a single lane or approach and did not change lanes to stop while they were blocking the intersection.

5.1.7. Distribution of Conflicting Approach and Lane Blocks

5.1.7.1. Findings

The approaches that were being blocked were also recorded over the specified time period for each intersection. Tables 9 through 14 below show which approaches were being blocked (i.e. conflicting approach) and the number and percentage of blockers blocking that approach. For this analysis the full and partial blocking are not analyzed separately. Also, as several of the approaches had multiple lanes it is possible that in some instances several blocking vehicles could be blocking the same conflicting movement simultaneously.

Table 9: Approaches blocked at Peachtree Road & Mathieson Drive.

Conflicting Approach	Number of Blocks	Percent of the Total Number of Blocks
EB	185	50.5 %
NBT	3	0.8 %
SBT	16	4.4 %
WB	162	44.3 %

Table 10: Approaches blocked at Peachtree Road & Piedmont Road.

Conflicting Approach	Number of Blocks	Percent of Total Number of Blockers
EBL	16	28.1 %
EBR	5	8.8 %
EBT	5	8.8 %
NBL	8	14.0 %
SBL	4	7.0 %
SBT	2	3.5 %
WBL	9	15.8 %
WBT	8	14.0 %

Table 11: Approaches blocked at Peachtree Road & Highland Drive.

Conflicting Approach	Number of Blocks	Percent of Total Number of Blockers
WB	94	35.5 %
SBT	3	1.1 %
SBL	35	13.2 %
NBT	16	6.0 %
NBL	17	6.4 %
EB	100	37.7 %

Table 12: Approaches blocked at Peachtree Road & Stratford Road.

Conflicting Approach	Number of Blocks	Percent of Total Number of Blockers
WB	151	36.3 %
SBT	9	2.2 %
SBL	42	10.1 %
NBT	56	13.5 %
NBL	14	3.4 %
EB	144	34.6 %

Table 13: Approaches blocked at Peachtree Road & Lenox Mall entrance.

Conflicting Approach	Number of Blocks	Percent of Total Number of Blockers
EB	91	10.1 %
NBL	1	0.1 %
NBT	283	31.4 %
SBL	240	26.6 %
WB	287	31.8 %

Table 14: Approaches blocked at 10th Street & Williams Street.

Conflicting Approach	Number of Blocks	Percent of Total Number of Blockers
WB	13	5.1 %
NB	103	40.2 %
EBL	113	44.1 %
EB	27	10.5 %

As multiple approaches had more than one lane, an analysis was conducted to determine the aggregate percent blockage for each approach. Figure 74 to 79 below shows the aggregate percent of time each lane, for all the approaches that were being blocked, was being blocked.

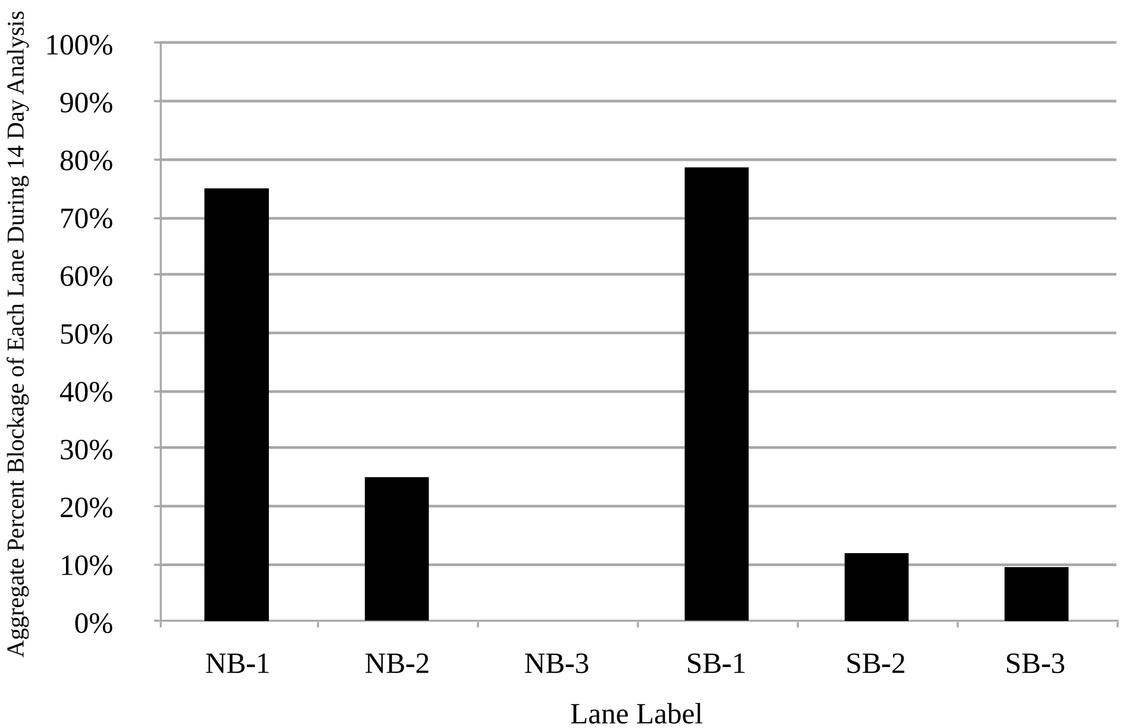


Figure 74: Aggregate percent of northbound and southbound lanes being blocked at Peachtree Road & Mathieson Drive.

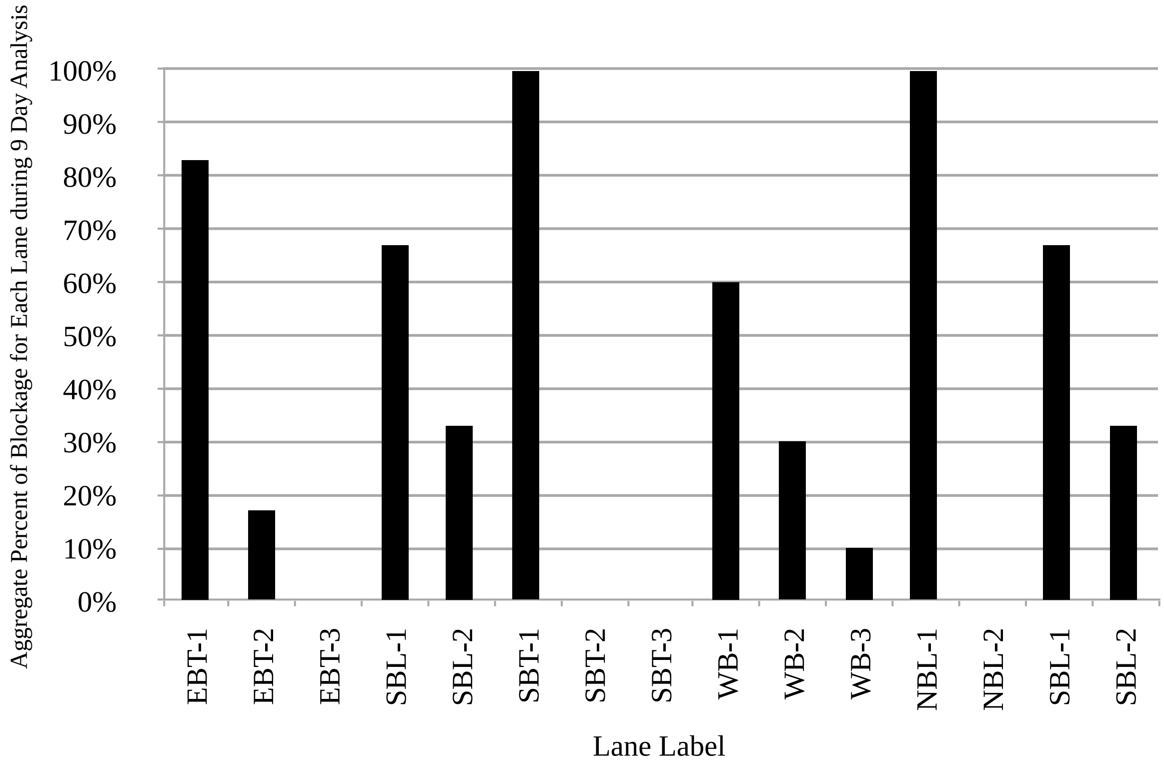


Figure 75: Aggregate percent of northbound, eastbound, westbound, and southbound lanes being blocked at Peachtree Road & Piedmont Road.

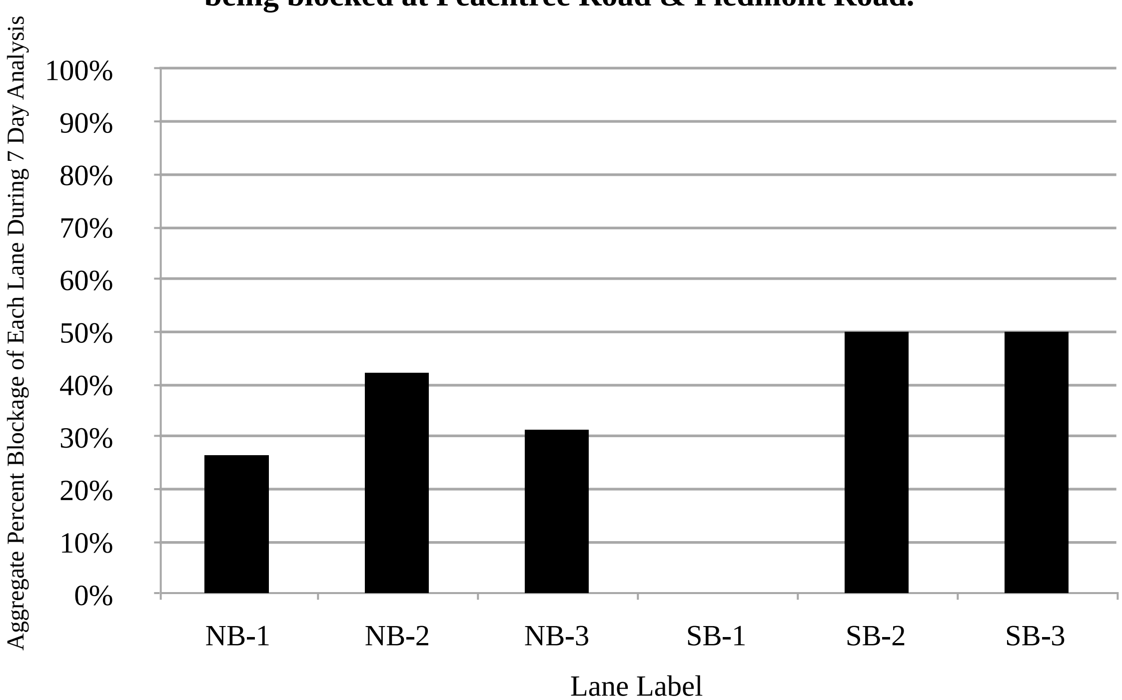


Figure 76: Aggregate percent of northbound and southbound lanes being blocked at Peachtree Road & Highland Drive.

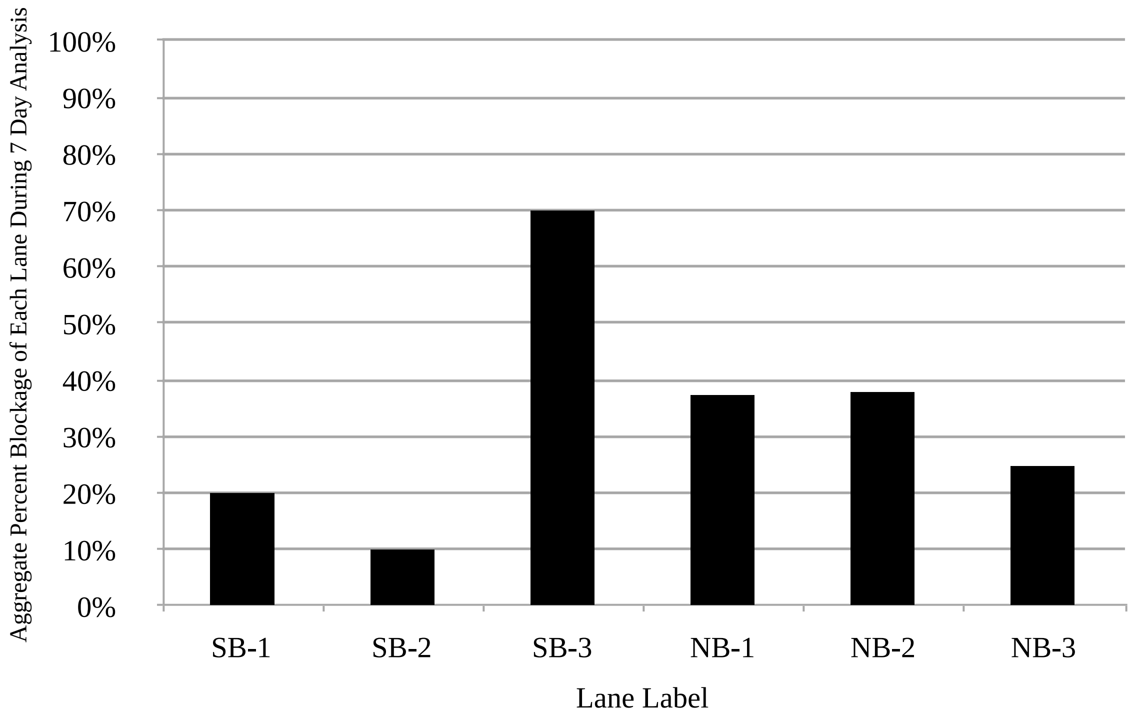


Figure 77: Aggregate percent of northbound and southbound lanes being blocked at Peachtree Road & Stratford Road.

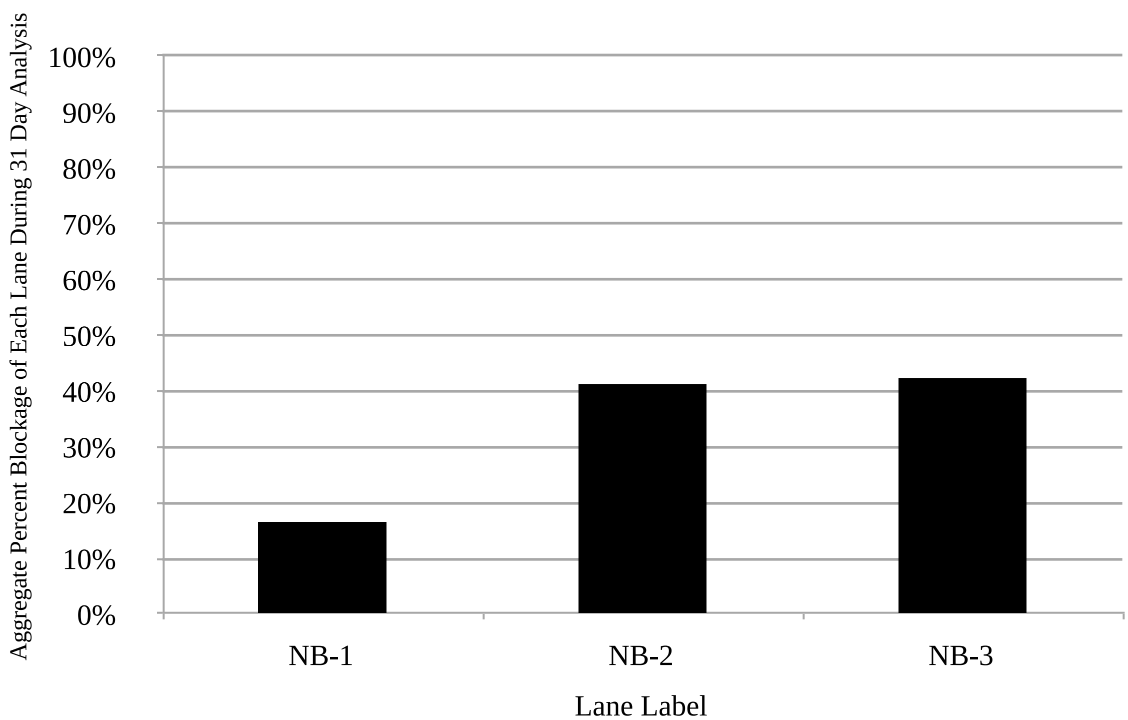


Figure 78: Aggregate percent of northbound and southbound lanes being blocked at Peachtree Road & Lenox Mall entrance.

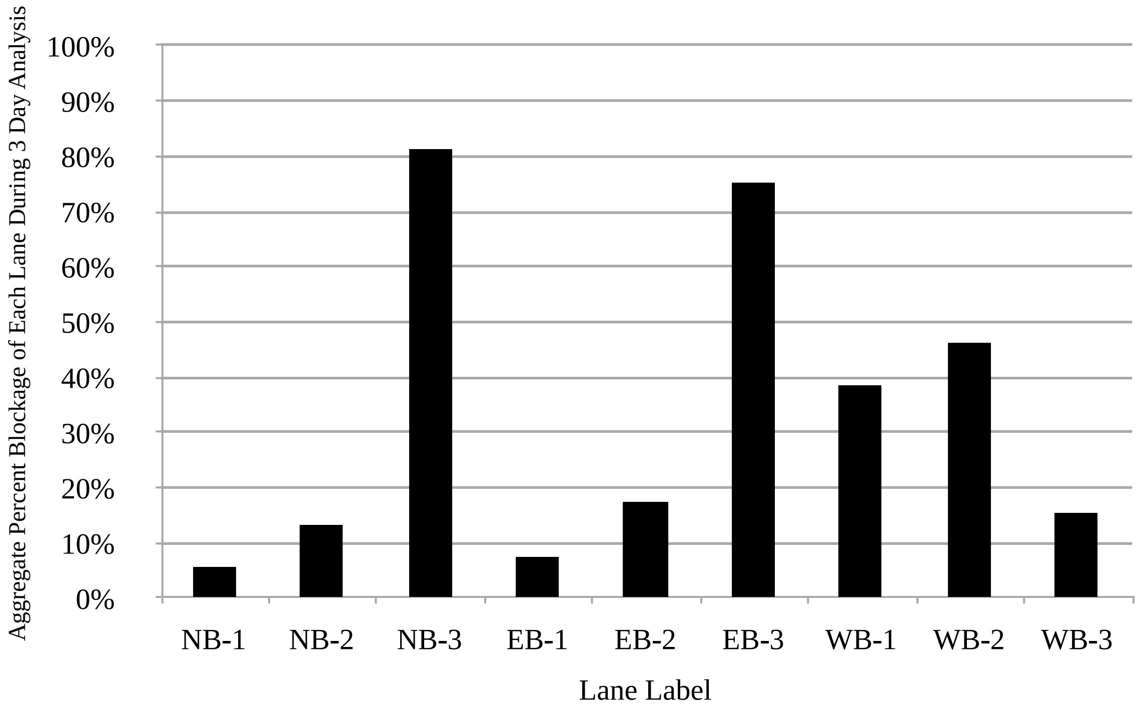


Figure 79: Aggregate percent of northbound, eastbound and westbound lanes being blocked at 10th Street & Williams Street.

<u>5.1.7.2. Analysis</u>

The main observation that can be taken away from this section was that the minor approaches were being blocked more often. From the previous section it was noted that most of the blockers came from the minor approaches, this indicates that when the blockers turned onto the major approaches they queued, results in the blocking of the opposite minor approach. Another important observation that was seen when the approach level was aggregated down to the lane level, the outside lanes of an approach (i.e. lane 1 or lane 3 depending on how the lane was labeled) were blocked more often. The rest of this section will specify the details that led to this observation.

The distribution of conflicting lane blocks was the highest for the minor approaches (eastbound and westbound) for the intersections of Peachtree Road & Mathieson, Peachtree

Road & Piedmont Road, Peachtree Road & Highland Drive, and Peachtree Road & Stratford Road with ranges from 14% to 50.5% during the two hour analysis period. These results can be observed in Tables 9 through 12. As for the intersections of Peachtree Road & Lenox Mall entrance and 10th Street & Williams Street the distribution of conflicting lane blocks was the highest for the SBL (26.6%), NBT (31.4%), and WB (31.8%) for the intersection of Peachtree Road & Lenox Mall entrance and the distribution of conflicting lane blocks was the highest for the northbound (40.2%) and EBL (44.1%) for the intersection of 10th Street and Williams Street. The SBL for the intersection of Peachtree Road & Lenox Mall Entrance tended to be the lane that initiated a high percentage of blocking for this intersection and this is why the NBT experienced a large percent of conflicting lane blocks. As for the intersection of 10th Street & Williams Street, it was previously recorded (section 5.1.6.) that the WB-3 initiated most of the blocks for this intersection, thus, blocking the northbound and EBL left approaches.

When referring to Figures 74 through 79 the aggregate percentages of the approaches with multiple lanes being blocked can be seen for each intersection. It was observed that the inside lanes (i.e. lane 1 or lane 3) for the approaches with multiple lanes were blocked the most with the ranges from 41% to 100%. However, there were instances that some approaches had the inside lane (i.e. lane 2) blocked equally or more than the outside lanes. This can be seen in Figures 76, 77, and 79.

5.1.8. Full or Partial Block

5.1.8.1 Findings

Each block for each approach was categorized as a partial or full block. For the specified duration of each intersection's analysis period the aggregate percent split an approach was either partially or fully blocked. Thesis results can be seen in Table 15 to 20 below.

Table 15: Total time an approach was partially or fully blocked at Peachtree Road & Mathieson Drive.

Conflicting Approach	Duration of Partial Blocks	Duration of Full Blocks
WB	31 minutes and 47 seconds	2 minutes and 14 seconds
SBT	5 minutes and 16 seconds	8 minutes and 16 seconds
NBT	Zero	1 minute and 9 seconds
EB	31 minutes and 58 seconds	2 minutes and 9 seconds

Table 16: Total time an approach was partially or fully blocked at Peachtree Road & Piedmont Road.

Conflicting Approach	Duration of Partial Blocks	Duration of Full Blocks
WBT	1 minute and 31 seconds	38 seconds
WBL	4 minutes and 41 seconds	Zero
SBT	3 minutes and 7 seconds	Zero
SBL	4 minutes and 41 seconds	Zero
NBL	4 minute and 41 seconds	Zero
EBT	2 minutes and 20 seconds	19 seconds
EBR	Zero	1 minutes and 15 seconds
EBL	3 minutes and 7 seconds	Zero

Table 17: Total time an approach was partially or fully blocked at Peachtree Road & Highland Drive.

Conflicting Approach	Duration of Partial Blocks	Duration of Full Blocks
EB	17 minutes and 3 seconds	7 seconds
NBL	9 minutes and 35 seconds	9 seconds
NBT	5 minutes and 56 seconds	3 minutes and 11 seconds
SBL	15 minutes and 27 seconds	55 seconds
SBT	2 minutes and 28 seconds	1 minute and 13 seconds
WB	17 minutes	9 seconds

Table 18: Total time an approach was partially or fully blocked at Peachtree Road & Stratford Road.

Conflicting Approach	Duration of Partial Blocks	Duration of Full Blocks
EB	17 minutes and 45 seconds	1 minute and 10 seconds
NBL	11 minutes and 48 seconds	51 seconds
NBT	6 minutes and 29 seconds	24 minutes and 55 seconds
SBL	16 minutes and 25 seconds	3 minutes and 24 seconds
SBT	10 minutes and 46 seconds	7 minutes and 38 seconds
WB	17 minutes and 3 seconds	2 minutes and 21 seconds

Table 19: Total time an approach was partially or fully blocked at Peachtree Road & Lenox Mall entrance.

Conflicting Approach	Duration of Partial Blocks	Duration of Full Blocks
EB	59 minutes and 51 seconds	1 minutes and 10 seconds
NBL	Zero	23 seconds
NBT	48 minutes and 8 seconds	6 minutes and 59 seconds
SBL	2 hour and 18 minutes	25 seconds
WB	1 hour and 58 minutes	2 minutes and 23 seconds

Table 20: Total time an approach was partially or fully blocked at 10th Street & Williams Street.

Conflicting Approach	Duration of Partial Blocks	Duration of Full Blocks
EB	16 minutes and 55 seconds	11 minutes and 45 seconds
EBL	35 minutes and 26 seconds	Zero
NB	21 minutes and 19 seconds	8 minutes and 42 seconds
WB	3 minutes and 38 seconds	5 minutes and 2 seconds

5.1.8.2 Analysis

The main observation that can be taken away from this section was that there were different behaviors observed for full blocks and partial blocks among the other characteristics analyzed in this report. Another key observation was that there were more partial blocks observed than full blocks. The rest of this section will specify the details that led to this observation.

In general the minor lanes and left turning lanes for the major approaches experienced the highest percent of partial blockages for the intersections of Peachtree Road & Mathieson Drive, Peachtree Road & Highland Drive, Peachtree Road & Lenox Mall entrances. The minor lanes and left turn lanes for the major approaches at these intersections ranged from 70% to 92% of their blocks being classified as partial. These results can be found in Tables 15, 17, 18, and 19. As for the rest of the intersections different trends were observed. It can be seen in Table 16 and Table 18 that the intersections of Peachtree Road & Piedmont Road and Peachtree Road & Stratford Road had an even distribution of partial blocking, excluding the EBR for Piedmont Road and NBT for Stratford Road, indicating that every approach had almost the same probability for a partial block.

Overall, the approaches for the intersections within this project with the highest percent of full blockages also had the most volume (i.e. major approaches). However, it was also observed that only one approach for the major approaches had a high percentage of full blocks. For instance, the intersection of Peachtree Road & Stratford Road had a high percentage of full blocking (61.8%) on the NBT while the other major approach (SBT) only had 18.9% of its blocks classified as full.

5.1.9. Probability Blocker will Change Lanes to End Block

5.1.9.1. Findings

The probability a blocker will change lanes to stop blocking the intersection was found for each intersection and can be seen in Table 21 below.

Table 21: Summary of the probability a blocker will change lanes to stop blocking for each intersection.

Intersection	Probability a Blocker will Change Lanes to End Block
Peachtree Rd. & Mathieson Dr.	6.6 %
Peachtree Rd. & Piedmont Rd.	15.9 %
Peachtree Rd. & Highland Dr.	6.4 %
Peachtree Rd. & Stratford Rd.	3.1 %
Peachtree Rd. & Lenox Mall entrance	6.8 %
10^{th} St. and Williams St.	7.1%

5.1.9.2. Analysis

The range for the probability that a blocker will change lanes to stop blocking was found to be between 3.1% and 15.9%. Generally, when a vehicle blocked an intersection in this project there was a small percentage of them that decided to stop blocking and move over to the next open lane.

5.1.10. Pedestrian Safety Analysis

The safety of VRU's is considered a top priority to traffic engineers and their involvement in the blocking of the intersection was considered during the collection of DBTB data. When a vehicle blocks the intersection they put pedestrians in danger because they may not see pedestrians crossing as a result of either other vehicles blocking their line of sight or because they were too focused on finding a way to exit the intersection. To analyze how many pedestrians that were in danger as a result of a vehicle blocking the intersection, the number of pedestrians were crossing during blocking sessions was recorded. The intersections of Peachtree Road & Highland Drive, Peachtree Road & Stratford Road, and Peachtree Road & Lenox Mall entrance were selected because there are located in a highly dense business area that has a large amount of pedestrian traffic.

5.1.10.1 Findings

The number of pedestrians that were crossing while the intersection was being blocked can be found in Figures 80 to 82 below. Pedestrian data was collected from January 8, 2014 to February 7, 2014 for all three intersections.

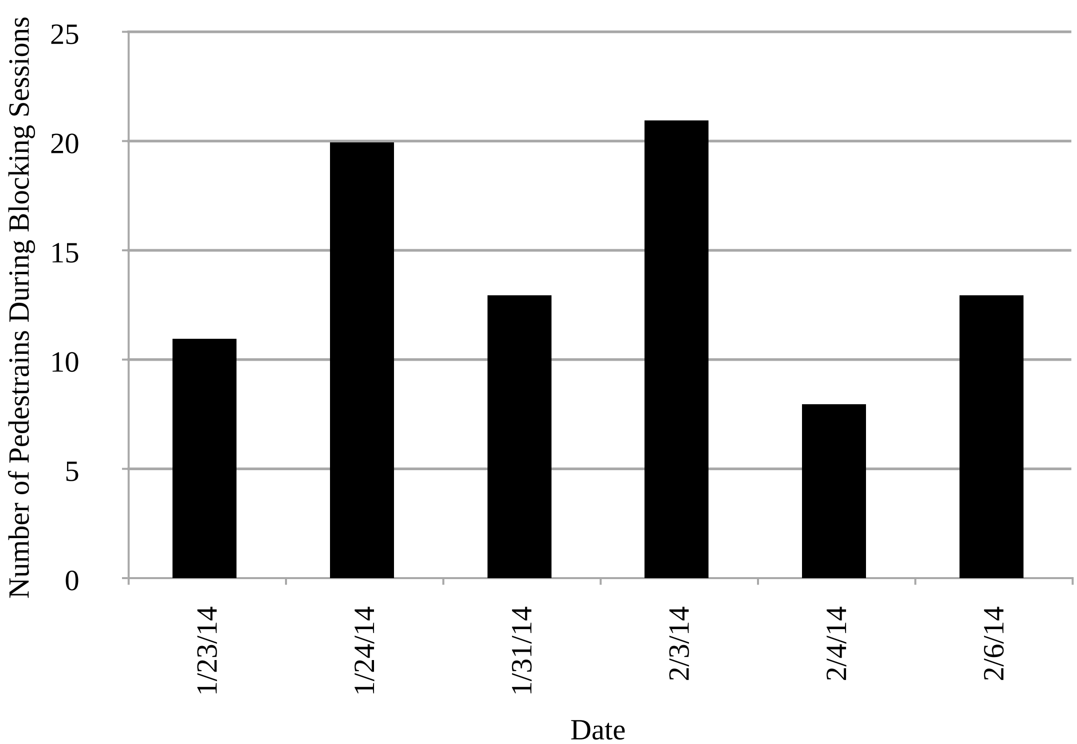


Figure 80: Number of pedestrians during blocking sessions for Peachtree Road & Highland Drive.

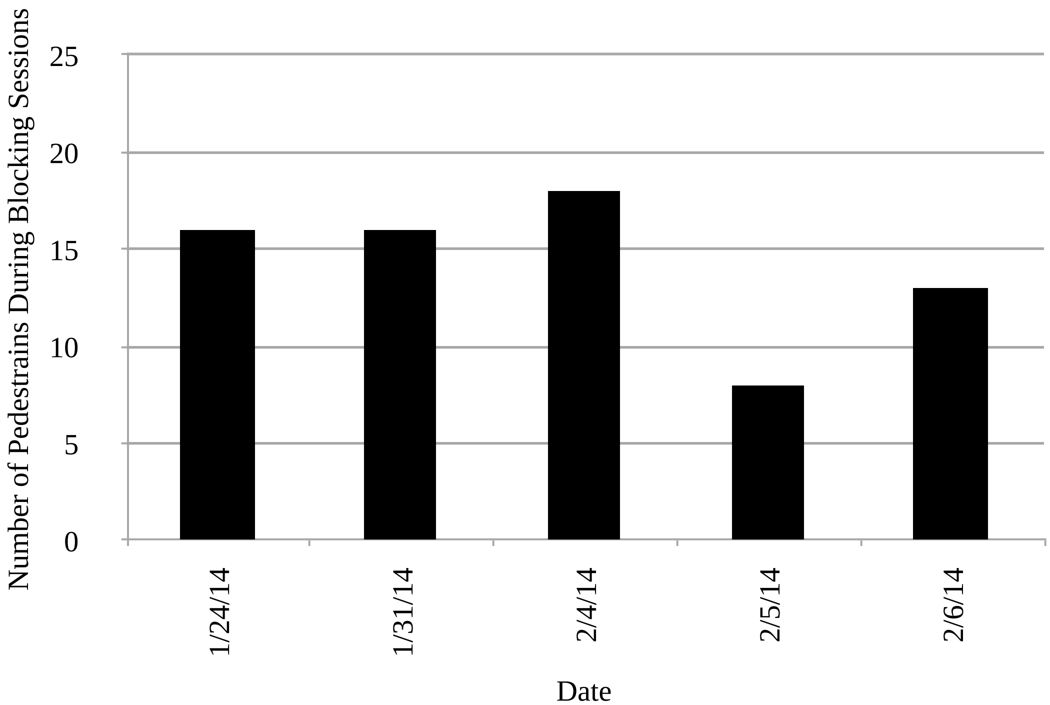


Figure 81: Number of pedestrians during blocking sessions for Peachtree Road & Stratford Road.

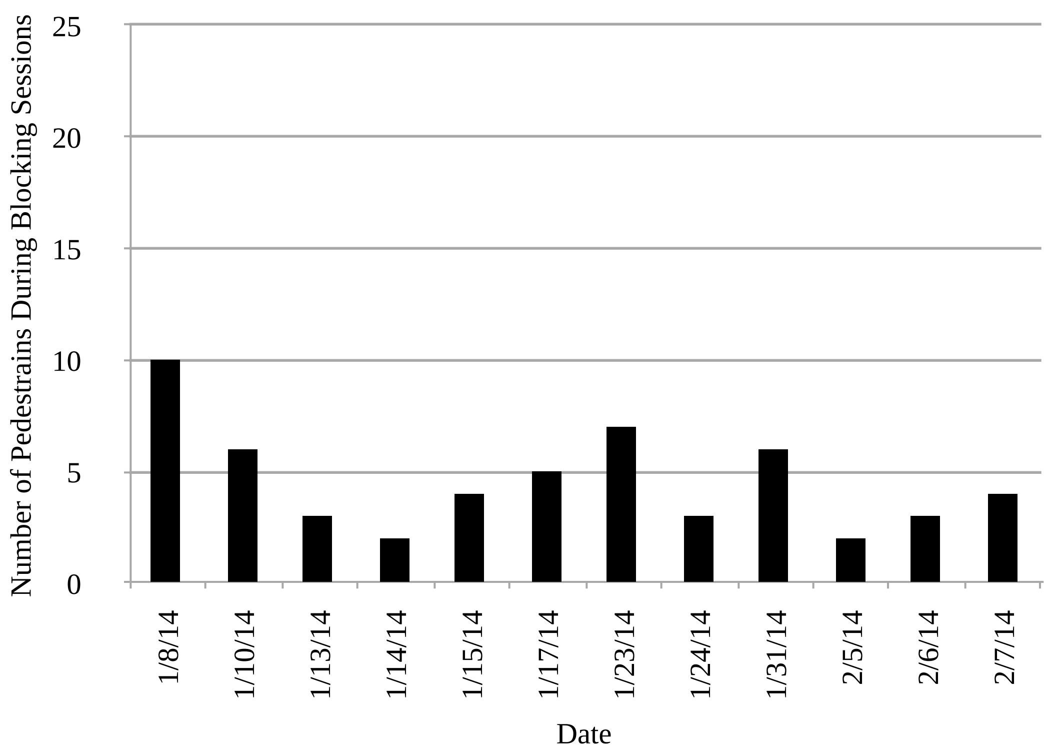


Figure 82: Number of pedestrians during blocking sessions for Peachtree Road & Lenox Mall entrance.

5.1.10.2 Analysis

Figures 80 through 82 show that there was a substantial number of pedestrians that were potentially put in danger because of blocking vehicles. On average these intersections had 5 to 14 pedestrians a day potentially in a dangerous situation.

5.1.11. Driver Characteristics

Driver characteristics, such as the tendency to block an intersection, were explored at the intersection of 10th Street & Williams Street.

5.1.11.1. Findings

Table 22 below lists the four percentages found under the actions of blocking and non-blocking in the analysis of driver characteristics.

Table 22: Driver characteristics for the intersection of 10th Street & Williams Street.

Action: Blocking		Action: Non-Blocking	
Percentage of drivers that enter on green indication, stops in intersection.	Percentage of drivers that stop at the stop bar during green indication, enter on yellow indication, and then block the intersection.	Percentage of drivers that stop at the stop bar during green indication, enter intersection on green to yellow indication transition, and do not block the intersection	Percentage of drivers that stop at the stop bar, do not enter on cycle, and do not block intersection.
49.8	12.7	2.2	35.4

5.1.11.2. Analysis

The main observation that can be taken away from this section was that almost half of the drivers during the two hour peak period were willing to acknowledge that by entering the intersection during the green indication they could block the intersection; they disregarded this fact and decided to block the intersection anyway. Next, it was found that 12.7% of driver stop at the stop bar (i.e. acknowledging that by entering the intersection they could block it), however, when the phase changes from the green indication they decided to move inside the intersection and block the intersection anyway.

As for the actions of non-blocking cases, first it was determined that 2.2% of drivers stopped at the stop bar during the green indication (acknowledging that by entering the intersection they could block it) and entered the intersection as the green or yellow indications elapsed, however, they did not block the intersection. This percentage indicates that a driver rarely has the ability to accurately determine if the congestion will dissipate in time for them to not block the intersection. Lastly, it was found that 35.4% of drivers stopped at the stop bar, did not enter the intersection during the current cycle length, and did not block the intersection. This percentage shows that there is a percentage of drivers that did show restraint and consideration for the opposite approach during the two hour peak.

5.1.12. Analysis of DBTB Campaign in Atlanta, Georgia

The main observation that can be taken away from this section was that there are many factors, including socioeconomic factors that play a role in the probability that a driver will block an intersection that has a DBTB campaign already installed. The rest of this section will specify the details that led to this observation.

The intersection of Riverside Drive & Heards Ferry Road is located in a high income neighborhood within Sandy Springs, Georgia. As stated before Riverside Road has several DBTB campaigns already in place. The reason the Riverside Road & Heards Ferry Road intersection was selected was because during pre-data collection site visits to Riverside Road it showed to have the best chances of a blocking session occurring. DBTB data was collected on September, 12, 2013, January 7th, 2014, February 7th, 2014, and February 18th, 2014. In conclusion, there were no blocks recorded for any day of the analysis for this intersection. It should also be noted that there were several chances for vehicles to block the intersection during the 4 days of analysis but drivers showed great restraint in not blocking the intersection.

The reasons for drivers deciding not to block this intersection are an assumption at this point because of the lack of supporting data. One potential reason for the lack of blocking could be a result of either the DBTB campaign was effectiveness or because of socioeconomic factors present at this intersection. As stated previously, this intersection resides in a high income area and several socioeconomic factors, such as high level of education, could come into play. Drivers within higher income brackets and higher education levels could be more reluctant to follow the rules and be more courteous. However, this is only an assumption and cannot be proved without further analysis. It should also be noted that more often than not there was not enough traffic for a blocking session to occur; meaning queues did not build up enough at the adjacent intersections. This was regarded as the main reason blocking sessions were not recorded for this intersection.

5.2. Don’t Block the Box Survey Responses

The objective of the “DBTB Survey” was to gain a bettering understanding of the current and potential trend in DBTB campaigns across the USA. The “DBTB Survey” received 75 responses from 415 organizations around the nation, a 18.1% response rate. Of those 75 responses 13 were partially complete with respondents only completing a portion of the survey. The participants included 29 local jurisdictions (City, County, etc.), 11 police departments, eight BIDs, four TMAs, one State Department of Transportation, one university, and one CID.

5.2.1. Respondents with a Don't Block the Box Campaign

5.2.1.1. Background

Of the 75 respondents only ten organizations currently have a DBTB campaign. Seven of the ten organizations started their DBTB campaign from 2010 to the present, two of the ten started between 2000 and 2010, and 1 started in between 1990 to 2000. Table 23 below shows what where the particular issued by the DBTB.

Table 23: What particular issued were addressed by DBTB.

What were the particular issues that were addressed by DBTB?		
Answer Options	**Response Percent (Based on 10 responses)**	**Response Count**
Traffic congestion	90.0%	9
Pedestrian safety	60.0%	6
Bicycle safety	60.0%	6
Vehicle safety	60.0%	6
Emission standards concerns	10.0%	1
Health and safety of residents	40.0%	4
Economic consequences to surrounding businesses	40.0%	4
Don't Know	0.0%	0
Other (please specify)		3
	answered question	**10**
	skipped question	**65**

In terms of who proposed the idea for the DBTB campaign it was found that DBTB campaigns usually were introduced by local jurisdictions, police departments, the organization's employee proposed the idea, or residents proposed the idea. Most of the ten organizations that currently have a DBTB campaign have zero to five intersections with DBTB. However, there were some respondents that had 20+ intersections with DBTB.

5.2.1.2. Public Education Campaign

Six of the 10 organizations used a public education campaign to inform the public about the DBTB campaign. In most cases the organization implementing the DBTB campaign and the police department were designated for conducting the public education campaign. The preferred media for the public education campaigns were pamphlets, websites, social media, email, radio, and press release. The public education campaigns were only repeated when it was deemed necessary by the organization implementing the DBTB campaign.

5.2.1.3. Obstacles

Table 24 shows which partnerships were found partially critical to the success of their DBTB campaign.

Table 24: Partnerships that organizations found critical to the success of their DBTB campaign.

Are there any partnerships that your organization found particularly critical to the success of this DBTB campaign?		
Answer Options	**Response Percent**	**Response Count**
Partnership with the Local Jurisdiction (City, County, etc.)	40.0%	4
Partnership with the police department	60.0%	6
Partnership with the State's Department of Transportation	10.0%	1
Partnership with the neighborhood associations	20.0%	2
None	20.0%	2
Don't Know	0.0%	0
Other (please specify)	10.0%	1
	answered question	**10**
	skipped question	**65**

Of the organizations that had a DBTB campaign most revealed that they did not experience any major obstacles when implement their DBTB campaign. If an organizations did have more difficult obstacles they were either getting support from the local police department or getting the public to notice the locations where the DBTB was located. One organization overcame the issue of getting the public to notice the DBTB campaigns by placing LED blinker lights to the DBTB signs and making the “X” inside the box larger on the pavement.

5.2.1.4. Controls

All ten of the organizations that currently have a DBTB campaign installed both signs and pavement markings at their intersections. Seven of the ten (70%) organizations paid for and installed their DBTB signs and 3 of the ten (30%) organizations had another organization pay for and install the DBTB signs. Nine of the ten (90%) organizations used option C pavement marking from the MUTCD guidelines and one of the ten (10%) organizations used option B from the MUTCD guidelines. Eight of the ten (80%) organizations paid for and installed their pavement markings and two of the ten (20%) organizations had another organization pay for and install the DBTB pavement markings. All ten organizations revealed that their estimated budget for installing the DBTB signs and pavement markings at an intersection was found to be $1000 to $1999.

5.2.1.5. Enforcement

Six of the ten (60%) organizations had active enforcement at their DBTB intersection. Six of the 75 (7%) respondents went on to answer more detailed questions regarding enforcement. Only one of the six (16.7%) organizations use automated enforcements, such as cameras. Two of the six (33.3%) organizations had a specific tasks force assigned to enforce DBTB intersections and 3 of the six (50%) organizations said that any officer can enforce their DBTB intersections. Four of six (66.6%) respondents confirmed that there is a need for additional enforcement. The fine for the DBTB violations was either under $100 or between $100 to $199 and half of the six organizations (50%) said that points were also added to the license for the DBTB violation. Organizations that do not currently have enforcement at their

DBTB intersections cited that limited time and resources, along with no evidence to support the need for enforcement were the reasons for no enforcement.

5.2.1.6. Effectiveness

Table 25 below shows the opinion of the ten organizations on the level of improvement in traffic operations since the DBTB campaign started.

Table 25: Level of Improvement in traffic operations since DBTB campaign started.

In your organization's opinion, what is the level of improvement in traffic operations since the DBTB campaign started?		
Answer Options	**Response Percent**	**Response Count**
Minimal	10.0%	1
Moderate	30.0%	3
Sufficient	60.0%	6
Don't know	0.0%	0
	answered question	**10**
	skipped question	**65**

Most of the organizations said that to improve their DBTB intersection there needed to be more enforcement. Table 26 below shows if the observed benefits of the DBTB campaign declined over time, assuming the campaign was initially successful for the ten organizations.

Table 26: Observed benefits of the DBTB campaign over time.

Assuming the DBTB campaign was initially successful, did the observed benefits decline over time?		
Answer Options	**Response Percent**	**Response Count**
Yes	20.0%	2
No	70.0%	7
DBTB campaign was not successful	0.0%	0
Don't know	10.0%	1
	answered question	**10**
	skipped question	**65**

Only three of the ten organizations (30%) record data to measure and document the improvements caused of the DBTB campaign. Nine of the ten organizations (90%) said there was a positive public perception regarding their DBTB campaign.

5.2.2. Respondents Who have Considered Implementing a Don't Block the Box Campaign and Chosen not to Proceed

Six of the 75 (8%) organizations considered implementing a DBTB campaign and chose not to proceed. The reasons for the abandoned their pursuit for a DBTB program because of the effort, no perceived benefits, and a lack of support from the city and police department.

5.2.3. Respondents Who are Currently Considering a Don't Block the Box Campaign

Two of the 75 (2.6%) organizations are currently considering a DBTB campaign. The two organizations noted the following benefits influenced their decision to consider a DBTB campaign: reduce in traffic congestion, increase pedestrian safety, increase bicycle safety, increase vehicle safety, and positive economical impact to surrounding businesses. The two organizations also noted the following concerns in DBTB campaign: cost, city approval, time, effort, and no perceived benefits.

5.2.4. Conclusion of Survey

In conclusion the respondents of the survey were asked if DBTB campaigns were shown to be an economical alternative in traffic management, would their organization consider starting a DBTB campaign to help with congestion and safety concerns. Forty-six of the 75 (60%) organizations responded to this questions and the results can be seen in Figure 83 below.

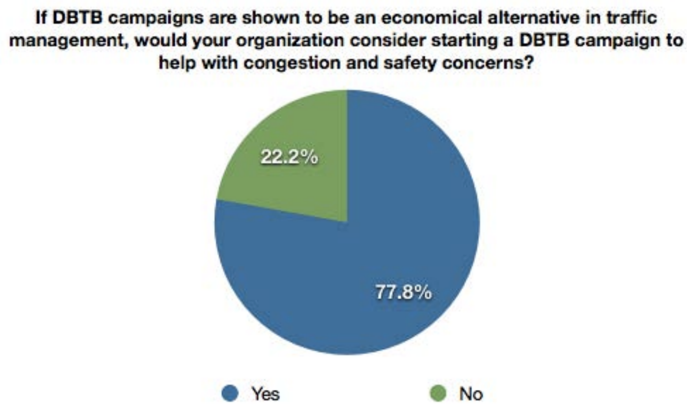


Figure 83: Will organizations consider DBTB campaigns if they are proved effective.

5.3. Summary of Results

The primary objectives of the DBTB study were the following:

1. Determine if the number of blocks increases during the peak hour and holiday season.
2. Determine if the percentage of green time with blocking increases during the holiday season.
3. Determine if the percentage of green time with blocking results in a substantial percentage of capacity lost.

The secondary objectives of the DBTB study were as follows:

1. Determine if the minor approach cause most of the blocking in any given intersection
2. Conclude if certain approaches and lanes get blocked more often
3. Check if there are more partial blocks when compared to the amount of full blocks

The results for these objectives confirmed the stated hypothesis that the negative impact that blocking can have on traffic operations within an intersection increases as the number of blocks, the percentage of green time with blocking, and the percent of capacity lost increases. The results from this chapter showed that during the holiday season there was as high as an 80% increase in blocks and as high as a 31% increase in percentage of green time with blocking when compared to normal operations (non-holiday). The results also confirmed that the percentage of green time with blocking during the holiday season did result in a substantial increase of percentage of capacity lost (as high as a 29% increase during the holiday season was observed when compared to normal conditions).

While there was a greater amount of partial blocks (70% to 100% of the blocks recorded) observed, when full blocks occurred they intensified the blocking session by greatly reducing the capacity at an intersection because vehicles could not pass the blocks. Additionally, it was found that vehicles originating from the minor approaches (eastbound or westbound) or turning approaches caused the most blocks and that the blocking vehicles exited on the major approaches (northbound and southbound) more often. Lastly, the minor approaches where blocked more often. Vehicles that originated from the minor approaches turned onto the major approaches, thus intensifying the queues on these approaches and blocking the minor approaches.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

As part of a larger UTC project, this thesis was meant to expand on the findings of a pervious study on emerging roles of TMAs in traffic operations and find traffic management alternatives that are cost effective for TMAs, TMOs, BIDs, and CIDs *(1)*. In response to the findings found in the literature review, this thesis explored various economical solutions and found that DBTB campaign is a potential option to help increase the feasibility of involvement of TMAs in traffic operations *(1)*. Several countries around the world have already used DBTB campaigns and reported it as being a successful economical traffic management tool. Another potential benefit that was documented for DBTB campaigns was the longevity of the campaign. The maintenance is considered minimal and the benefits of a campaign can be experienced throughout the day, whenever there is significant congestion, and not just during the peak hours. While a DBTB campaign will not completely mitigate effects that gridlock and congestion has on the economy, driver psyche, air quality, and safety of vulnerable road users (VRUs), it can provide a productive countermeasure.

Vehicles that were considered blockers in this report had to match the following requirements:

1. The vehicle must enter a predefined box within the intersection,
2. The vehicle must be stopped (or nearly stopped),
3. There must be an conflicting approach for the vehicle to be blocking (vehicle presence in the conflicting approach is not required), and

4. The conflicting approach, that is being blocked, must have a green indication.

Most states currently have laws already set in place to bar vehicles from entering an intersection and blocking the conflicting approach, however, these laws are ineffective unless there are proper enforcement tactics. The literature review found that the presence of enforcement at a DBTB intersection increased the effectiveness of the campaign (i.e. the more the enforcement the more effective the DBTB campaign). Proper enforcement also provided DBTB intersections the ability to help traffic operations not only during the daily peak volume hours but also during holiday seasons and sporting events. Lastly, the literature review revealed that box junctions can be easily installed at any intersection and are relatively inexpensive (average cost from $1,100 to $1,800, with at most $2,000 in maintenance cost over a 20 year period) when compared to other traffic management alternatives.

To determine if box junctions are applicable for Atlanta, Georgia a project was organized through the findings from the literature review to examine the impacts that blocking an intersection can have on traffic operations. The objective of this project was to look for characteristics that can be used in the process of deciding if a DBTB campaign is viable. A deployment plan for collecting blocking data was developed for six intersections in Buckhead, Sandy Springs, and Midtown, Atlanta. These intersections were selected because they were either located in dense urban environment, already had a DBTB campaign, or were coordinated together along the same corridor. Another reason these intersection were selected was that by averting blockers at these locations, especially during peak volume hours, unnecessary gridlock can be avoided, resulting in reductions in travel times, providing a safer environment for VRUs, increasing air quality, providing opportunities for positive impacts on the economy, and decreasing aggressive acts by drivers.

Data was collected using PTZ cameras or HD cameras at each intersection from 4:30 P.M. to 6:30 P.M. (i.e. the evening peak hour). To obtain DBTB data a custom computer program called VideoAnalyzer was developed at Georgia Tech. The VideoAnalyzer software was used to extract the initial blocking data, such as signal interval timestamps, entry lane of the blocker, start time of the block, exit lane of blocker, and exit time of the blocker. The initial blocking data was then subjected to two series of data reductions that helped determine key characteristics of blocking, such as, the number of blocks, the percentage of green time with blocking, and the percent of capacity lost. These factors were seen as critical characteristics because they were seen to have the greatest impact on traffic operations.

This thesis also surveyed a sample of organizations around the nation to gain a better understanding of the current state of DBTB campaigns in the United States and also to give further guidance on how DBTB campaigns can be used as an economical alternative for traffic management for DOTs, Cities, TMAs, BIDs, CIDs, etc. that already have box junctions. The main objective of the survey was to gather information from the survey's results to serve as a guideline to help understand how to best implement DBTB campaigns and help improve pervious constraints observed in current DBTB campaigns. Additionally, the survey was also meant to confirm the findings from the literature review. The following sections provide a summary of results, research limitations, and recommendations for future work.

6.1. Summary of Results

6.1.1. Don’t Block the Box Data

The primary objectives of the DBTB study were the following:

1. Determine if the number of blocks increases during the peak hour and holiday season.

2. Determine if the percentage of green time with blocking increases during the holiday season.

3. Determine if the percentage of green time with blocking results in a substantial percentage of capacity lost.

The secondary objectives of the DBTB study were as follows:

1. Determine if the minor approach cause most of the blocking in any given intersection.

2. Conclude if certain approaches and lanes get blocked more often.

3. Check if there are more partial blocks when compared to the amount of full blocks.

The results from Chapter 5 confirmed the stated hypothesis that the impact that blocking can have on traffic operations within an intersection increases as the number of blocks, the percentage of green time with blocking, and the percent of capacity lost increases. The results also showed that during the holiday season more blocks (as high as an 80% increase), a greater percentage of green time with blocking (as high as a 31% increase), and a greater percentages of capacity lost (as high as a 29% increase) was observed when compared to normal conditions (non-holiday). It was also observed that these characteristics were amplified during the middle of the two hour peak during the time period of 4:30 P.M. to 6:30 P.M. and by the degree of the block. While there was a greater amount of partial blocks (70% to 100% of the blocks recorded) observed, when full blocks occurred they intensified the blocking session by greatly reducing the capacity at an intersection because vehicles could not pass the blocks.

Another important result obtained was that vehicles originating from the minor approaches (eastbound or westbound) or turning approaches caused the most blocks and that the blocking vehicles exited from the major approaches (northbound and southbound) more often.

Additionally, it was also found that the probability that a blocker will change lanes to end a block was found to be very low (3.1% to 15.9%) and that almost half of the drivers that would block the intersection if they entered during a green indication choose to enter the intersection. Additionally, it was found that on average over all observation periods for each intersection 5 to 14 pedestrians were put in danger because of blocking vehicles in studied dense environments. Lastly, it was found that there are many factors, including socioeconomic influences, which play a role in the probability that a driver will block an intersection that has DBTB already installed.

6.1.2. Don't Block the Box Survey

The "DBTB Survey" received 75 responses from 415 organizations around the nation, a 18.1% response rate. Of these 75 responses 13 were partially complete with respondents only completing a portion of the survey. The main takeaways from the DBTB survey were that the organizations that currently have a DBTB campaign chose to implement one because safety reasons and traffic congestion were large issues at the subject intersections, which coincides with the findings from the literature review. In terms of cost for implementing box junction, 100% of the respondents that currently had a DBTB campaign, reported that their estimated budget for installing the DBTB signs and pavement markings at an intersection was between $1000 to $1999, which coincides with the range of costs found in the literature review. Additionally, 40% to 60% of the organizations that have a DBTB campaign found that partnerships with the police department and local jurisdictions to be critical in the process of implementing their DBTB campaign. Sixty percent of the organizations that have a DBTB campaign found that the level of improvement in traffic operations has sufficiently improved since their DBTB campaign started, and 70% said that observed benefits did not decline over time, assuming their DBTB was successful at first.

Only 8% of the organizations that took the survey, and did not currently have a DBTB campaign have previously considered a DBTB campaign and noted the reasons they stopped considering a DBTB campaign because of the effort, lack of perceived benefits, and a lack of support from the city and police departments. Lastly, 60% percent of the organizations that responded to question 49 in the survey agreed that if DBTB campaigns were shown to be an economical alternative in traffic management they could consider starting a DBTB campaign to address congestion and safety concerns.

In summary the results from the blocking data collected in this study as well as the results from the survey showed that blocking an intersection can have a profound effect on traffic operations, and a DBTB campaign can help mitigate safety concerns and traffic congestion. As the number of blocks increased (it was assumed in this paper that traffic volume was correlated to this) the percentage of green time with blocking and the capacity lost also increased, causing negative impacts on traffic operations, such as longer travel times. These characteristics also presented various safety concerns, as noted by the respondents in the survey. While a DBTB campaign can be seen as a long lasting mitigation measure because of its extended life cycle, the success likely depends on the enforcement of the intersections. If the drivers do not feel they will receive a penalty for blocking the box, they likely will continue to do so and cause traffic operation problems. This effect was well documented from the participants in the survey and literature review.

6.2. Study Limitations

6.2.1. Site Restrictions

The selection of the site for the DBTB data collection was limited because some locations presented safety concerns for data collectors, limited amount of PTZ cameras were available for various arterials, and only a limited number of intersections currently have a box junction. Many of the busiest intersections that showed a substantial amount of blocking were located in dense parts of Midtown and Downtown Atlanta, presenting safety concerns for data collectors. The current placement of PTZ cameras within Atlanta proved be a major limitation in this project because there was only a few major arterials that had PTZs. Lastly, there was only one location, in Sandy Springs, Atlanta, that currently has a box junction and this restricted the amount of data that could be gathered for intersections that had box junctions.

6.2.2. Video Restrictions

For the intersections that used PTZ cameras to record DBTB data there were several limitations. During the early stages of data collection, the research team did not have the ability to move the cameras to the optimal angle, resulting in limited data collection. When permission was granted to move the cameras and create presets there was no guarantee that the cameras would not be moved, eliminating usable data. If an accident or any other emergency occurred the owning agency had the priority to move the cameras, also resulting in a loss of DBTB data. It should also be noted that PTZ cameras were not always available for intersections upstream. This presented problems in knowing if congestion was actually being caused by blocking vehicles or by another factor upstream.

6.2.3. Data Processing Time

Since the research team on this project was small there was a limited amount of data that could be processed during the time this project was conducted. The VideoAnalzer tool reduced initial blocking data processing by 50% to 70%, however, a large percentage of data had to be extracted manually and this took a significant amount of time. Improvements to the software should be consider to decrease the manual efforts.

6.3. Future Research

Based on the results of this project the characteristics pertinent to the decision on implementing a DBTB campaign were the number of blocks, percentage of green time with blocking, and percentage of capacity lost at an intersection. If these characteristics are shown to be high a DBTB campaign can potentially be a viable option for traffic management. After considering these characteristics in this study the intersections of Peachtree Road & Highland Drive, Peachtree Road & Stratford Road, Peachtree Road & Lenox Mall entrance, and 10th Street & Williams Street would be potential candidates for a DBTB campaign. Intersections of Peachtree Road & Stratford Road and Peachtree Road & Highland Drive showed to have the highest number of blocks and a more consistent (day by day analysis) amount of blocking when compared to the other intersection within the study. These intersections are also located in a dense part of Buckhead and if blocking was reduced it would allow people leaving their jobs to get home faster. VRU safety was also a major consideration for why these intersections were recommended for further consideration because these intersections had the highest average number of pedestrians that were potentially put in a hazardous situation by blocking vehicles. If these intersections are considered for a DBTB campaign, a secondary analysis must be performed to determine the efficiency of the box junctions at these locations, impacts on signal timing, enforcement support, etc.

As for the intersection of Peachtree Road & Lenox Mall entrance, a DBTB campaign should be considered at this intersection because the blocking that was observed during the peak holiday seasons. By installing a box junction at this intersection multiple benefits could be reaped, the average amount of blocking that does occur at this intersection should decrease greatly during the non-holiday season and the high amount of blocking that occurs during the holiday seasons should also decrease. Another added benefit of installing a box junction at this intersection is the VRU safety benefits, as this intersection did experience some pedestrians in hazardous situations because of blocking vehicles. Lastly, the intersection of 10th Street & Williams Street was recommended because on average it experienced the highest percentage of green time with blocking and capacity lost, and safety reasons. By potentially reducing the amount of blocking at these intersections drivers have a better chance to access the interstate and other major arterials faster. Another critical safety concern that also could be alleviated could be the queueing back onto the interstate. Again, if these intersections are considered for a DBTB campaign, a secondary analysis must be performed to determine the efficiency of the box junctions at these locations, impacts on signal timing, enforcement support, etc

Future research involving a before and after analysis of the DBTB intersections, volume data in conjunction with the DBTB data would provide critical analysis that could give insightful information on blocking sessions, such as observed effects of delay and saturation headway. The assumption made in this study that the number of blocks increases as traffic volume increases, could also be validated with volume data. In additional, assumptions were made regarding the impact of blocking on saturation flow. A detailed analysis at the lane and approach level should be made to validate or adjust these assumptions. Another potential study that could be conducted for this project is to conduct a socioeconomic analysis at the Riverside Road & Heard Ferry Road intersection. If another intersection within a high income neighborhood was found in a similar area, a comparison could be drawn to determine if the DBTB campaign at Sandy Springs was the reason drivers were not blocking or if the reason was because of the socioeconomic characteristics of the drivers. Lastly, additional analysis on upstream congestion could be considered to determine if blocking at an intersection is the sole reason that some intersection experience delays in traffic operations.

APPENDIX A

ORGANIZATIONS AND CONTACT INFORMATION

Table 27: Cities and department of transportations included in survey.

State	Organization Name
AL	City of Birmingham
AL	City of Mobile
AL	City of Huntsville
AL	City of Tuscaloosa
AR	City of Little Rock
AR	City of Fort Smith
AR	City of Fayetteville
CA	City of Los Angeles
CA	City of Los Angeles
CA	City of San Diego
CA	City of San Jose
CA	City of San Francisco
CA	City of Fresno
CA	City of Sacramento
CA	City of Oakland
CA	City of Bakersfield
CA	City of Anaheim
CA	City of Chula Vista
CA	City of Fremont
CA	City of Irvine
CO	City of Denver

State	Organization Name
CO	City of Colorado Springs
CO	City of Fort Collins
CO	City of Thornton
CT	City of Hartford
CT	City of Bridgeport
CT	City of New Haven
CT	City of Stamford
DE	City of Wilmington
District of Columbia	City of Washington D.C
FL	City of Miami
FL	City of Orlando
FL	City of Miami
FL	City of Homestead
FL	City of Fort Lauderdale
FL	City of Tampa
FL	City of Daytona Beach
FL	City of Gainesville
FL	City of Tallahassee
FL	City of Jacksonville
GA	City of Sandy Springs
GA	City of Macon
GA	City of Augusta
GA	City of Athens
GA	City of Columbus
GA	City of Atlanta
GA	City of Roswell
GA	City of Marietta

State	Organization Name
HI	City of Honolulu
IA	City of Des Moines
IA	City of Cedar Rapids
IA	City of Davenport
ID	City of Boise
IL	City of Chicago
IL	City of Naperville
IL	City of Springfield
IN	City of Indianapolis
IN	City of Fort Wayne
IN	City of Evansville
KS	City of Wichita
KS	City of Overland Park
KS	City of Kansas City
KS	City of Olatheks
KS	City of Topeka
KY	City of Louisville
KY	City of Lexington
LA	City of Baton Rouge
LA	City of Shreveport
MA	City of Boston
MA	City of Worcester
MA	City of Springfield
MA	City of Lowell
MA	City of Cambridge
MD	City of Annapolis
MD	City of Baltimore
MD	City of Columbia

State	Organization Name
ME	City of Portland
MI	City of Grand Rapids
MI	City of Lansing
MI	City of Sterling Heights
MI	City of Ann Arbor
MN	City of Minneapolis
MN	City of Rochester
MO	City of Kansas City
MO	City of St. Louis
MO	City of Springfield
MO	City of Independence
MO	City of Columbia
MS	City of Jackson
MT	City of Billings
NC	City of Charlotte
NC	City of Raleigh
NC	City of Wilmington
NC	City of Durham
ND	City of Fargo
NE	City of Omaha
NE	City of Lincoln
NH	City of Manchester
NH	City of Nashua
NH	City of Concord
NJ	City of Trenton
NJ	City of Newark
NM	City of Albuquerque
NM	City of Las Cruces

State	Organization Name
NV	City of Henderson
NV	City of North Las Vegas
NV	City of Reno
NY	City of New York City
NY	City of New York City
NY	City of Buffalo
NY	City of Rochester
NY	City of Yonkers
NY	City of Albany
OH	City of Columbus
OH	City of Cleveland
OH	City of Cincinnati
OH	City of Toledo
OH	City of Akron
OH	City of Dayton
OK	City of Oklahoma City
OK	City of Tulsa
OK	City of Norman
OR	City of Portland
OR	City of Eugene
OR	City of Salem
PA	City of Philadelphia
PA	City of Pittsburgh
PA	City of Allentown
SC	City of Charleston
SC	City of Myrtle Beach
SC	City of Greenville
SC	City of Columbia

State	Organization Name
SD	City of Sioux Falls
TN	City of Germantown
TN	City of Knoxville
TN	City of Clarksville
TN	City of Murfreesboro
TX	City of Houston
TX	City of Austin
TX	City of El Paso
TX	City of Arlington
TX	City of Corpus Christi
TX	City of Laredo
TX	City of Garland
TX	City of Irving
UT	City of Salt Lake City
UT	City of West Valley City
UT	City of Provo
VA	City of Blackburg
VA	City of Richmond
VA	City of Norfolk
Virginia	City of Virginia Beach
VT	City of Burlington
VT	City of Montpelier
WA	City of Seattle
WA	City of Spokane
WA	City of Tacoma
WA	City of Vancouver
WI	City of Madison
WI	City of Green Bay

State	Organization Name
WV	City of Charleston
WV	City of Huntington

Table 28: Police departments included in survey.

State	Organization Name
AL	Mobile Police Department
AR	Little Rock Police Department
AR	Fort Smith Police Department
AR	Fayetteville Police Department
CA	Los Angeles Police Department
CA	San Jose Police Department
CA	San Francisco Police Department
CA	Fresno Police Department
CA	Police Department
CA	Oakland Police Department
CA	Bakersfield Police Department
CA	Anaheim Police Department
CA	Fremont Police Department
CA	Irvine Police Department
CO	Denver Police Department
CO	Colorado Springs Police Department
CO	Thornton Police Department
D.C.	Washington D.C Police Department
DE	Dover Police Department
FL	Miami Police Department
FL	Orlando Police Department

State	Organization Name
FL	Daytona Beach Police Department
FL	Gainesville Police Department
FL	Tallahassee Police Department
FL	Jacksonville Police Department
GA	Macon Police Department
GA	Augusta Police Department
GA	Athens Police Department
GA	Columbus Police Department
GA	Roswell Police Department
GA	Marietta Police Department
HI	Honolulu Police Department
IA	Des Moines Police Department
IA	Cedar Rapids Police Department
IA	Davenport Police Department
ID	Boise Police Department
IL	Aurora Police Department
IN	Indianapolis Police Department
IN	Evansville Police Department
KS	Wichita Police Department
KS	Kansas City Police Department
KS	Topeka Police Department
KY	Louisville Police Department
KY	Lexington Police Department
LA	Baton Rouge Police Department
LA	Shreveport Police Department
LA	Lafayette Police Department
MA	Boston Police Department
MA	Worcester Police Department

State	Organization Name
MA	Springfield Police Department
MA	Lowell Police Department
MA	Cambridge Police Department
MD	Annapolis Police Department
MD	Baltimore Police Department
MD	Columbia Police Department
MD	Germantown Police Department
MI	Detroit Police Department
MI	Grand Rapids Police Department
MI	Warren Police Department
MI	Lansing Police Department
MI	Ann Arbor Police Department
MN	Minneapolis Police Department
MN	Rochester Police Department
MO	Kansas City Police Department
MO	Springfield Police Department
MO	Independence Police Department
MO	Columbia Police Department
MS	Jackson Police Department
MT	Billings Police Department
NC	Raleigh Police Department
NC	Wilmington Police Department
NC	Durham Police Department
ND	Fargo Police Department
NH	Manchester Police Department
NH	Nashua Police Department
NH	Concord Police Department
NJ	Newark Police Department

State	Organization Name
NJ	Jersey City Police Department
NV	Henderson Police Department
NV	North Las Vegas Police Department
NV	Reno Police Department
NY	New York City Police Department
NY	Buffalo Police Department
NY	Rochester Police Department
NY	Albany Police Department
NY	Bridgeport Police Department
OH	Cleveland Police Department
OH	Cincinnati Police Department
OH	Toledo Police Department
OH	Akron Police Department
OH	Dayton Police Department
OK	Oklahoma City Police Department
OK	Tulsa Police Department
OK	Norman Police Department
OR	Salem Police Department
PA	Philadelphia Police Department
PA	Allentown Police Department
SC	Charleston Police Department
SC	Greenville Police Department
SC	Columbia Police Department
SD	Sioux Falls Police Department
TN	Knoxville Police Department
TN	Clarksville Police Department
TN	Murfreesboro Police Department
TX	Houston Police Department

State	Organization Name
TX	Austin Police Department
TX	Arlington Police Department
TX	Corpus Christi Police Department
TX	Laredo Police Department
TX	Irving Police Department
UT	Salt Lake City Police Department
UT	Provo Police Department
VA	Blacksburg Police Department
VA	Richmond Police Department
VA	Virginia Beach Police Department
VA	Norfolk Police Department
VT	Montpelier Police Department
WA	Spokane Police Department
WA	Vancouver Police Department
WI	Madison Police Department
WI	Green Bay Police Department
WV	Charleston Police Department

Table 29: TMAs included in survey *(1)*.

Organization	Website Address
128 Business Council	http://www.128bc.org
36 Commuting Solutions	http://36commutingsolutions.org
494 Corridor Commission	http://494corridor.org
50 Corridor Transportation Management Association	http://50corridor.com/
A Better City (ABC) Transportation Management Association	http://abctma.com
Airport Corridor Transportation Association	http://acta-pgh.org
Anaheim Resort Transportation	www.rideart.org
Annapolis Regional Transportation Management Association	http://www.artma.org
Anoka County TMO	http://anokacountytmo.com

Organization	Website Address
Appleton Downtown Inc	www.appletondowntown.org
Batavia Business Improvement District	www.downtownbataviany.com
Bay Area Houston Transportation Management Association	http://www.baytran.org
Bethesda Transportation Solutions	http://bethesdatransit.org
Boulder Transportation Connections	http://www.bouldertc.org
Burbank Transportation Management Organization	www.btmo.org
Business Improvement District of Coral Gables	www.shopcoralgables.com
Campus Area Transportation Management Association	http://catmavt.org
Capital Crossroads and Discovery Special Improvement Districts	www.downtowncolumbus.com
Center City District	www.centercityphila.org
Central District Management Association, Inc	http://www.centralbid.com
Central Philadelphia Transportation Management Association	http://centercityphila.org/about/CPTMA.php
Centro San Antonio/Downtown Alliance	www.Downtownsa.org
Century City TMO	http://www.commute90067.com
Chapel West Special Services District	http://www.chapelwest.com
Charles River Transportation Management Association	http://www.charlesrivertma.org
Charlotte Center City Partners	http://charlottecentercity.org
City of Fort Smith	www.GoDowntownFS.com
City of Fremont	www.fremontne.gov
City of Monterey Park	http://www.ci.monterey-park.ca.us/index.aspx?page=1811
City of Santa Monica Virtual TMA	http://www.CommuteSM.com
Commute Seattle	http://www.commuteseattle.com
Commuter Challenge	http://commuterchallenge.org
Commuter Connections	http://www.mwcog.org/commuter2
Contra Costa Centre Transit Village	http://www.contracostacentre.com/
Corpus Christi Downtown Management District	www.downtowncorpuschristi.com
Cross County Connection Transportation Management Association	http://www.driveless.com
Delaware County Transportation Management Association	http://www.dctma.org
Downtown Akron Partnership	www.downtownakron.com
Downtown and University Hill Management Division, Parking Services	http://www.bouldercolorado.gov/index.php?option=com_content&task=view&id=1238&Itemid=436
Downtown Beloit Association	www.downtownbeloit.com
Downtown Cincinnati Inc.	www.downtowncincinnati.com
Downtown Committee of Syracuse, Inc.	www.downtownsyracuse.com

Organization	Website Address
Downtown Dartmouth Business Commission	http://www.downtowndartmouth.ca/
Downtown Denver Partnership	http://downtowndenver.com/AboutUs/ProgramsandInitiatives/DowntownDenverTMA/tabid/95/Defau lt.aspx
Downtown Fort Lauderdale Transportation Management Association	http://www.suntrolley.com
Downtown in Motion/Central Houston, Inc.	http://centralhouston.com/Home/default.asp
Downtown Inc	www.downtown-santaana.com
Downtown Ithaca Alliance	www.downtownithaca.com
Downtown Manchester Special Service District	www.downtownmanchester.org
Downtown Minneapolis Transportation Management Organization	http://www.commuter-connection.org
Downtown Phoenix Partnership	www.downtownphoenix.com
Downtown Roanoke, Inc.	www.downtownroanoke.org
Downtown Sanford, Inc.	www.downtownsanford.com
Downtown Stockton Alliance	www.downtownstockton.org
Downtown Tempe Community	www.downtowntempe.com
Downtown Ventura Partners	www.downtownventura.org
Dulles Area Transportation Management Association	http://datatrans.org/about.html
Duwamish Transportation Management Association	http://www.duwamishtma.org
East Aldine Management District	www.aldinedistrict.org
Emeryville Transportation Management Association	http://emerygoround.com/
Energy Corridor District	www.energycorridor.org
EZ Ride	http://www.ezride.org
Fast Potomac Yard	http://fastpotomacyard.com
Florin Road Partnership	www.florinroad.com
Glendale Transportation Management Association	http://www.glendaletma.net/
goDCgo	http://www.godcgo.com
Greater Broadway Partnership	www.greaterbroadwaypartnership.co m
Greater Des Moines Transportation Management Association	http://www.downtowndesmoines.com/pages/drivetime-des-moines
Greater Mercer Transportation Management Association	http://gmtma.org
Greater Redmond Transportation Management Association	http://grtma.org
Greater Valley Forge Transportation Management Association	http://www.gvftma.com
Hacienda Business Park	http://www.hacienda.org/main/home.html
Hackettstown Business Improvement District	www.hackettstownbid.com

Organization	Website Address
HART Commuter Information Services	http://www.harttma.com
Hollywood Media District BID	www.mediadistrict.org
Hudson Transportation Management Association	http://hudsontma.org
I-70 Coalition	http://www.i70solutions.org
Ironbound Business Improvement District (IBID)	www.goironbound.com
Junction Transportation Management Association	http://www.junctiontmo.com/
Kailua Village BID	www.kvbid.org
Keep Middlesex Moving Inc.	http://kmm.org
LA Fashion District	www.fashiondistrict.org
Leeward Oahu Transportation Management Association	http://lotma.org
Little Italy Association	www.littleitalysd.com
Lloyd District Transportation Management Association	http://lloydtma.org
Lower East Side BID	www.lowereastsideny.com
Masco/Commute Works	http://www.masco.org/directions/commuteworks?ql=commuteworks
McClellan Park TMA	www.mcclellanparktma.org
Merrimack Valley Transportation management Association	http://merrimackvalleytma.com
MetroWest/495 TMA	http://metrowest495tma1.org
Midtown Business Association	www.mbasac.com
Milwaukee Downtown, BID #21	www.milwaukeedowntown.com
miracle mile improvement district	www.stocktonmiraclemile.com
Missoula Ravalli Transportation Management Association	http://www.mrtma.org
Moffett Park & Business Transportation Association	http://www.mpbta.org
Montclair Village Association	www.montclairvillage.com
Mooresville Downtown Commission	www.downtownmooresville.com
Neponset Valley TMA	http://www.neponsetvalleytma.org
New Britain Downtown District	www.newbritaindd.com
New North Transportation Alliance	http://newnorthalliance.org
North Bethesda Transportation Center	http://www.nbtc.org/indexcommunity.html
North Natomas TMA	http://www.northnatomastma.org
North Shore TMA	http://northshoretma.org
Northern Neck Rideshare	http://www.neckride.org
Northwest Side CDC	www.nwscdc.org
Oakland Transportation Management Association	http://otma-pgh.org
Old Town San Diego Chamber of Commerce	www.oldtownsandiego.org
Oldtown Salinas Association	www.oldtownsalinas.com
Omaha Downtown Improvement District Association	www.omahadowntown.org
Orange Regional Transportation Management Association	
Ozarks Transportation Organization	http://www.ozarkstransportation.org

Organization	Website Address
Pasadena TMO	http://www.ci.pasadena.ca.us/Transportation/Transportation_Management_Association
Pensacola Downtown Improvement Board	www.downtownpensacola.com
Placer Country Transportation Management Association	http://pctpa.net/
Point West Area TMA	http://www.80corridor.com
Portland Business Alliance	www.portlandalliance.com
Potomac and Rappahannock Transportation Commission	http://prtctransit.org
Prairie Stone TMA	http://www.prairiestone.com/transport.html
Ride-on TMA	http://www.ride-on.org/
Ridewise	http://www.ridewise.org
Sacramento TMA	http://sacramento-tma.org
San Francisco International Airport Commission	http://www.flysfo.com/web/page/about/commission
Seaport TMA	http://seaporttma.org
SmartCommute Transportation Management Association	http://www.smartcommute.org
South 125 TMA	http://www.southeastconnections.com
South Bay Westside TMA	
South Florida Education Center TMA	http://www.sfec.org
South Natomas TMA	http://sntma.org
South Waterfront Transportation Management Association	http://www.southwaterfront.com/category/transportation
Spectrumotion TMA	http://www.spectrumotion.com/mission.asp
St. Paul Smart Trips	http://smart-trips.org
St. Petersburg Downtown Partnership	http://www.stpetepartnership.org
Stapleton TMA	http://stapletontma.com
Superior Business Improvment District	www.superiorbid.com
Swan Island Transportation Management Association	http://swanislandtma.org
Tampa Downtown Partnership	http://www.tampasdowntown.com
The BWI Business Partnership	http://bwipartner.org
The Partnership Transportation Management Association of Montgomery County	http://ptma-mc.org
The Presidio Trust	http://www.presidio.gov/visit/transportation/Pages/default.aspx
TMA Bucks	http://tmabucks.com
TMA of Lake Cook	http://tmalakecook.org
TMA of San Francisco	http://tmasfconnects.org
Town Center Area CID	www.tcacid.com
Town Green District	www.infonewhaven.com
Township of Haddon	www.haddontwp.com/
Traffic Solutions	http://www.trafficsolutions.info/default.htm

Organization	Website Address
TranSComm at Boston University Medical Campus	http://www.bumc.bu.edu/transcomm
Transit Alliance	http://www.transitalliance.org
Transmanage/Bellevue Downtown Association	http://www.bellevuedowntown.org/about/contact.html
TransOptions	http://www.transoptions.org
Transportation Management Association Group	http://www.tmagroup.org
Transportation Management Association of Chester County	http://www.tmacc.org
Transportation Management Association of Greater Springfield	http://tagsva.org
Transportation Solutions	http://transolutions.org
Trek Transportation Management Organization	http://trekhouston.org
Truckee North Lake Tahoe TMS	http://www.laketahoetransit.com/home
Tysons Transportation Association	http://www.tytran.org
Ukiah Main Street Program	www.downtownukiah.com
Upper Valley Transportation Management	http://vitalcommunities.org/Transport/translinks.htm
Urban Districts Alliance	www.itsalldowntown.com
Warner Center TMA	
West Ridge Chamber of Commerce	www.westridgechamber.org
West Shore Alliance TMA	http://www.choosewestshore.com
West Side Transportation Alliance	http://wta-tma.org
Wildwoods Boardwalk Special Improvement District, Management Corporation	www.dowildwood.com

APPENDIX B

DBTB SURVEY

Don't Block the Block Survey

The Georgia Institute of Technology (Georgia Tech) in Atlanta, GA. is investigating Don't Block the Box (DBTB) campaigns across the United States. As part of this effort we hope you will be willing to complete the attached survey regarding DBTB in your area, or if you are not the correct person to complete this survey, to direct us to the proper contact. The survey should take no more than 5-15 minutes.

The results from this survey will be used to help inform guidance on the potential use of DBTB campaigns as an economical alternative for traffic management. While you are not likely to directly benefit from completing this survey it is hoped that this research will aid DOTs, Cities, TMAs, BIDs, CIDs, etc. in the implementation of DBTB as a transportation management tool.

The results of this survey will be used by Georgia Tech researchers. Your participation in this study is voluntary. You may change your mind and exit the survey at any time. Your name and any other identifying information will not appear when results of this study are presented or published. Your participation and expertise are invaluable and we sincerely thank you for your time and responses. As part of the survey you will also be offered the opportunity to receive a final copy of this report.

If you have any questions, please do not hesitate to email Michael Hunter (michael.hunter@ce.gatech.edu), Angshuman Guin (angshuman.guin@ce.gatech.edu) or Samuel Harris (dharris41@gatech.edu).

Note: Questions with an asterisk (*) require answers.

***1. By selecting yes, it means that you have read (or have had read to you) the preceding information given in this consent form, and you would like to be a volunteer to take this survey and be in this research study. Thank you, Dr. Hunter, Dr. Guin, and Samuel Harris.**

- ○ Yes
- ○ No

Don't Block the Block Survey

The image below shows one example of a DBTB intersection. (Image source:http://www.masco.org/news/sp-don't-block-intersection)

The image below shows an example of a DBTB sign that can be installed at an intersection. (Image source: Farylrobin.com)

***2. Organization Contact:**

Name:

Title:

E-mail address:

Phone Number:

Website address:

Don't Block the Block Survey

*3. Organization Classification

- State Department of Transportation
- Transportation Management Association
- Business Improvement District
- University
- Police Department
- Local Jurisdiction (City, County, etc.)
- Other (please specify)

*4. Does your organization currently have a DBTB campaign?

- Yes
- No

Don't Block the Block Survey

***5. When did the DBTB campaign start?**

- ○ Before 1980
- ○ 1980 - 1990
- ○ 1990 - 2000
- ○ 2000 - 2010
- ○ 2010 - Present
- ○ Don't Know

***6. What were the particular issues that were addressed by DBTB?**

- ☐ Traffic congestion
- ☐ Pedestrian safety
- ☐ Bicycle safety
- ☐ Vehicle safety
- ☐ Emission standards concerns
- ☐ Health and safety of residents
- ☐ Economic consequences to surrounding businesses
- ☐ Don't Know

Other (please specify)

***7. Who proposed your organization's DBTB campaign?**

- ☐ Employee proposed idea
- ☐ State Department of Transportation
- ☐ Transportation Management Association
- ☐ Business Improvement District
- ☐ University
- ☐ Private Consulting Firm
- ☐ Police Department
- ☐ Local Jurisdiction (City, County, etc.)
- ☐ Don't Know
- ☐ Other (please specify)

Don't Block the Block Survey

***8. Approximately how many intersections currently have DBTB?**

- ○ 0 - 5
- ○ 6 - 10
- ○ 11 - 15
- ○ 15 - 20
- ○ 20+
- ○ Don't Know

***9. Was there a public education campaign launched to inform the public about DBTB?**

- ○ Yes
- ○ No

Don't Block the Block Survey

***10. Who was designated for conducting the public education campaign? (Select multiple for collaborative efforts.)**

- ☐ Our Organization
- ☐ State Department of Transportation
- ☐ Transportation Management Association
- ☐ Business Improvement District
- ☐ Private Consulting Firm
- ☐ University
- ☐ Police Department
- ☐ Local Jurisdiction (City, County, etc.)
- ☐ Don't Know

Other (please specify)

***11. What type of public education campaign(s) did your organization launch?**

- ☐ Television ads
- ☐ Newspaper ads
- ☐ Handed out pamphlets
- ☐ Billboards
- ☐ Website
- ☐ E-mail
- ☐ Social media
- ☐ None
- ☐ Don't know
- ☐ Other (please specify)

***12. What was the estimated budget for the public education campaign?**

- ○ No Dedicated Budget
- ○ Up to $4,999
- ○ $5,000 - $9,999
- ○ $10,000+
- ○ Don't Know

Don't Block the Block Survey

***13. How often is the public education campaign repeated?**

- ☐ Never
- ☐ Once a year
- ☐ Twice a year
- ☐ Three times a year
- ☐ 3+ time a year
- ☐ Don't know
- ☐ Other (please specify)

Don't Block the Block Survey

***14. Are there any partnerships that your organization found particularly critical to the success of this DBTB campaign?**

- ☐ Partnership with the Local Jurisdiction (City, County, etc.)
- ☐ Partnership with the police department
- ☐ Partnership with the State's Department of Transportation
- ☐ Partnership with the neighborhood associations
- ☐ None
- ☐ Don't Know
- ☐ Other (please specify)

***15. What were some of the more difficult obstacles in implementing the DBTB campaign?**

- ☐ Enforcement from the police department
- ☐ Financial restrictions
- ☐ Public disapproval
- ☐ No major obstacle(s)
- ☐ Don't Know
- ☐ Other (please specify)

16. If your organization had difficulties in the implementation of the DBTB campaign, how did you overcome them?

Don't Block the Block Survey

***17. Which of the following were installed in your organization's DBTB intersection(s)?**

- ○ Sign(s)
- ○ Pavement markings
- ○ Sign(s) and Pavement markings
- ○ Don't Know
- ○ None of the Above

Other, please specify.

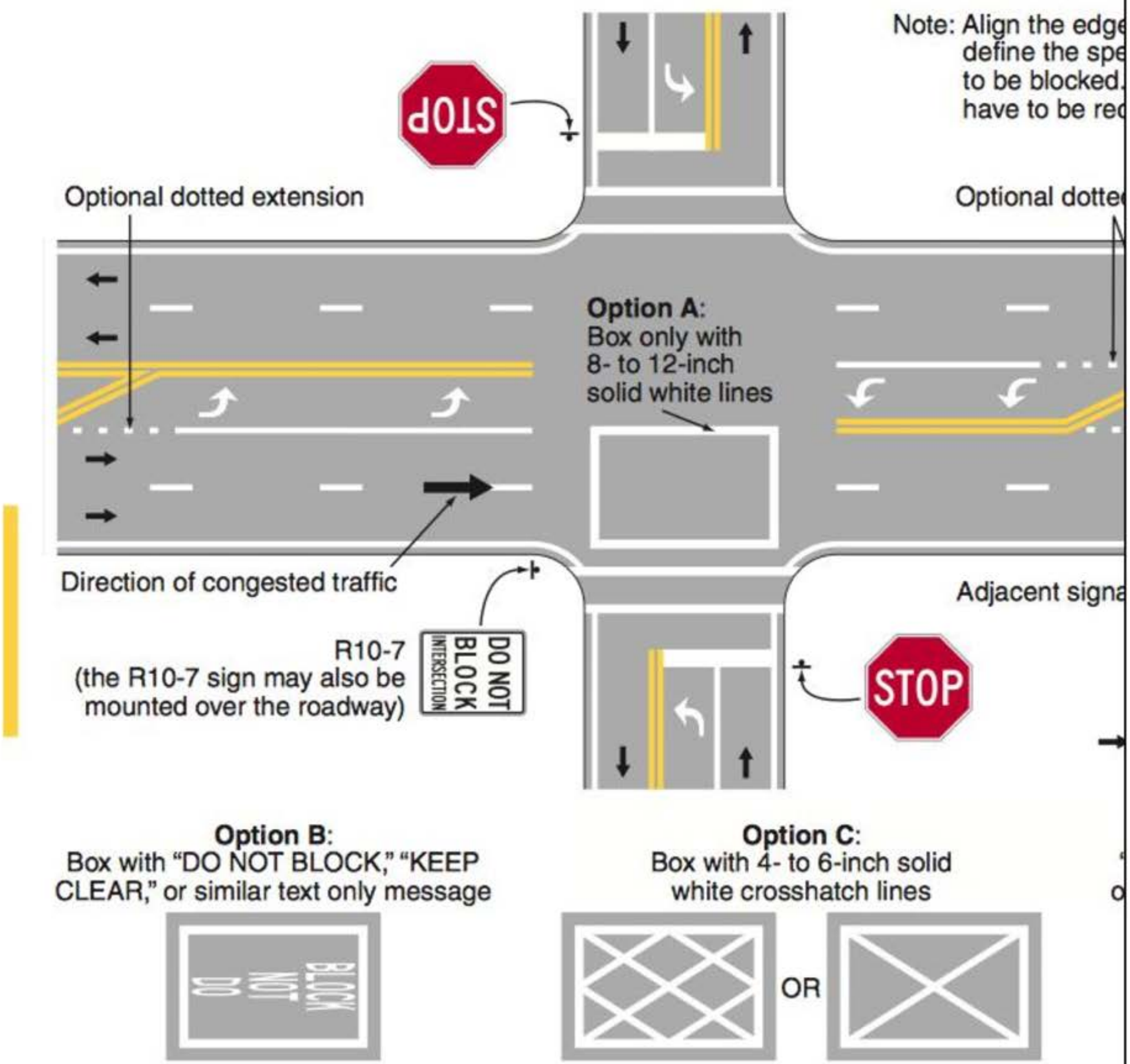
Don't Block the Block Survey

***18. Who installed and paid for the DBTB sign(s)?**

- ☐ My organization paid for and installed the sign(s)
- ☐ My organization paid for the sign(s) and another organization installed them
- ☐ Another organization paid for the sign(s) and my organization installed them
- ☐ Another organization paid for and installed the sign(s)
- ☐ Don't know
- ☐ Other (please specify)

Don't Block the Block Survey

MUTCD Do not Block the Intersection Guidelines (Source: MUTCD, 2009)



Don't Block the Block Survey

***19. Based on the MUTCD guidelines shown above, what type of pavement markings were installed in the DBTB intersection(s)?**

- ☐ Option A
- ☐ Option B
- ☐ Option C
- ☐ Option D
- ☐ Don't Know
- ☐ None of the Above

Other, please briery describe or provide link to specification, if possible.

***20. Who installed and paid for the pavement markings in the DBTB intersection(s)?**

- ☐ My organization paid for and installed the pavement markings
- ☐ My organization paid for the pavement markings and another organization installed them
- ☐ Another organization paid for the pavement markings and my organization installed them
- ☐ Another organization agency paid for and installed the pavement markings
- ☐ Don't know
- ☐ Other (please specify)

Don't Block the Block Survey

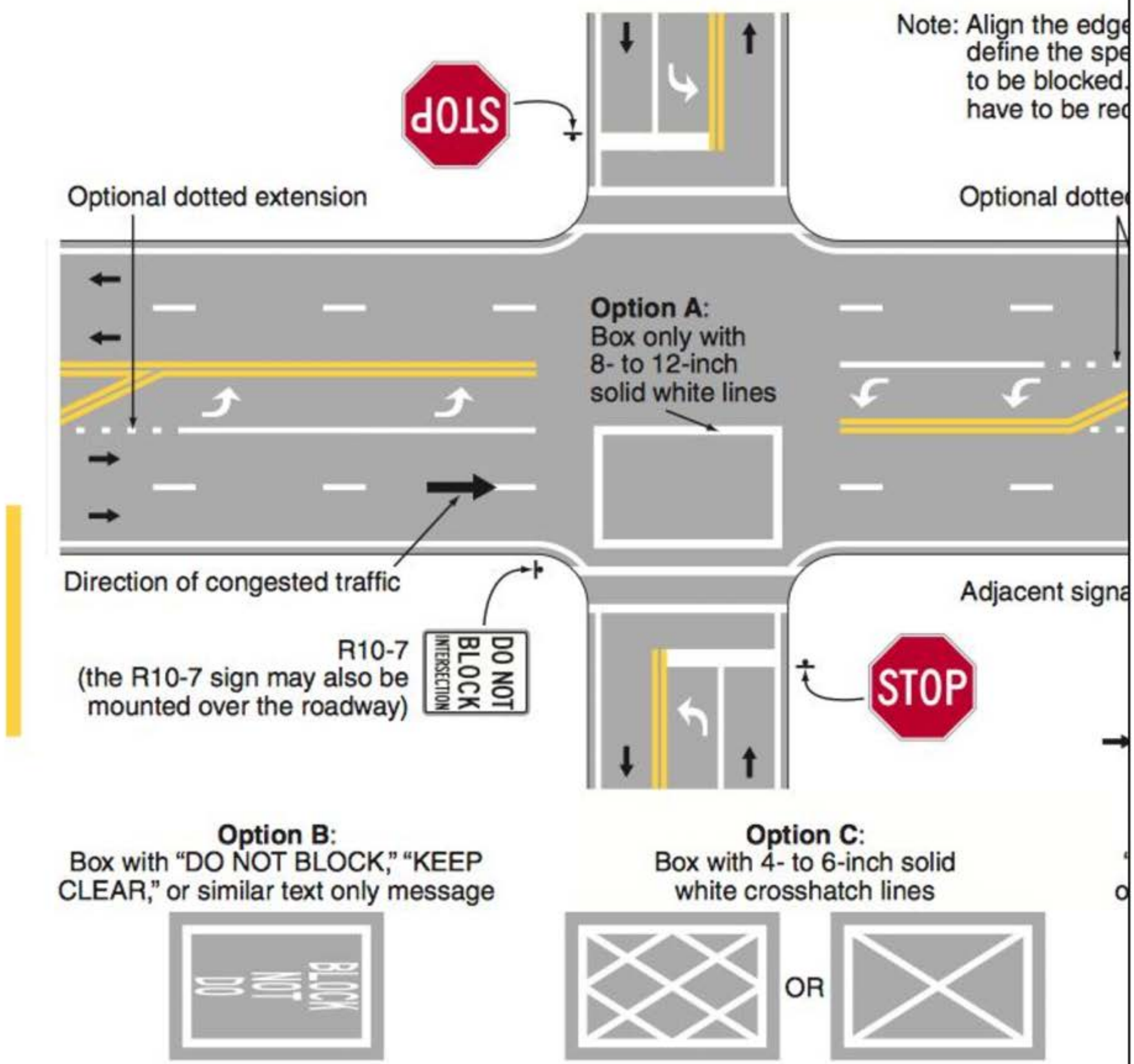
***21. Who installed and paid for the DBTB sign(s)?**

- ☐ My organization paid for and installed the sign(s)
- ☐ My organization paid for the sign(s) and another organization installed them
- ☐ Another organization paid for the sign(s) and my organization installed them
- ☐ Another organization paid for and installed the sign(s)
- ☐ Don't know

Other (please specify)

Don't Block the Block Survey

MUTCD Do not Block the Intersection Guidelines (Source: MUTCD, 2009)



Don't Block the Block Survey

***22. Based on the MUTCD guidelines shown above, what type of pavement markings were installed in the DBTB intersection(s)?**

- ☐ Option A
- ☐ Option B
- ☐ Option C
- ☐ Option D
- ☐ Don't Know
- ☐ None of the Above

Other, please briery describe or provide link to specification, if possible.

***23. Who installed and paid for the pavement markings in the DBTB intersection(s)?**

- ☐ My organization paid for and installed the pavement markings
- ☐ My organization paid for the pavement markings and another organization installed them
- ☐ Another organization paid for the pavement markings and my organization installed them
- ☐ organization agency paid for and installed the pavement markings
- ☐ Don't know

Other (please specify)

Don't Block the Block Survey

***24. What is the estimated budget for installing the DBTB sign(s) and/or pavement markings at an intersection?**

- Under $499
- $500 to $999
- $1,000 to $1,999
- $2,000 to $2,999
- $3,000+
- Don't know

Don't Block the Block Survey

***25. Are the intersections within the DBTB campaign enforced?**

- ◯ Yes
- ◯ No

Don't Block the Block Survey

***25. Are the intersections within the DBTB campaign enforced?**

- ○ Yes
- ○ No

Don't Block the Block Survey

***26. Is blocking the box considered a moving violation or a non-moving violation? (A moving violation means only a police officer can issue a ticket and a non-moving violation means other agencies, such as parking services, can issue a ticket)**

- ○ Moving violation
- ○ Non-moving violation
- ○ Don't know

Don't Block the Block Survey

***27. Are there currently plans to make blocking the box a non-moving violation?**

- ○ Yes
- ○ No
- ○ Don't know

Don't Block the Block Survey

***28. Was allowing non-police officers to issue tickets to blocking violators the primary purpose for changing the DBTB violation to a non-moving violation?**

- Yes
- No
- Don't know

Don't Block the Block Survey

***29. Are automated enforcements, such as cameras, used?**

- Yes
- No
- Don't Know

Don't Block the Block Survey

***30. Is there a specific task force assigned to enforce DBTB intersection(s) or can any officer enforce DBTB intersection(s).**

- ○ Specific task force assigned to enforce DBTB intersection(s)
- ○ Any officers can enforce DBTB intersection(s)
- ○ Don't know

***31. Is there a set budget for DBTB enforcement?**

- ○ Yes
- ○ No
- ○ Don't know

Don't Block the Block Survey

***32. Do you believe there is a need for additional enforcement at the DBTB locations?**

- Yes
- No

***33. How much is the fine for a DBTB violation?**

- Under $100
- $100 - $199
- $200 - $299
- $300 - $399
- $400 - $499
- $500 or more
- Don't know

34. Are points added to the driver's license for a DBTB violation?

- Yes
- No
- Don't know

If yes, how many points are taken off (if known)?

Don't Block the Block Survey

* 35. Why is there currently no enforcement for the DBTB intersection(s)?

- ☐ Time and resources not available
- ☐ There is no evidence to support the need for enforcement
- ☐ Don't know
- ☐ Other (please specify)

* 36. Are there plans to add enforcement in the future?

- ○ Yes
- ○ No
- ○ Don't know

Don't Block the Block Survey

***37. In your organization's opinion, what is the level of improvement in traffic operations since the DBTB campaign started?**

- Minimal
- Moderate
- Sufficient
- Don't know

38. In your organization's opinion, what can be done to improve DBTB?

***39. Assuming the DBTB campaign was initally successful, did the observed benefits decline over time?**

- Yes
- No
- DBTB campaign was not successful
- Don't know

***40. Does your organization record data to measure and document the improvements caused by the DBTB campaign?**

- Yes
- No
- Don't know

Don't Block the Block Survey

41. If your organization has any studies or data related to the DBTB campaign that may be shared, please provide the references or contacts so that we may follow up on this.

***42. Is there a positive public perception for your organization's DBTB campaign?**

- Yes
- No
- Don't know

If yes, can you please elaborate (Give examples of what people, newspapers, social media, etc, have said).

Don't Block the Block Survey

***43. Has your organization considered implementing a DBTB campaign and chosen not to proceed?**

- ◯ Yes
- ◯ No

Don't Block the Block Survey

***44. What were the reason(s) your organization stopped considering a DBTB campaign?**

- ☐ Cost
- ☐ Time
- ☐ Effort
- ☐ No perceived benefits
- ☐ Public disapproval
- ☐ Don't know
- ☐ Other (please specify)

***45. Is your organization currently considering a DBTB campaign?**

- ○ Yes
- ○ No
- ○ Don't Know

Don't Block the Block Survey

***46. What benefits do you anticipate from the DBTB campaign?**

- ☐ Reduction in traffic congestion
- ☐ Increased pedestrian safety
- ☐ Increased bicycle safety
- ☐ Increased vehicle safety
- ☐ Reduction in vehicle emissions
- ☐ Increase the health and safety of residents
- ☐ Positive economical impact to surrounding businesses
- ☐ Don't Know
- ☐ Other (please specify)

***47. What concerns does your organization have in the DBTB campaign?**

- ☐ Cost
- ☐ Time
- ☐ Effort
- ☐ No perceived benefits
- ☐ Public disapproval
- ☐ Don't know
- ☐ Other (please specify)

***48. Approximately how many intersections would you expect to be included in your organization's DBTB campaign?**

- ○ 0 - 5
- ○ 6 - 10
- ○ 11 -15
- ○ 15 - 20
- ○ 20+
- ○ Don't know

Don't Block the Block Survey

***49. If DBTB campaigns are shown to be an economical alternative in traffic management, would your organization consider starting a DBTB campaign to help with congestion and safety concerns?**

- ○ Yes
- ○ No

Don't Block the Block Survey

50. Is your organization interested in receiving a copy of the final report?

- Yes
- No

51. Is it okay to contact you for a follow-up interview based on your survey results?

- Yes
- No
- No, but you may contact this individual instead (name, title, phone number, email address):

Don't Block the Block Survey

Thank you for completing the DBTB survey.

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