A Demonstration of Virtual Transportation Management:

Strategies for Smart Cities in New York State

Final Report | Report Number 22-33 | DOT Number C-17-08 | April 2023

NEW YORK STATE | NYSERDA | Department of Transportation

A Demonstration of Virtual Transportation Management: Strategies for Smart Cities in New York State

Final Report

Prepared for:

New York State Energy Research and Development Authority

Albany, NY

Robyn Marquis, Ph.D.
Project Manager

and

New York State Department of Transportation

Albany, NY

Richard Batchelder
Project Manager and Transportation Analyst

Prepared by:

University Transportation Research Center, Region 2 (UTRC)/City College of New York

Camille Kamga, Ph.D.
Bahman Moghimi, Ph.D.
Rodrigue Tchamna, Ph.D.
Sandeep Mudigonda, Ph.D.
Kyriacos Mouskos, Ph.D.
Project Managers

In partnership with:

Colliers Engineering & Design CT, P.C. (DBA Maser Consulting)

Maurice Rached, P.E.
Keith Hall, P.E.
Samantha Beckett
Project Managers

NYSERDA Report 22-33
NYSERDA Contract 112013
DOT Task Assignment C-17-08
April 2023

Notice

This report was prepared by the University Transportation Research Center at the City College of New York in partnership with Colliers Engineering & Design CT, P.C. (DBA Maser Consulting) (CED) in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority and the New York State Energy Research and Development Authority (NYSERDA) and the New York State Department of Transportation (hereafter the "Sponsors"). The opinions expressed in this report do not necessarily reflect those of the Sponsors or the State of New York, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, the Sponsors, the State of New York, and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. The Sponsors, the State of New York, and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

NYSERDA makes every effort to provide accurate information about copyright owners and related matters in the reports we publish. Contractors are responsible for determining and satisfying copyright or other use restrictions regarding the content of the reports that they write, in compliance with NYSERDA's policies and federal law. If you are the copyright owner and believe a NYSERDA report has not properly attributed your work to you or has used it without permission, please email print@nyserda.ny.gov

Information contained in this document, such as web page addresses, are current at the time of publication.

Disclaimer

This report was funded in part through grant(s) from the Federal Highway Administration, United States Department of Transportation, under the State Planning and Research Program, Section 505 of Title 23, U.S. Code. The contents of this report do not necessarily reflect the official views or policy of the United States Department of Transportation, the Federal Highway Administration (FHWA) or the New York State Department of Transportation (NYSDOT). This report does not constitute a standard, specification, regulation, product endorsement, or an endorsement of manufacturers.

Technical Report Documentation Page

1. Report No. C-17-08	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle: Demonstration of Virtual Transportation Management Strategies for Smart Cities in New York State		5. Report Date April 2023	
		6. Performing Organization Code	
7. Author(s): Camille Kamga, Bahman Moghimi, Rodrigue Tchamna, Sandeep Mudigonda, Kyriacos Mouskos, Maurice Rached, Keith Hall, Samantha Beckett		8. Performing Organization Report Number 22-33	
9. Performing Organization Name and Address: The University Transportation Research Center, The City College of NY, 160 Convent Avenue, New York 10031. Colliers Engineering & Design CT,P.C. (DBA Maser Consulting), 1000 Water View Drive #201, Hamilton Township, NJ 08691		10. Work Unit No.	
		11. Contract or Grant No. NYSERDA #112013	
12. Sponsoring Agency Name and Address: NYS Department of Transportation 50 Wolf Road, Albany, NY 12232 NYS Energy Research and Development Authority, 17 Columbia Circle, Albany, NY 12203		13. Type of Report and Period Covered	
		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract This report documents the activities performed at the City of Mount Vernon, NY by the University Transportation Research Center, Colliers Engineering & Design CT, P.C., Miovision Technologies Inc., Live Traffic Data Corp, and Traffic Systems Incorporated to demonstrate an effective strategy to deploy advanced transportation management systems (ATMS) to better manage and operate the transportation systems on municipal streets and arterials. The traffic technologies were installed at seven intersections along the Gramatan Avenue corridor in the City of Mount Vernon. This "Demonstration of Virtual Transportation Management Strategies for Smart Cities in New York State" provided an opportunity to establish the effectiveness of a Virtual Transportation Management (VTM) for any small, medium, and large city. In this case, the City of Mount Vernon VTM would be especially beneficial in improving the efficiency and safety of its transportation system, which would also result in the reduction of energy use, improvement in air quality, and reduction in the use of natural resources. It is anticipated that it will also help improve and foster economic growth in specific portions of the city.			
17. Key Words Advanced Transportation Management System (ATMS), Virtual Transportation Management (VTM), Smart Cities, Traffic Technologies	18. Distribution Statement		
19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages: 98	22. Price

USDOT Form DOT F 1700.7 (8-72)

Abstract

This report documents the activities performed at the City of Mount Vernon, NY by the University Transportation Research Center, Colliers Engineering & Design CT, P.C., Miovision Technologies Inc., Live Traffic Data Corp., and Traffic Systems Incorporated to demonstrate an effective strategy to deploy advanced transportation management systems (ATMS) to better manage and operate the transportation systems on municipal streets and arterials. The traffic technologies were installed at seven intersections along the Gramatan Avenue corridor in the City of Mount Vernon. This "Demonstration of Virtual Transportation Management Strategies for Smart Cities in New York State" provided an opportunity to establish the effectiveness of a Virtual Transportation Management (VTM) for any small, medium, and large city. In this case, the City of Mount Vernon VTM would be especially beneficial in improving the efficiency and safety of its transportation system, which would also result in the reduction of energy use, improvement in air quality, and reduction in the use of natural resources. It is anticipated that it will also help improve and foster economic growth in specific portions of the city.

Keywords

Advanced Transportation Management System (ATMS), virtual transportation

Acknowledgments

The project team at the City College of NY and CED would like to acknowledge everyone that helped make this project successful. Many former and current staff of the Office of the Mayor, the Department of Planning & Community Development, the Department of Public Work, and the Department of Police at the City of Mount Vernon have been instrumental toward the successful implementation of the project. We would like to thank Steve Lawrence, Christopher Piarulli, Carmine Busa, Karen Buddenhagen, Chantelle Okarter, Darren Morton, William Long, Shawyn Patterson-Howard, Fraida Hickson, Carie Mobley-Johnson, Damani Bush, and former Mayor Richard Thomas for their support and assistance.

We are grateful to the support and assistance provided by Andrew Fonseca, Kyle Othmer, Joel Quigley, Mike Di Blasio, Ian Davis, and Carl Puddy at Miovision Technologies Inc., Maria Grazia Verardi and Heng Hu at Live Traffic Data Corp, Richard Marsanico at Traffic Systems Incorporated, and Steven Atkins at Northeast Signal Inc.

The authors would like to acknowledge project managers Dr. Robyn Marquis of NYSERDA and Richard Batchelder of the NYS Department of Transportation, who have continually supported environmentally friendly and innovative transportation in New York State.

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

Act-Coord	Actuated Coordination Control
AI	Artificial Intelligence
AM	Ante Meridiem
API	Application Programming Interface
ATMS	Advanced Transportation Management System
ATSPM	Automated Traffic Signal Performance Measures
AWS	Amazon Web Services
CCNY	The City College of New York
CED	Colliers Engineering & Design CT, P.C. (DBA Maser Consulting)
CO	Carbon Monoxide
CMS	Content Management System
CUNY	The City University of New York
DNN	Deep Neural Networks
DSRC	Dedicated Short-range Communication
FHWA	Federal Highway Administration
GHG	Greenhouse gas
GPS	Global Positioning System
HCM	Highway Capacity Manual
HGV	Heavy Goods Vehicle
ID	Identity Document
IT	Information Technology
ITS	Intelligent Transportation System
PoE	Powered over Ethernet
LTD	Live Traffic Data Corp.
LTE	Long-Term Evolution
MAC	Media Access Control
MD	Midday
NB	Northbound
NEMA	National Electrical Manufacturers Association
NOx	Nitrogen Oxides
NTCIP	National Transportation Communications for ITS Protocol
NTOC	The National Transportation Operations Coalition
NYCDOT	New York City Department of Transportation
NYS	New York State
NYSDOT	New York State Department of Transportation
NYSERDA	New York State Energy Research and Development Authority
PM	Post Meridiem

RBC	Ring Barrier System
RSU	Roadside Unit
SB	Southbound
SIGPAT	SIGnal Performance Analysis Toolbox
SMS	Short Message Service
SOW	Statement of Work
SPaT	Signal Phase and Timing
SPR	State Planning and Research
TSI	Traffic Systems Incorporated
TSP	Transit Signal Priority
TSM&O	Transportation Systems Management and Operations
UPS	Uninterruptible Power Supply
U.S.	United States
V2I	Vehicle to Infrastructure
VMT	Vehicle Miles Travelled
VOC	Volatile Organic Compound
VPH	Vehicles per hour
VPM	Vehicle per minute
VPN	Virtual Private Network
VTM	Virtual Transportation Management

Executive Summary

Over the past 30 years, congestion has rapidly increased, particularly in metropolitan areas. As population numbers continue to increase, and with the volume of freight expected to double by 2020, congestion is a significant issue that needs to be addressed. Poorly managed traffic signal systems can exacerbate congestion, particularly in metropolitan settings. Ineffective management, operations, and maintenance of traffic signals contributes to almost 300 million vehicle-hours of delay annually in the United States (U.S.). In response to these turbulent conditions, technology is advancing rapidly and is providing new approaches to managing congestion, including the application of advanced transportation systems management and operations. Agencies, counties, and municipalities are focusing their efforts and funds on operating roadways more efficiently. Larger agencies throughout New York State, such as the New York City Department of Transportation, have done a great job of deploying Intelligent Transportation Systems over the past several years to help gather data, manage incidents, and improve congestion and mobility along their roadway systems. However, many local municipal roadway systems lack the same level of technology and resources, which in many cases degrades the critical first and final leg of the journey. As our larger roadway facilities utilize these tools to better manage and operate the systems, these congested local roadways will become bottlenecks that prevent the movement of people and goods throughout the State. As citizens become more familiar with the benefits of these technologies on regional, State, and Interstate roadways, local governments may be called upon to implement similar smart technology solutions on local roadways.

This project was funded under the Program Opportunity Notice (PON 3345: Making Transportation Smart and Sustainable) administered by the New York State Energy and Research Development Authority (NYSERDA) and the New York State Department of Transportation (NYSDOT). The objective of this project entitled “A Demonstration of Virtual Transportation Management Strategies for Smart Cities in New York” is to perform a demonstration of an effective strategy to deploy advanced transportation management systems (ATMS) to better manage and operate the transportation systems on municipal streets and arterials. The project team demonstrated a “Virtual Traffic Management Strategy” (VTM) for the City of Mount Vernon, NY by employing underutilized strategies and policies related to advanced traffic management and integrated corridor management. Wireless communication technologies and cloud-based ATMS with dynamic video detection units and wireless magnetometer sensors capable of covering entire intersections have been deployed.

Upon an assessment of corridors at the City of Mount Vernon, two major areas were selected for the location of the tests: Gramatan Avenue, South and Gramatan Avenue, North. The selected test locations were reviewed based on the integration with recommended technologies and the cost of equipment. Traffic systems provided by Miovision Technologies Inc. were installed in four intersections of Gramatan Avenue, South and traffic systems provided by Live Traffic Data Corp (LTD) and Traffic Systems Incorporated (TSI) were installed at three intersections on Gramatan Avenue, North.

It was the intent of the project for Wi-Fi and/or Bluetooth readers and environmental sensors to also be installed throughout the corridor to allow the validation of the performance measures and demonstration of the potential to reduce transportation greenhouse gases (GHG)/energy consumption while requiring only minor implementation of equipment, materials, and effort. However, given the limited resources of the project, environmental sensors were not deployed in the field and the environmental impacts were quantified using simulation.

An important outcome of this project is to develop the key performance measures that define the effectiveness of the project. One of the key elements of the demonstration is the remote monitoring or the “virtual management” of the corridor. ATMS technologies are managed through either a central software or direct IP address, meaning they are accessible from anywhere an authorized user has internet connection. Throughout the project, virtual management was proven through the assessment of corridor traffic flow by uploading traffic count data collected by the field devices and analyzing that data to provide better progression along the corridor. Signal timing directive changes have been suggested to be deployed remotely and/or in the field to routinely optimize operations.

This report presents the main activities performed by the project team to demonstrate and evaluate the effectiveness of deploying ATMS to better manage and operate the transportation systems on municipal streets and arterials. The City of Mount Vernon in New York State was the site for the tests. The project activities were affected and permanently interrupted by the COVID-19 pandemic starting in early March 2020. As a result of the pandemic, the field tests were halted prematurely. The analyses performed were supported with state-of-the art traffic simulation for the selected test beds and were calibrated using the field sensors: wireless magnetic detectors, video image processing as well as traffic operations data: signal timing, incident data, etc. The supercomputing capabilities of the City College of New York was utilized to develop the traffic simulation models and to perform the data analysis.

This report provided an opportunity to establish the effectiveness of a Virtual Transportation Management system for any small, medium, and large city. It has demonstrated the benefits of collaboration with private entity teams to monitor, analyze, and deploy operational modifications throughout their systems. We believe that this collaboration will be beneficial in implementing an effective Smart City solution capable of serving jurisdictions from an integrated corridor management approach. In this case, the City of Mount Vernon VTM would be especially beneficial in improving the efficiency and safety of its transportation system, which would also result in the reduction of energy use, improvement in air quality, and reduction in the use of natural resources. It is also anticipated that it will help improve and foster economic growth in specific portions of the city.

1 Introduction

1.1 Background

The state of transportation in the United States is firmly on the cusp of a paradigm shift as it grapples with new, unique problems while at the same time anticipating unbridled potential and opportunity from emerging technologies. In 2015, vehicle miles travelled (VMT) in the U.S. surpassed 3.1 trillion miles, which broke the previous record high set in 2007.[1] The increase in miles has put a strain on the country's roadways, placing a renewed priority on our ability to transport people and goods. The strain is compounded in cities in the Northeast, as many roadways are already severely congested and are further constrained by factors such as a lack of property to make improvements, strict regulatory guidelines, interjurisdictional coordination, and environmental concerns.

Congestion, which occurs when traffic approaches or exceeds the capacity of the roadway system, illustrates the stress placed on roadways. Over the past 30 years, congestion has rapidly increased, particularly in metropolitan areas. As an example, the Texas Transportation Institute published in their *2019 Urban Mobility Report*[2] that during the year of 2017 alone, congestion in 498 metropolitan areas caused urban Americans to travel 8.8 billion hours more and to purchase an extra 3.3 billion gallons of fuel with a congestion cost of $179 billion. As population numbers continue to increase, and with freight activity in the U.S. expected to grow fifty percent by 2050, congestion is a significant issue that needs to be addressed.[3]

One area that can have a dramatic impact on congestion, especially in the metropolitan environment, is poorly managed traffic signal systems. Ineffective management, operations, and maintenance of traffic signals contributes to almost 300 million vehicle-hours of delay annually. The National Transportation Operations Coalition (NTOC) 2019 National Traffic Signal Report Card showed that our country's agencies and municipalities are lacking in various areas, scoring an overall grade of a C+[4].

Despite these turbulent conditions, technology is advancing rapidly, and new ideas are providing fresh ways to handle problems related to congestion. This environment, particularly in the Northeast, has resulted in an increased emphasis on transportation systems management and operations. Agencies, counties, and municipalities are focusing their efforts and funds to operate their roadways more efficiently.

Larger agencies throughout New York State, such as the New York City Department of Transportation (NYCDOT), have done a great job of deploying Intelligent Transportation Systems over the past several years to help gather data, manage traffic incidents, and improve congestion and mobility along roadway systems. These agency facilities have a full range of advanced technology tools related to traffic signal operations and management such as Advanced Transportation Management Systems (ATMS), which helps to improve overall operational and management capabilities. Tools like ATMS help users adapt to changing traffic demands based on time of day/week, seasonal traffic variations, weather impacts, work zones, traffic incidents, or other non-recurring events.

Many local municipal roadway systems lack these technologies. The impact is that while our larger roadway facilities utilize the tools to better manage and operate the systems, the congested local roadways could become bottlenecks and hinder the movement of people and goods throughout the State. This results in a degraded experience for the critical first and final leg of journeys and related socioeconomic and environmental impacts such as diminished local air quality and additional time spent commuting. As citizens become more familiar with the benefits of these technologies on regional, State, and Interstate roadways, local governments may be called upon to implement similar “Smart” solutions on local roadways.

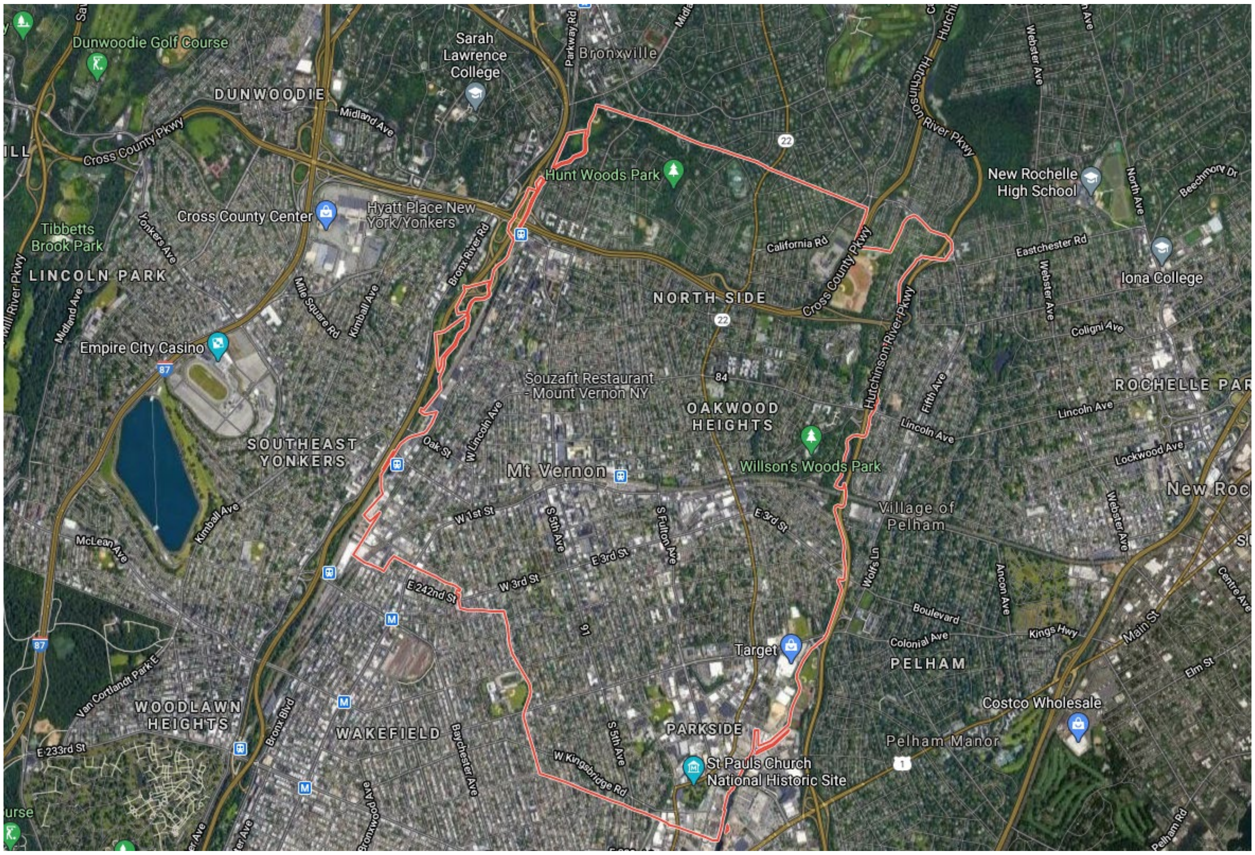
Further, where local authorities have been able to purchase and install the technologies, the successful outcome of the implementations have been hindered by many other factors, which will be explored throughout the report.

- Lack of technology.
- Lack of knowhow when technology is available.
- Reliance on external parties for operation and maintenance (O&M).
- Communication between parties.
- Project length and administrative turnover.

Even though there is significant funding available for technology enhancements and system development projects, the situations listed are often factors that deter implementation. Therefore, the demonstration of an effective strategy to deploy, monitor, and maintain advanced transportation management systems is what is required.

The City of Mount Vernon, in the southern part of Westchester County, is located about 13 miles north of Manhattan. It encompasses 4.4 square miles and is home to almost 69,000 residents (according to 2010 U.S. Census numbers). As one of the more densely populated areas outside New York City, the City of Mount Vernon is a “small city with big city issues” according to local officials. Among the issues are congestion and a lack of intelligent transportation technologies.

Figure 1. Aerial of Mount Vernon, NY



The City of Mount Vernon is well situated, with good access to the rest of Westchester County, New York City, and the region. Principal arterials serving Mount Vernon include the Bronx River, Hutchinson River, and Cross County Parkways, as well as the New York State Thruway (Interstate 87) and the New England Thruway (Interstate 95). The city’s local street network generally takes the form of a traditional rectilinear grid, providing a relatively high degree of connectivity among its various neighborhoods.

The City of Mount Vernon is well served by public transportation services. It is served by three train stations on two Metro-North commuter rail lines from Grand Central Station in Manhattan—the Harlem line running north to White Plains and New Haven line running east into Connecticut. Two New York City subway stations—the Eastchester-Dyre Avenue station (5 trains) and the Wakefield-241 Street station (2 trains)—are located within a ten-minute walk from the Mount Vernon-Bronx border. The Westchester County Bee Line Bus Service operates ten individual bus lines in Mount Vernon, the majority of which pass through the Petrillo Plaza transit hub in the downtown area.[5]

Seeking for opportunities to prepare for new technologies that can be leveraged to support advanced transportation management, the City of Mount Vernon joined the Smart City ComPACT in 2016. The Smart City ComPACT was launched in 2016 by the Westchester County Association as a public-private partnership to spearhead the Smart Growth initiatives in Westchester County's four largest cities: Mount Vernon, New Rochelle, White Plains, and Yonkers. The partnership is the first such launch between cities in the nation that is aimed at modernizing county infrastructure, creating jobs, and closing the digital divide. Under the terms of the pact, the cities will seek joint funding, share best practices, develop joint federal and State legislative agendas, and collaborate on creating innovation districts, among other matters.[6]

1.2 Project Overview

The objective of this project is to demonstrate a "Virtual Traffic Management Strategy" for the City of Mount Vernon, which includes the demonstration of underutilized strategies and polices related to advanced traffic management and integrated corridor management. The project team led by the City College of New York and Colliers Engineering & Design CT, P.C. (CED) worked closely with City of Mount Vernon officials to identify a signalized corridor that is suitable to conduct the study. The Gramatan Avenue corridor was selected as the location for the test.

The major objectives of the demonstration project at the Gramatan Avenue corridor are to:

- Maximize the capacity of the existing corridor (including lane and parking management) through the optimization of traffic signal operation.
- Improve safety for all road users, including transit vehicles, private vehicles, commercial vehicles, emergency vehicles, pedestrians (especially school children), and cyclists.
- Reduce delays, stops, fuel consumption and vehicle emissions resulting from the inefficient operation of traffic signals.

- Monitor traffic flow conditions and collect real-time data for analysis and subsequent recommendations for improvement.
- Develop performance measures for the corridor.
- Monitor the operation of traffic signal equipment and report malfunctions to minimize equipment “down time” by providing alerts to traffic operators.

The project team worked with two main partners—Miovision Technologies Inc. and Live Traffic Data Corp—to deploy wireless communication technologies, dynamic video detection and monitoring units, and a cloud-based ATMS solution at seven signalized intersections at Gramatan Avenue.[7]

The project team’s main focus in this demonstration is the remote monitoring or the “virtual management” of the corridor. Since the ATMS technologies are managed through either a central software or direct IP address, they enable remote access. Utilizing the Federal Highway Administration’s (FHWA) “Guidelines for Virtual Transportation Management Center Development,” the project team aimed to remotely monitor the overall “health” of the signal system. Connecting remotely to the transportation infrastructure assets along the corridor, the team assisted in oversight, troubleshooting equipment issues, mitigating congestion conditions, and improving traffic operations. The project team performed the assessment of traffic flow through the corridor by uploading traffic count data collected by the field devices and analyzing that data to provide better progression along the corridor. Signal timing changes have been suggested to be deployed remotely and/or in the field to routinely optimize operations.

As of mid-March 2020, with the orders enacted by the governor of New York State in response to the COVID-19 pandemic, the project team was unable to continue to access the project site at the City of Mount Vernon. The stay-at-home order enacted throughout NYS has impacted transportation activities with the closing of schools and non-essential businesses. Travel was sharply reduced in both private vehicle and transit, and pedestrian traffic was also reduced, as limited businesses were opened to the public and non-essential workers were encouraged to stay home and limit their travel. The project provided a unique opportunity for the team to utilize the data collected by technology installed at the intersections to analyze and understand the impact of the COVID-19 on the transportation mobility in the City of Mount Vernon.

2 Corridor Selection

The project team accompanied by officials from the City of Mount Vernon toured the city to pre-select suitable sites for the tests required to deploy the Virtual Transportation Management Strategies with the intent to accomplish the following three goals:

- A reduction in the greenhouse gas (GHG) emissions and the associated energy consumption of the existing multi-modal transportation system.
- Providing innovative transportation solutions that enhance transportation system efficiency, resiliency, reliability, safety and energy usage.
- Provide a strategy that can increase economic competitiveness and quality of life and support community revitalization and environmental sustainability.

The locations of interest toured for considerations are:

- Fleetwood Section: "Broad Street" and Exit 8 East Cross County Parkway
- Gramatan Corridor
- Prospect Avenue
- East Sandford Boulevard
- East Lincoln Avenue
- South Fulton Avenue
- MacQuesten Parkway
- South 4th Avenue (between East 1st/2nd Streets)
- Mt Vernon Avenue
- Mt Vernon West Station
- Mt Vernon East Station
- Park and Ride Potential

Two major areas in the City of Mount Vernon were considered during the initial review: Mount Vernon West Train Station Area and Gramatan Avenue Corridor. The Gramatan Avenue Corridor was selected due to a more streamlined process of project development and approval. The Mount Vernon West Station area required involvement of the New York State Department of Transportation (NYSDOT) and the City of Yonkers. Engaging these parties would have lengthened the process of improving selected intersections and reduced clarity on the role of each party involved in the project, ultimately disqualifying the Mount Vernon West Station area from consideration.

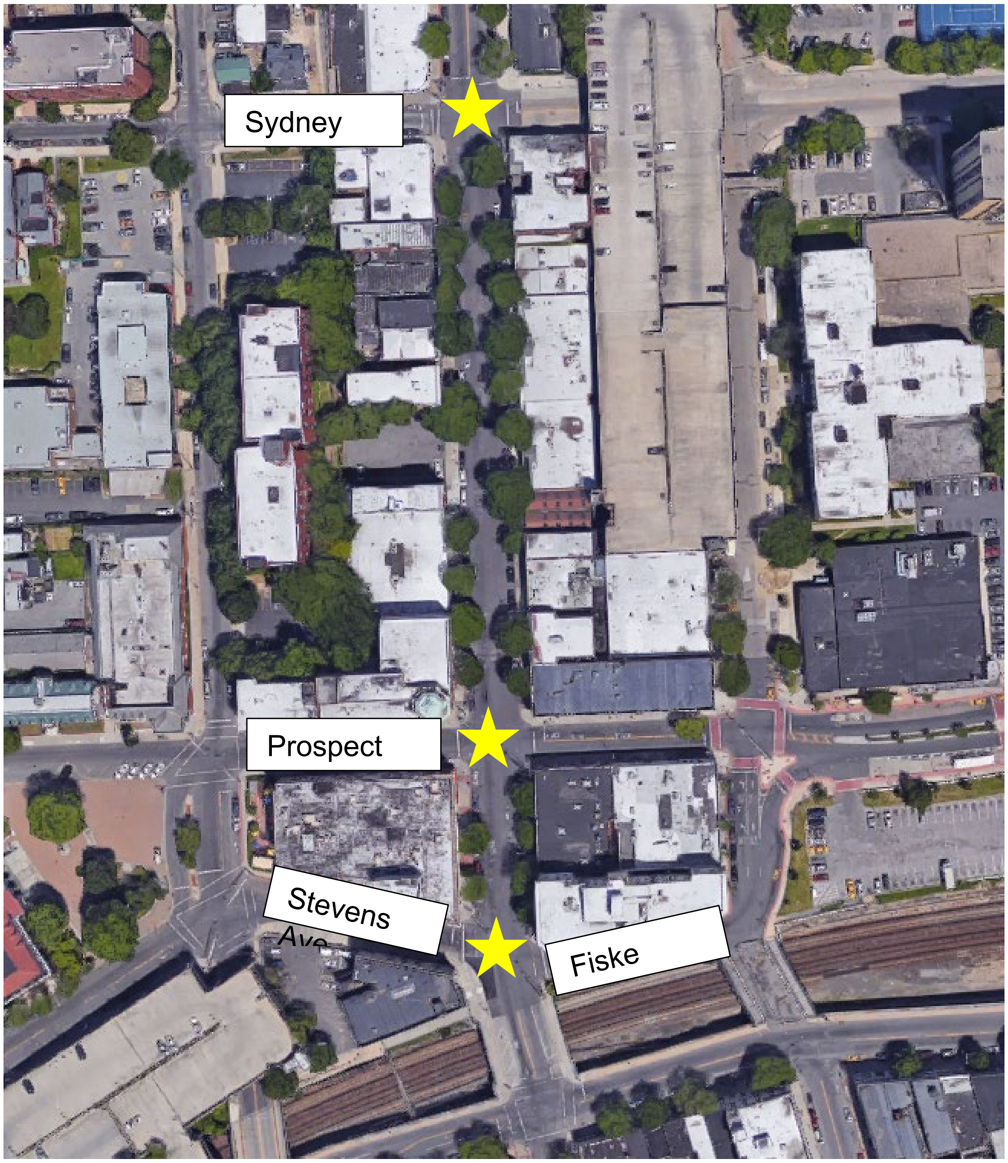
The following sections highlight the areas that were considered along the Gramatan Corridor, as well as additional areas that were considered during the preliminary location review. Candidate areas were ranked based on pedestrian activity, transit options, availability of parking, and type of area (land use characters such as commercial or residential). These categories were deemed relevant due to how each effects traffic movement. Google maps was primarily used to pre-assess each area and to provide a high-level review of each location. Once a final location was chosen by city officials, all stakeholders conducted a field investigation to record existing information for each intersection. The recorded information enabled an in-depth review to determine the potential strategies that can reduce greenhouse gas emissions, improve quality of life, and support community revitalization.

2.1 Gramatan Avenue, South

2.1.1 Corridor Description

During the review of the proposed locations for signal improvements in the City of Mount Vernon, it was determined that the Gramatan Avenue corridor (south section) would be the ideal location to begin this study. Figure 2 below shows an aerial photo of the corridor consisting of three signalized intersections: Stevens Avenue/Fiske Place, Prospect Avenue, and Sydney Avenue.

Figure 2. Aerial of Gramatan Avenue, South



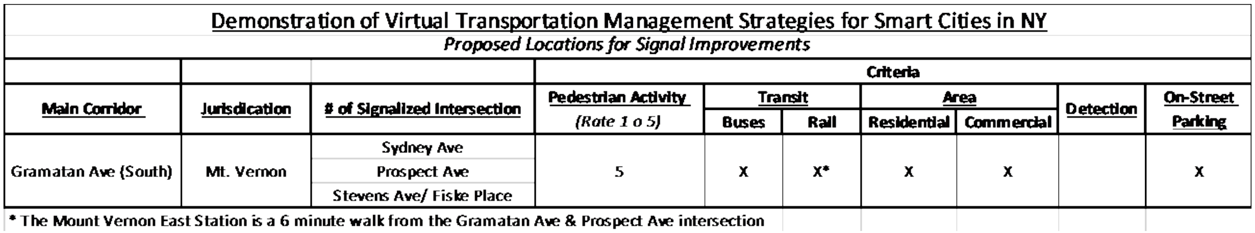
2.1.2 Evaluation

Upon further review, it was determined that a fourth signalized intersection along Gramatan Avenue, Oakley Avenue, could benefit from the proposed strategies and was added to the project scope. The final list of intersections is:

- Oakley Avenue
- Sydney Avenue
- Prospect Avenue
- Stevens Avenue/Fiske Place

Table 1 depicts the criteria considered during review, as applied to Gramatan Avenue, South.

Table 1. Criteria for Gramatan Avenue. South



Demonstration of Virtual Transportation Management Strategies for Smart Cities in NY

Proposed Locations for Signal Improvements

			Criteria						
Main Corridor	Jurisdication	# of Signalized Intersection	Pedestrian Activity (Rate 1 o 5)	Transit		Area		Detection	On-Street Parking
				Buses	Rail	Residential	Commercial		
Gramatan Ave (South)	Mt. Vernon	Sydney Ave	5	X	X*	X	X		X
		Prospect Ave							
		Stevens Ave/ Fiske Place							

* The Mount Vernon East Station is a 6 minute walk from the Gramatan Ave & Prospect Ave intersection

The three major categories that were used to rank these areas were pedestrian activity, transit, and the type of area. Google satellite images indicate that this is a heavily traveled area for pedestrians due to the quantity of shops along the corridor and on adjacent side streets. Currently, there are at least seven bus stops along Gramatan Avenue and more on nearby streets. The Mount Vernon East Station, which provides commuter rail service, is a six-minute walk from the Gramatan Avenue & Prospect Avenue intersection. Additional criteria that were considered included availability of detection sensors and presence of on-street parking. After the initial walkthrough of these four intersections, it was determined that there was no detection along the approaches. This would be a major key in refining traffic movements along the roadways and could greatly improve traffic conditions if installed and operated appropriately. On-street parking was the last criteria evaluated and Gramatan Avenue has on-street parking on both sides of the corridor.

2.1.3 Signal Technology

During the field investigation it was determined that the intersections of Fiske Place, Prospect Avenue, and Oakley Avenue all have PEEK 3000 controllers, while the Sydney intersection has a Transyt 1880E. All controllers were deemed compatible with the selected ATMS technology. Figure 3 and Figure 4 below shows all four cabinets for the selected intersections mentioned above, respectively.

Figure 3. Cabinet Equipment for Fiske Place (left) and Prospect Avenue (right)

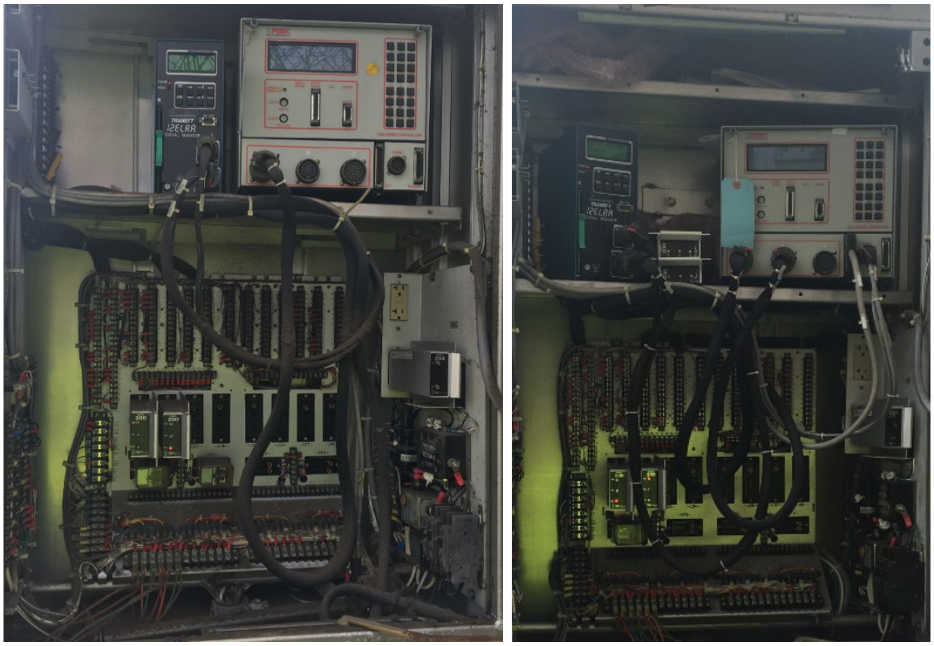
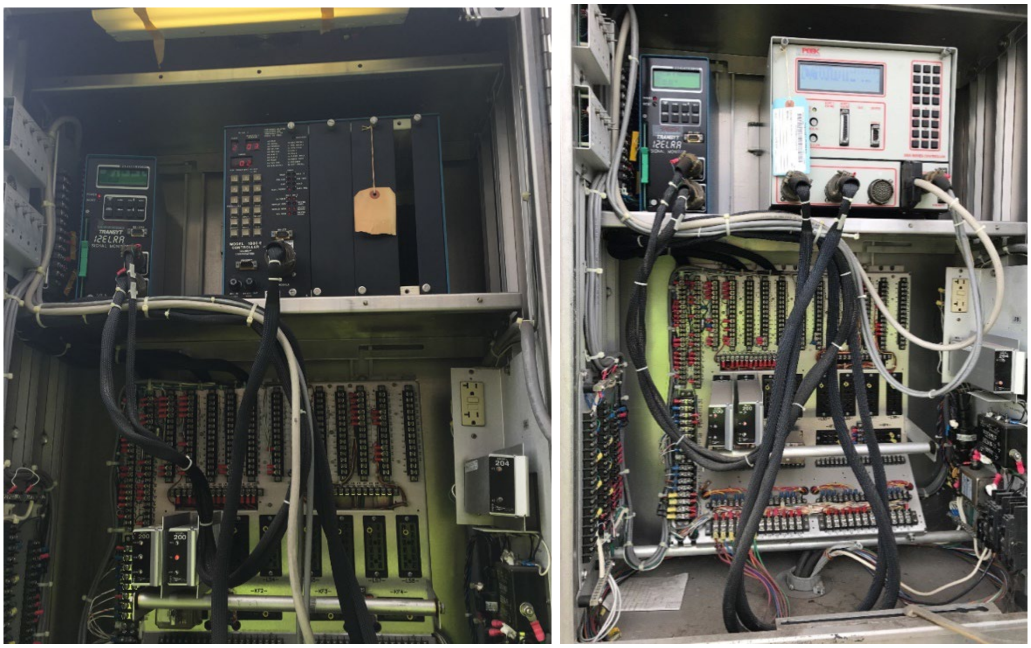


Figure 4. Cabinet Equipment for Sydney Avenue (left) and Oakley Avenue (right)



2.2 Gramatan Avenue (North)

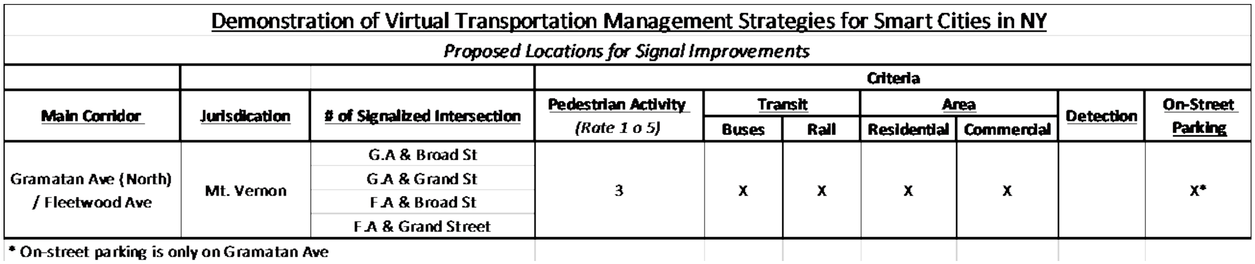
2.2.1 Corridor Description

During the preliminary review with the City of Mount Vernon, the intersections of Broad Street and Fleetwood Avenue, Grand Street and Fleetwood Avenue, Grand Street and Gramatan Avenue, and Gramatan Avenue and Broad Street were considered for this project.

2.2.2 Evaluation

After further review and field investigation, three alternate intersections along the Gramatan North corridor were chosen due to the proximity to the other intersections on Gramatan Avenue (South) and the position of the intersections in relation to each other (Figure 5).

Table 2. Criteria for Gramatan Avenue (North)



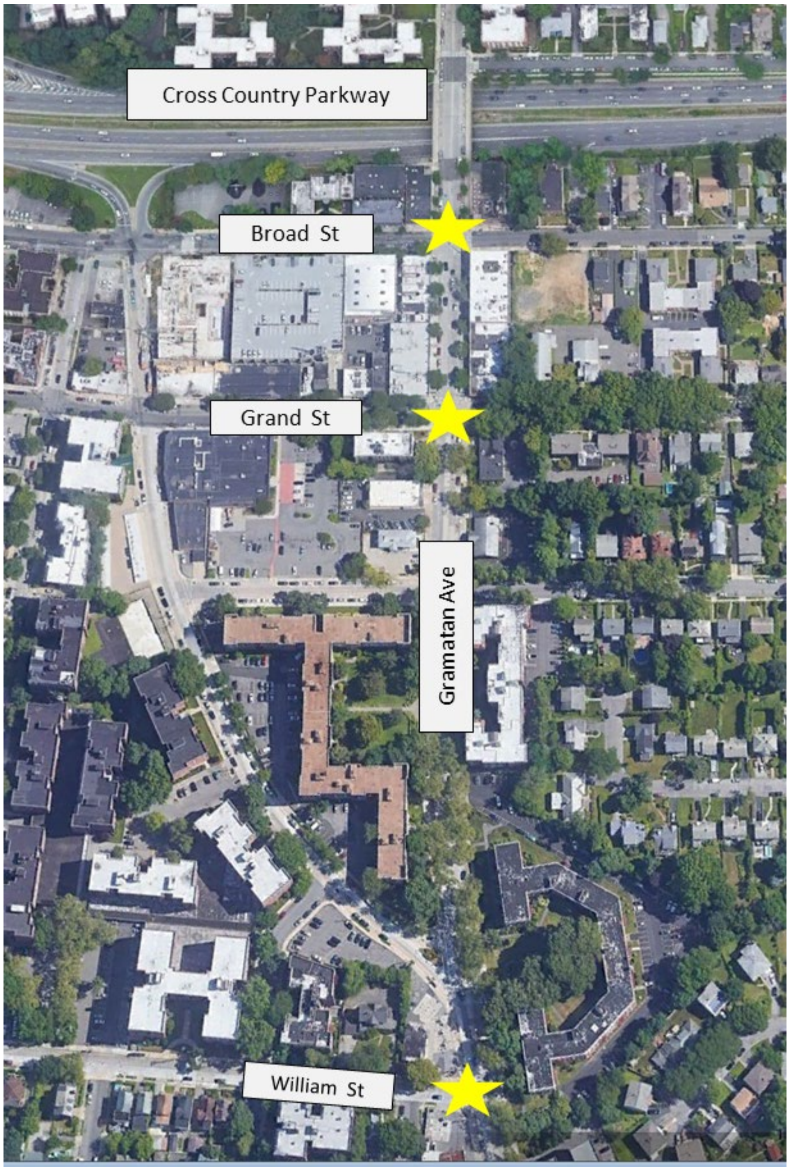
Demonstration of Virtual Transportation Management Strategies for Smart Cities in NY

Proposed Locations for Signal Improvements

			Criteria						
Main Corridor	**Jurisdication**	**# of Signalized Intersection**	**Pedestrian Activity** *(Rate 1 o 5)*	**Transit**		**Area**		**Detection**	**On-Street Parking**
				Buses	**Rail**	**Residential**	**Commercial**		
Gramatan Ave (North) / Fleetwood Ave	Mt. Vernon	G.A & Broad St	3	X	X	X	X		X*
		G.A & Grand St							
		F.A & Broad St							
		F.A & Grand Street							

* On-street parking is only on Gramatan Ave

Figure 5. Aerial of Gramatan Avenue (North)/Fleetwood Avenue

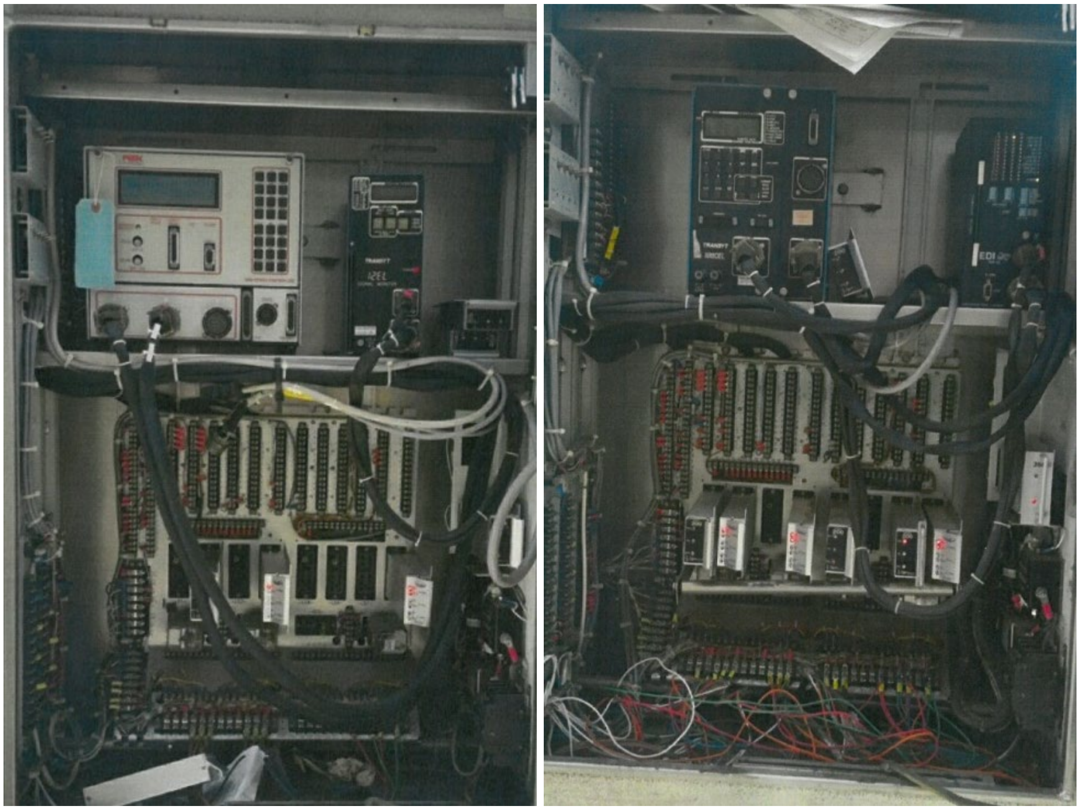


This area appeared to have moderate pedestrian activity (less than the southern portion of Gramatan Avenue) generated by limited commercial establishments and a school located just south of the area. Bus and rail services are accessible within a five-block radius. No detection sensors were identified at the intersections during the field investigation and limited pedestrian signals (no pushbuttons) were identified at certain locations.

2.2.3 Signal Technology

During the field investigation it was determined that the intersection of Grand Street has a PEEK 3000 controller, while Broad Street and Williams Street both have Transyt 1880E controllers. All controllers were deemed compatible with the selected ATMS technology. Figure 6 demonstrates traffic signal cabinet equipment at these locations.

Figure 6. Cabinet Equipment for Grand Street (left) and Broad Street (right)



2.3 East Sandford Boulevard

2.3.1 Corridor Description

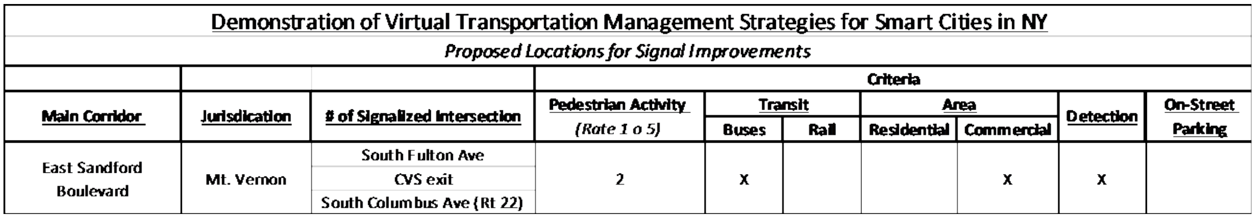
The third area considered was the East Sanford Boulevard at the South Fulton Avenue and South Columbus Avenue intersections. These intersections appeared to be the most active areas along East Sanford Boulevard. Figure 7 below is a map of this area including two signalized intersections.

Figure 7. Aerial of East Sanford Boulevard

Table 3 summarizes the evaluation of East Sanford Boulevard.

2.3.2 Evaluation

Table 3. Criteria for East Sanford Boulevard



Demonstration of Virtual Transportation Management Strategies for Smart Cities in NY

Proposed Locations for Signal Improvements

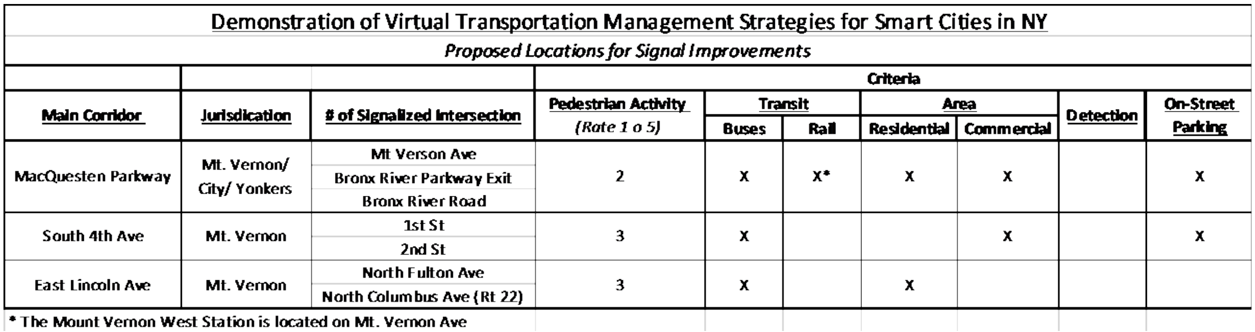
			Criteria						
Main Corridor	**Jurisdication**	**# of Signalized Intersection**	**Pedestrian Activity** *(Rate 1 o 5)*	**Transit**		**Area**		**Detection**	**On-Street Parking**
				Buses	**Rail**	**Residential**	**Commercial**		
East Sandford Boulevard	Mt. Vernon	South Fulton Ave CVS exit South Columbus Ave (Rt 22)	2	x			x	x	

This area ranked lower than the previous two areas due to the lack of pedestrian activity and distance from transit services. There are bus stops located within the area, but the nearest rail station is a 20-minute walk. This area has limited commercial land uses with residential areas to the north and south. An initial field investigation was not performed and ruled out by stakeholders due to the above-mentioned criteria.

2.4 Other Areas Considered

Three other locations were also analyzed during the preliminary process, as shown in Table 4.

Table 4. Criteria for Remainder Locations



Demonstration of Virtual Transportation Management Strategies for Smart Cities in NY

Proposed Locations for Signal Improvements

			Criteria						
Main Corridor	**Jurisdication**	**# of Signalized Intersection**	**Pedestrian Activity** *(Rate 1 o 5)*	**Transit**		**Area**		**Detection**	**On-Street Parking**
				Buses	**Rail**	**Residential**	**Commercial**		
MacQuesten Parkway	Mt. Vernon/ City/ Yonkers	Mt Verson Ave Bronx River Parkway Exit Bronx River Road	2	X	X*	X	X		X
South 4th Ave	Mt. Vernon	1st St 2nd St	3	X			X		X
East Lincoln Ave	Mt. Vernon	North Fulton Ave North Columbus Ave (Rt 22)	3	X		X			

* The Mount Vernon West Station is located on Mt. Vernon Ave

MacQuesten Parkway, near the Mount Vernon West Station would have been one of the top areas, but due to the concern over jurisdictional issues, the area was ranked lower than the three locations mentioned earlier. Unfortunately, a memorandum of understanding agreement or MOU between the City of Yonkers and the City of Mt. Vernon would be needed to conduct the necessary work at the location, usually resulting in the non-owner taking on any maintenance responsibilities during this time. This financial responsibility could be more than the local agencies are willing to take on, especially under the scope of the research effort. Keeping to the timeline of the project was key at the start as well. Exploring conversations with other agencies would have prolonged the initial effort of collecting data, which would have pushed the initial timeline. It tends to be beneficial to keep an open relationship with surrounding jurisdictions to allow for those locations on the jurisdictional boundaries to be addressed and a collaborative solution and system put forth. The collaboration could allow local agencies to utilize larger regional infrastructure for such locations and better support regional transportation mobility. The other two areas were not considered due to the type of area and lack of pedestrian/vehicle activity.

3 Technology Selection, Specifications, System Architecture, and Installations

3.1 Required Field Infrastructure

A key component of this project was to leverage existing traffic control infrastructure to monitor traffic volumes and deploy signal timing updates in response to identified congestion. Prior to the selection of the technologies (as identified in section 3.2) utilized during this project, a full inventory of the existing traffic signal infrastructure at the selected locations was conducted. This included a detailed walk through each intersection, primarily focusing on equipment located within the traffic signal cabinets. During the walk throughs, it was found that most existing signal equipment could be utilized with the intended technologies. Some intersections have older legacy infrastructure that is not compatible. There are grants and local or statewide aid that can be investigated if hardware needs to be updated.

Connections to an up-to-date controller, back panel, and wiring are necessary for the intended work of certain technologies. Access to all these items are critical to ensuring positive outcomes. Outdated equipment and weathered hardware could potentially cause issues when trying to integrate new equipment, so ensuring equipment is frequently maintained and updated regularly is key in advancement of such virtual transportation management solutions.

3.2 Selection of Technologies

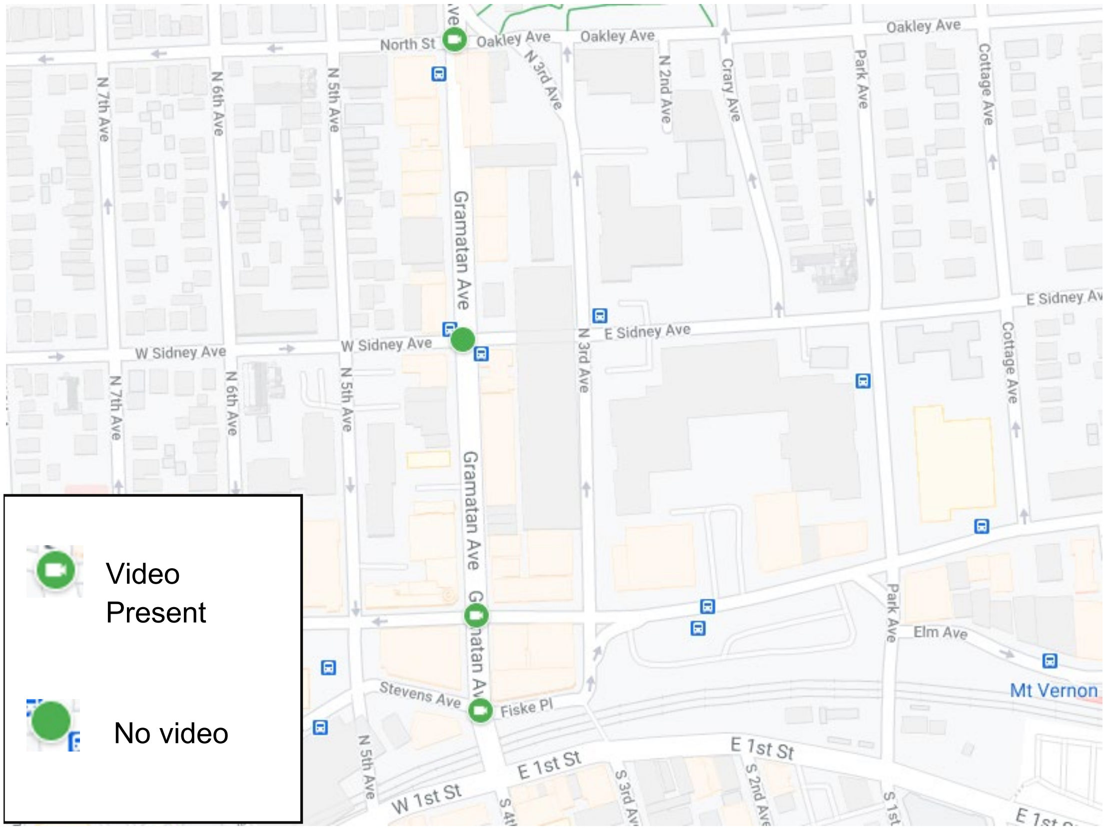
The smart technologies were selected to monitor in real time and gather intersection traffic flow data in terms of volume, travel time, delay, queue length, vehicle classification, event detection, and more. Upon scanning available technologies and providers, Miovision Technologies Inc. and Live Traffic Data Corp (LTD), with Traffic Systems Incorporated (TSI) were the partners identified to provide the hardware for the selected intersections (full specifications of the hardware and technologies utilized are provided in section 3.3). In addition, the above-mentioned smart technologies of Miovision and LTD were selected to enable the calibration of the traffic simulation models of the selected corridors developed by the project team to evaluate traffic scenarios, while providing the corridor controlling system the capability to access the live data at each selected intersection. The smart technologies were selected to support the city engineers and planners in making real-time, short-term, and long-term transportation related decisions.

The selected test-bed area starts at Gramatan Avenue and Fiske Place in the south and extends to the northern part to Gramatan Avenue and Broad Street. With the availability of two partners offering different types of technologies for traffic flow monitoring at intersections, it was decided to split the Gramatan corridor into two distinct segments, the south and the north of Gramatan Avenue:

- Miovision (Gramatan Avenue South segment) installed their devices (SmartLink + ABC Interface + SmartSense) at: Gramatan Ave South and Prospect Avenue, Gramatan Avenue South and Sydney Avenue, Gramatan Avenue and Stevens Avenue/Fiske Place, and Gramatan Avenue, North Street/Oakley Avenue.
- LTD (Gramatan Avenue North segment) instrumented three intersections at: Gramatan Avenue and William Street, Gramatan Avenue and East Grand Avenue, and Gramatan Avenue and Broad Street East.

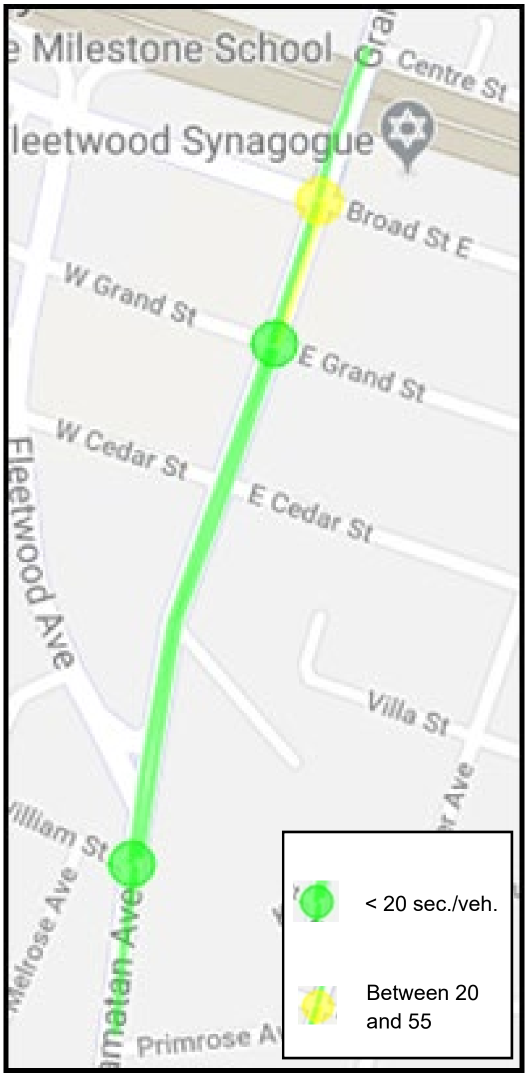
Figure 8 and Figure 9 show the two segments instrumented by Miovision and LTD & TSI at Gramatan Avenue respectively.

Figure 8. Intersections Instrumented by Miovision



Intermingling was not considered so the analytics could maintain a “baseline” throughout the data collection. Various existing controllers were used, which already added variability to the research effort. In addition, the systems are not a one-for-one swap; both systems collect data with their own methods while reporting the same information and making similar signal timing adjustments.

Figure 9. Intersections Instrumented by LTD and TSI



4 Miovision’s Technology

The project installed Miovision’s technology to manage traffic. The Miovision’s TrafficLink allows traffic operators to remotely manage and track a traffic network, while also providing performance measures and actionable insights. In addition of having features needed to monitor and manage a traffic network remotely, the system was also selected for its easy above ground installation and because troubleshooting is possible with minimum downtime.

4.1 Specifications

Miovision uses a 4k SmartView 360 camera to get a complete view of an intersection, and thereby builds solutions that can help improve mobility in cities. One of the main features of Miovision is the true multimodal detection. The Miovision TrafficLink video detection system is composed of three core hardware elements:

1. Miovision SmartLink
2. Miovision SmartView 360
3. Miovision SmartSense

These three elements generate unprecedented amounts of traffic data for analysis that can be viewed through the TrafficLink web portal. Each element is described in greater detail below in Figure 10.

Figure 10. Solution Overview

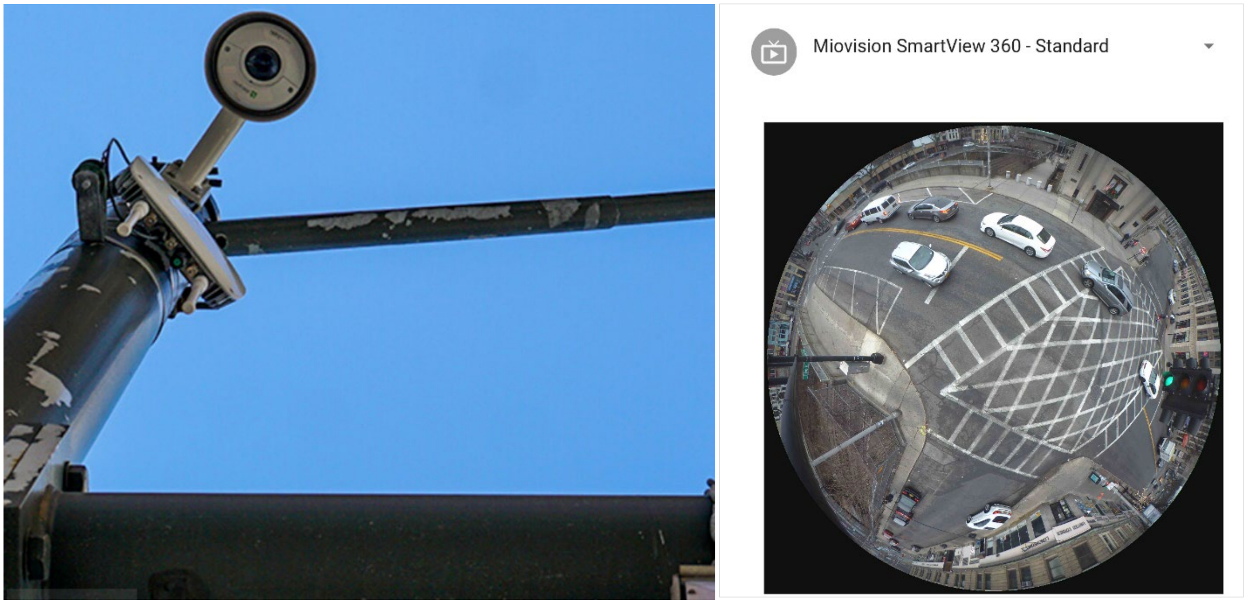
4.1.1 Miovision SmartLink

Miovision SmartLink is a NEMA-rated Intelligent Transportation System (ITS) device that provides 4G/LTE connectivity for remote access to video and data from Miovision's devices listed below. The device allows for several third-party devices to be connected, including traffic cameras, traffic signal controllers, malfunctioning management units, third-party detection systems, and preemption devices. Miovision SmartLink collects anonymous media access control (MAC) IDs for the purpose of travel time and origin-destination analysis. SmartLink also features a battery backup as a failsafe for power-loss situations, Global Positioning System (GPS) time sync to accurately synchronize the timing of the traffic signals, Content Management System (CMS) integration over Virtual Private Network (VPN) to securely deliver maintenance alerts and reporting to the CMS as well as to the TrafficLink web portal.

4.1.2 Miovision SmartView 360

Miovision SmartView 360 is an NEMA outdoor-rated 4K spherical camera typically deployed at signalized intersections (with a midblock/non-signalized intersection option) for a full view with a single camera. The SmartView 360 requires a Cat5 ethernet cable and is powered over ethernet (PoE) by the Miovision SmartSense. Data is processed at the roadside, but the video feed can optionally be recorded by the user. Figure 11 shows an image and a view from the SmartView 360.

Figure 11. Miovision SmartView 360 Camera



4.1.3 Miovision SmartSense

Miovision SmartSense is the roadside artificial intelligence device that processes 4K video from the Miovision SmartView 360 to generate vehicular, pedestrian, and bicycle (beta) data. This data includes turning movement counts with vehicle classification, pedestrian, and bicycle (beta) counts, pedestrian crosswalk metrics, and intersection safety data. SmartSense provides vehicle detection and actuation. Artificial Intelligence (AI) and deep neural networks (DNN) are computational algorithms that attempt to mimic how a brain's neurons work together to solve complex problems. One example of a problem that's easy for humans but hard for machines is image processing: we know a vehicle when we see one, but only advanced algorithms running on powerful hardware can achieve this feat. In TrafficLink, DNN powers the computer vision processing algorithms within SmartSense that identify the presence, location, and movement of vehicles, cyclists (beta), and pedestrians from the SmartView 360 camera's video stream. These algorithms lay the groundwork for innovative smart city applications, which are outlined in the sections below.

4.1.4 TrafficLink Web Portal

The TrafficLink Web Portal provides agencies with signal and cabinet device monitoring and alerts, travel time and Automated Traffic Signal Performance Measures (ATSPM) all of which help improve traffic safety and efficiency, while reducing traffic congestion and cost. High resolution traffic data provided through TrafficLink helps support objectives and performance-based traffic signal timing efforts. The traffic data through TrafficLink would also aid the agency or third-party consultant in developing signal retiming plans, non-traditional Transportation Systems Management and Operations (TSM&O) signal retiming efforts, context-sensitive timing plans, and others.

The comprehensive ATSPM data reported through Miovision's TrafficLink portal is used to continually measure signal operations and performance in support of objectives and performance-based maintenance and management strategies that improve safety and efficiency while cutting congestion and cost.

Signal retiming efforts can be based directly on actual performance without dependence on software modeling or expensive, manually collected data.

4.1.5 Signal Communications and Management

The TrafficLink platform allows agencies to monitor and manage their signals remotely. Miovision SmartLink is the practical way to a smarter traffic cabinet as it transforms data from your existing controllers and cabinet devices into meaningful insights. Data collected from the intersection is hosted securely in the cloud for fast, reliable, and secure access. TrafficLink is a backward-compatible, future-proof platform that works with existing traffic controllers, so agencies can protect their investment and easily address future needs without additional hardware investments.

Miovision provides a full-turnkey solution including maintenance and support meaning so that agencies do not need to maintain their own IT infrastructure, improving user experience and reducing total cost of ownership. Miovision TrafficLink allows agencies to quickly identify and rank issues, solve them, validate the fix, and share the results. It provides real-time problem detection, meaning that agencies no longer need to wait for citizen complaints to know that there is a problem that needs to be addressed. Automatic alerts allow for those responsible to receive a notification as soon as issues arises. TrafficLink is an urgency-based system in which report cards ensure that agencies focus on the most urgent and impactful problems first. ATSPMs provide agencies with a clear before and after view into problems and the impact of implemented solutions, allowing them to measure and demonstrate efficiency and efficacy.

The system provides automated smart alerts with configurable short message service (SMS) and email alerts for:

- Signal in flash
- Power loss
- UPS activity
- Faulty detector
- Loss of connection

The system allows remote responds for:

- Power cycle
- Detector recall

4.1.6 Traffic Operations and Automated Traffic Signal Performance Measures

TrafficLink automatically generates easy to understand ATSPMs allowing agencies to solve traffic operation issues 10 times faster than via traditional approaches. It also provides travel time reporting and continuous multi-modal counts.

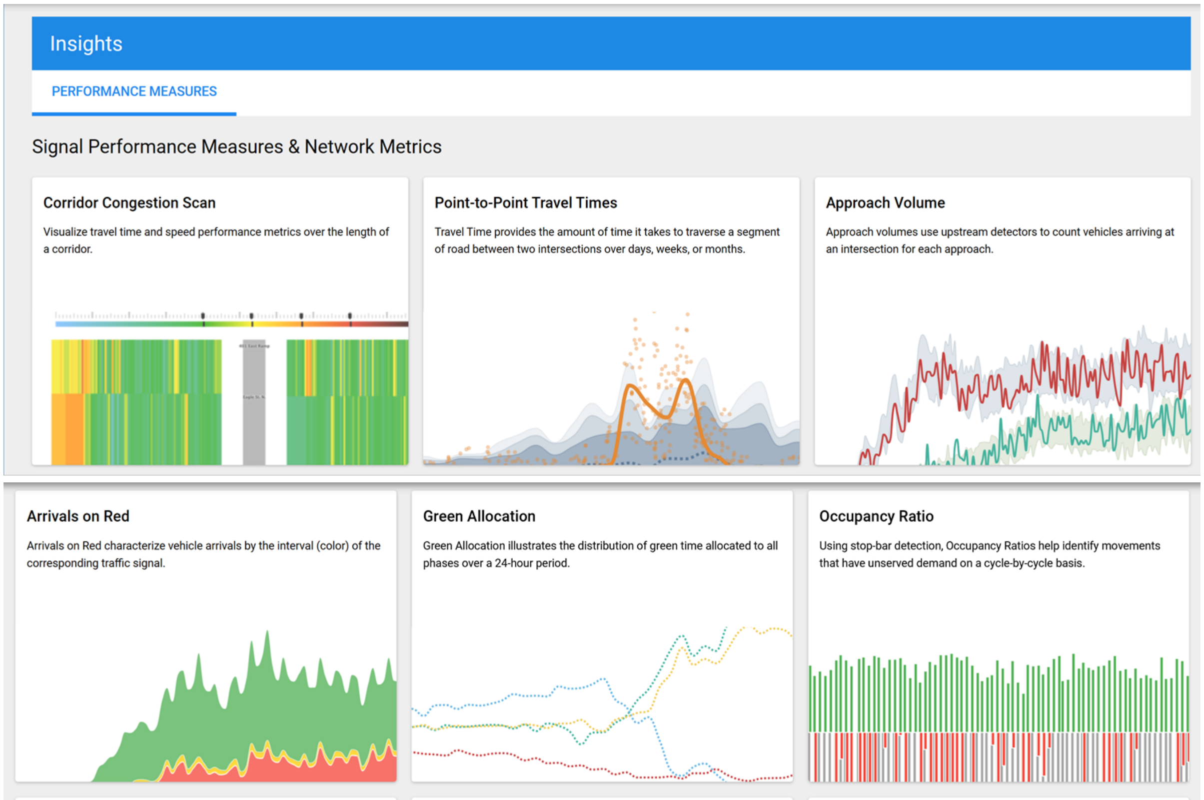
Miovision’s TrafficLink video detection system comes with a suite of signal performance analytics and tools that help improve traffic safety and efficiency, while reducing congestion and costs. High-resolution traffic intersection data provided by Miovision TrafficLink helps support objectives and performance-based traffic signal maintenance and operations strategies.

The following items are a list of Miovision Automated Traffic Signal Performance Measures (ATSPMs) that can be used to measure performances of the traffic network.

- Corridor Heat Map
- Travel Time
- Approach Volumes
- Arrivals on Red
- Arterial Analysis
- Purdue Coordination Diagram
- Occupancy Ratio
- Split Failures
- Split Trends
- Split Trend Analysis
- Simple Approach Delay
- Phase Interval
- Green Allocation
- Pedestrian Delay
- Intersection Report Cards

Below are some examples of the many performance measures and metrics available through the Miovision system (Figure 12).

Figure 12. Miovision Performance Measures and Metrics



Signal Performance Measures & Network Metrics

Corridor Congestion Scan

Visualize travel time and speed performance metrics over the length of a corridor.

Point-to-Point Travel Times

Travel Time provides the amount of time it takes to traverse a segment of road between two intersections over days, weeks, or months.

Approach Volume

Approach volumes use upstream detectors to count vehicles arriving at an intersection for each approach.

Arrivals on Red

Arrivals on Red characterize vehicle arrivals by the interval (color) of the corresponding traffic signal.

Green Allocation

Green Allocation illustrates the distribution of green time allocated to all phases over a 24-hour period.

Occupancy Ratio

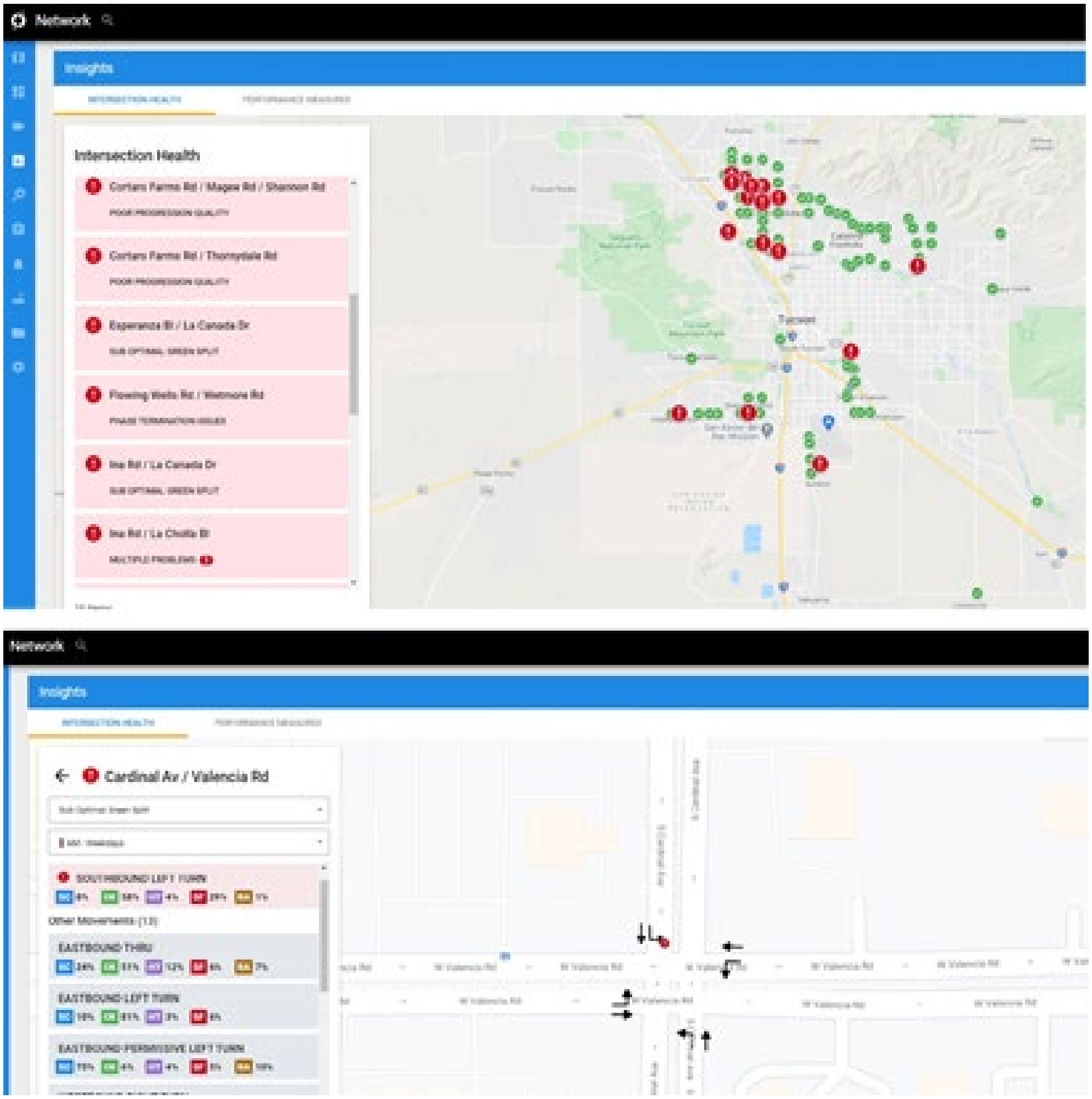
Using stop-bar detection, Occupancy Ratios help identify movements that have unserved demand on a cycle-by-cycle basis.

TrafficLink Detection’s suite of ATSPM analytic reporting tools help improve traffic safety and efficiency, while reducing traffic congestion and cost. High resolution traffic data provided through SmartLink helps support objectives and performance-based traffic signal timing efforts and would aid in developing signal retiming plans, non-traditional traffic signal maintenance and operations (TSM&O) signal retiming efforts, context-sensitive timing plans, and others. Signal retiming efforts can be based directly on actual performance without dependence on software modeling or expensive, manually collected data. ATSPM data is delivered both at the intersection level and on aggregate level through “dashboards” and report cards. Optimized traffic signal timing offers inherent safety benefits through the reduction in network stops and delay, resulting in lower probability of crash instances.

4.1.7 Miovision Intersection Health

One of the major challenges in taking full advantage of this rich data is the large amount of available data and the lack of orientation to performance measures toward specific tasks. To address this issue, Miovision provides, with its intelligent automated problem identification system, Intersection Health, which automatically scans thousands of data points and reveals inefficiencies. Version 1 of these inefficiencies include phase termination issues, green split allocation problems, and poor coordination. Miovision plans to add more problems to this list in the coming year based on the priority of their customers. Figure 13 shows a screenshot of the intersection health.

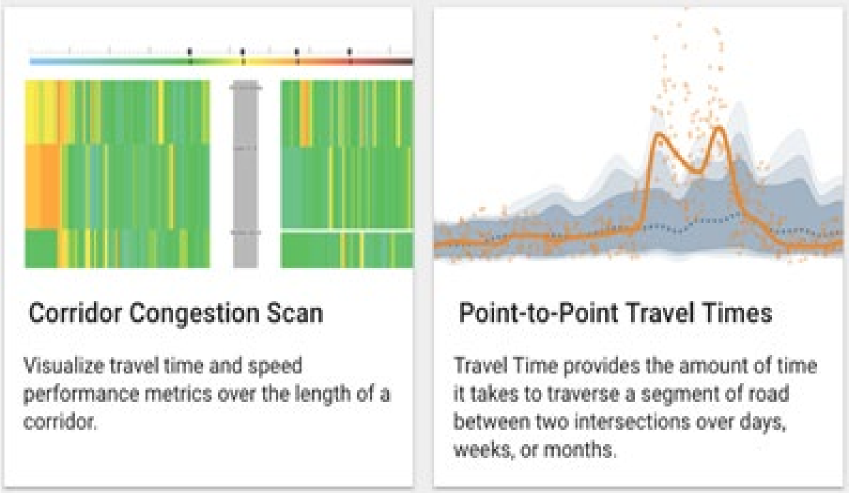
Figure 13. Miovision Intersection Health



4.1.8 Miovision's Travel Time Reporting

Collecting information from passing vehicles is the best method for collecting a consistent, historical, and comparable set of high-resolution data. WiFi traffic probes collect and store hashed MAC addresses from cellular devices that pass through their designated zone. A probe is included in every TrafficLink Detection location and is thus available at every intersection along a corridor and throughout a network and can provide a robust view of congestion and show the direct impact of changes and overall corridor health.

Figure 14. Miovision Travel Time Reporting



Corridor Congestion Scan

Visualize travel time and speed performance metrics over the length of a corridor.

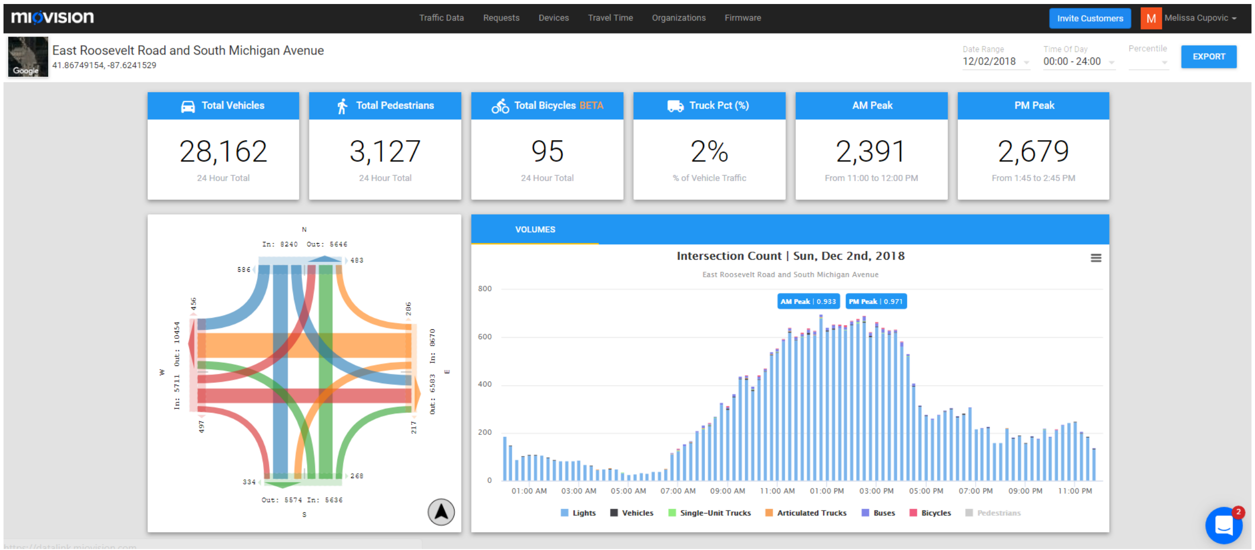
Point-to-Point Travel Times

Travel Time provides the amount of time it takes to traverse a segment of road between two intersections over days, weeks, or months.

4.1.9 Continuous Intersection Counts: 24/7: 365 Days

With Miovision TrafficLink video detection installed, agencies can access high-resolution traffic data on demand, and as they require it. The cloud-based platform stores count data from the intersection on a continuous basis providing engineers with access to turning movement count data and vehicle classification data from any point in time. The TrafficLink software interface is easy to use so agencies can spot patterns and trends in their data to better inform their decisions and help deliver a superior transportation experience to their citizens.

Figure 15. Continuous Turning Movement Counts Web Interface



East Roosevelt Road and South Michigan Avenue
41.86749154, -87.6241529

Date Range 12/02/2018
Time Of Day 00:00 - 24:00

4.1.10 System Self-Monitoring

The Miovision TrafficLink Performance system has multiple alerts to help with monitoring. First, Detector and Preemption Threshold alerts provide a simple way to identify items that are malfunctioning. This is one of the most common outcomes of assessing ATSPM metrics, so this alert helps identify that earlier. Secondly, Telemetry Offline alerts identify when connectivity and/or data capture has been interrupted on a per-intersection basis.

4.1.11 System Responsiveness and Scalability

The Miovision TrafficLink portal is built on highly scalable cloud technology capable of supporting thousands of intersections. The system leverages Amazon Web Services (AWS) that provides a highly reliable, secure, and scalable platform for the deployment of the Miovision TafficLink portal. Front-end load times that are most directly impacted by the number of intersections are aggregated reports, such as the Corridor Report Card and the Intersection Report Card—particularly when loading long-term aggregations (such as 12 weeks or more). However, these aggregated reports for a similar intersection deployment with 12-week aggregation, load all intersections in less than one minute.

4.1.12 Data Accessibility

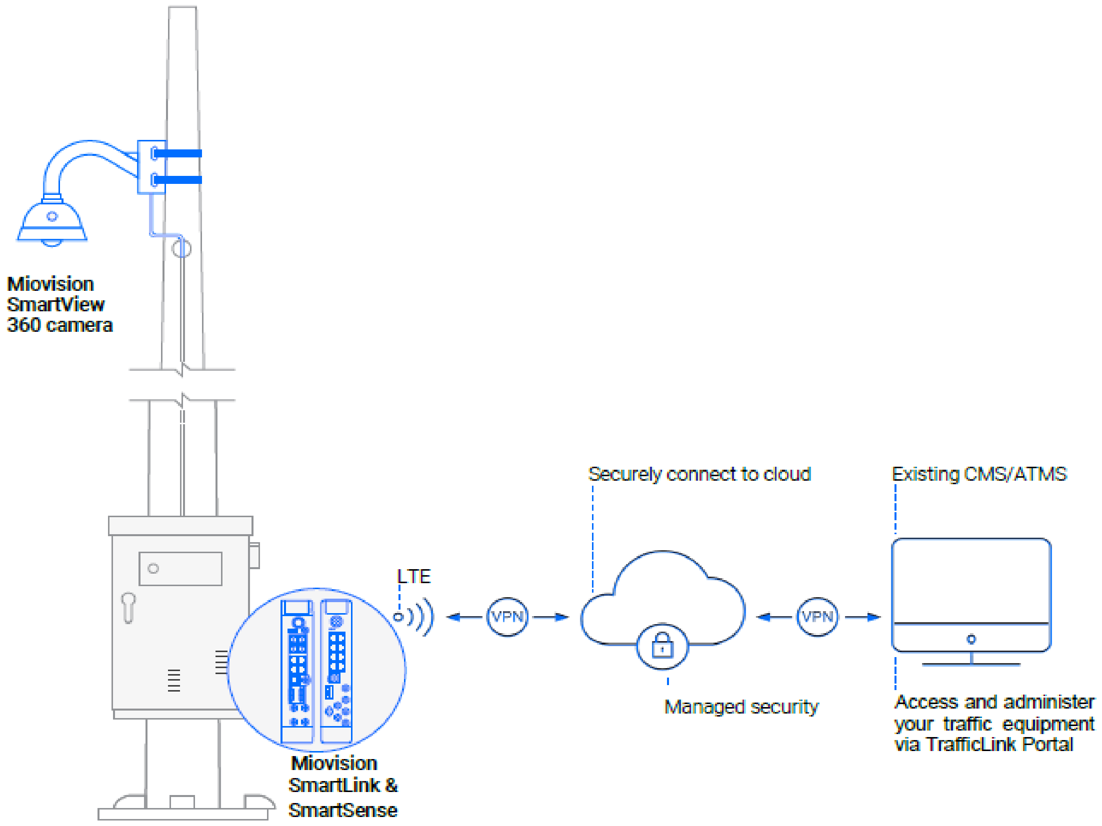
The API documentation for the Miovision system can be found at http://docs.api.miovision.com/. The API provides raw event codes in the Purdue Hi-Resolution format for all intersections in the system, lists of intersection locations, intersection configuration, and any active alerts in the system, all in a JSON format. The API requires the generation of per-user API keys to access the cloud-stored data.

4.2 Miovision System Architecture and Installation Process

4.2.1 Miovision System Architecture

Data collected from the traffic network is stored in the TrafficLink cloud, allowing agencies to compare traffic patterns year-over-year based off quantifiable data points. The technical architecture figure below outlines the communications path and flow of data in more detail.

Figure 16. Technical Architecture



Miovision has architected an “open by default” platform. This means that both hardware and software systems are designed by nature to be interoperable with other technologies and the existing traffic cabinet configuration. Examples include providing signal phasing and timing (SPaT) data to power a safe crossing app for the visually impaired, integrating with an existing CMS, partnering with a dedicated short-range communication (DSRC) vendor to provide pedestrian presence messages to onboard vehicle units, etc.

The Miovision TrafficLink Detection solution supports simultaneous integration across a heterogeneous mix of different technologies and providers, including different cellular providers, fiber connected networks, and point-to-point radio solutions.

Data APIs are available to access data collected through deployment that can be easily ingested by third-party systems.

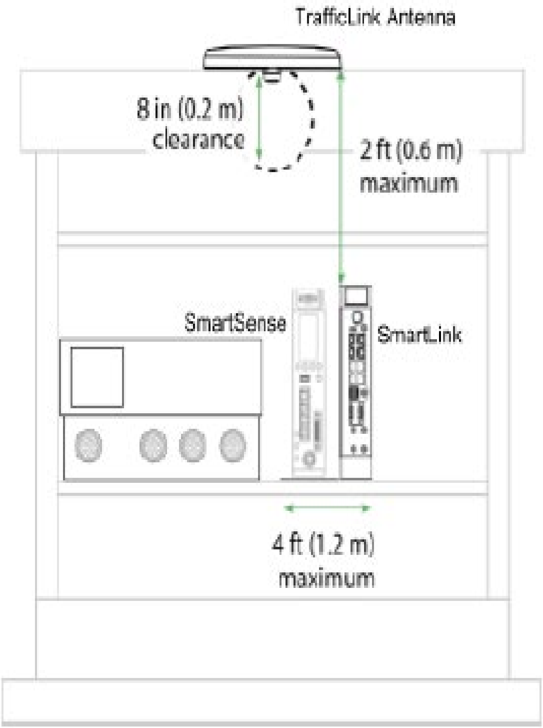
4.2.2 General Installation Procedure of Miovision:

The Miovision TrafficLink Detection installation process is designed to minimize impact/downtime while in the field. The installation is broken down into the following categories:

- Cabinet hardware install
- Camera mounting
- Intersection configuration

Cabinet hardware installation: Both Miovision SmartLink and SmartSense are designed for plug and play installation with typical installations only taking 20 minutes per location in the field.

Figure 17. Recommended Layout of Cabinet Hardware Install



Camera mounting: Miovision SmartView 360 camera comes equipped with mounting hardware and can support vertical pole installation, horizontal pole installation, or attachment via a 1¼ inch threaded fitting. A mounting height of >25 feet is recommended, to have a clear view of the intersection, and all approaches.

Intersection configuration: Each intersection is then configured with detection zones or all corresponding lanes and movements for vehicle traffic plus configuring pedestrian zones where appropriate.

Figure 18. Occupancy Zone Configuration (Pedestrians and Vehicles)

Figure 19. Turning Movement Count Configuration

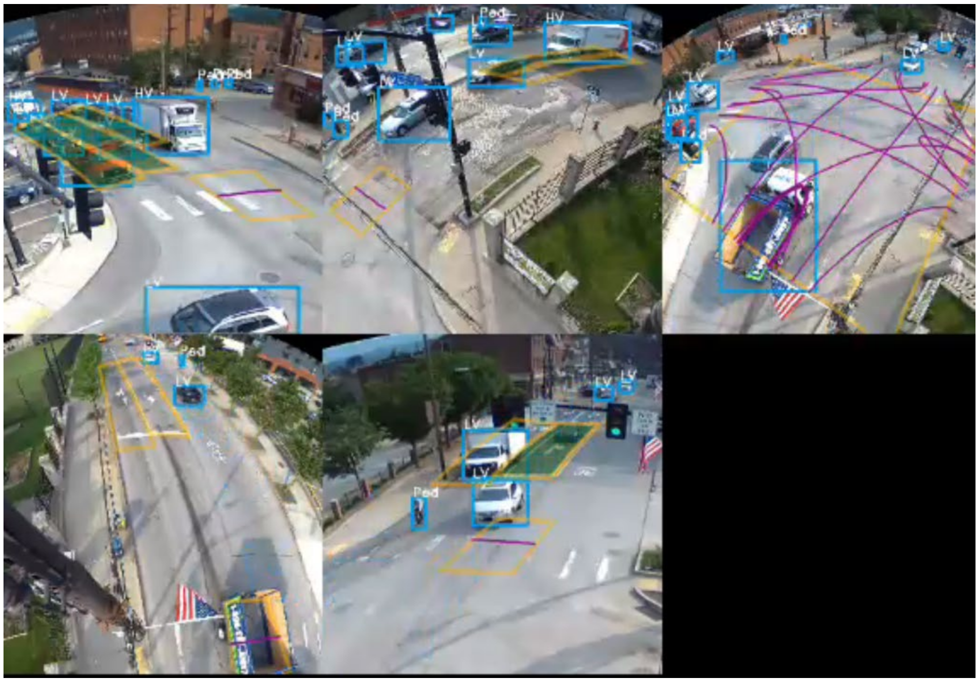
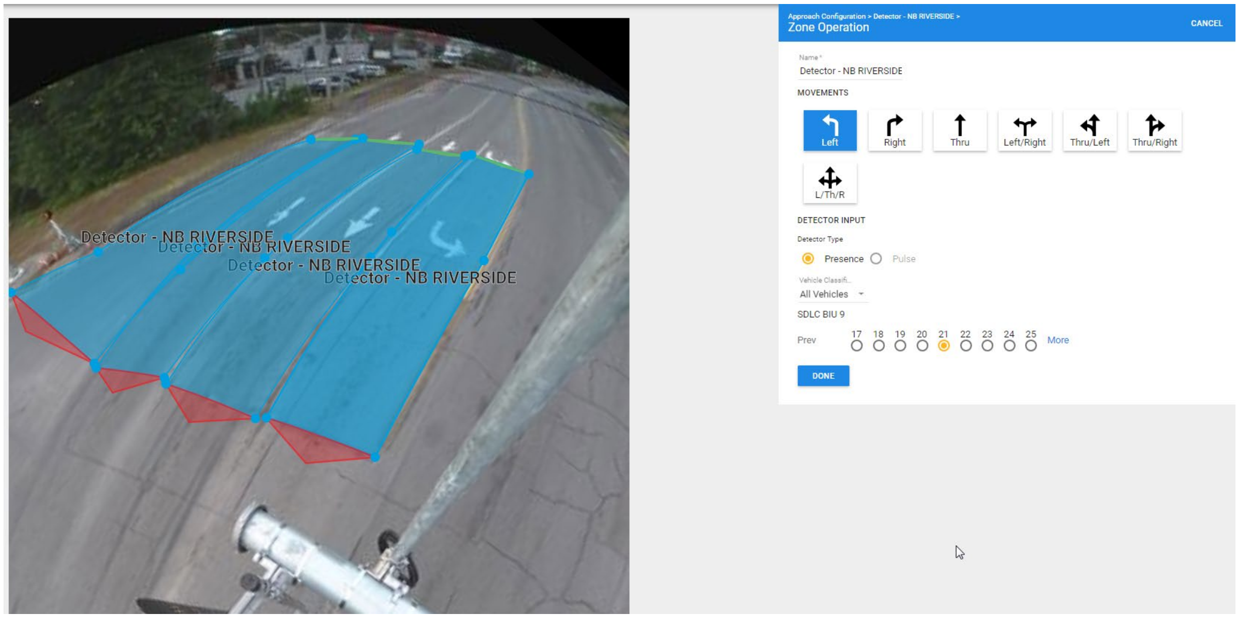


Figure 20. Detection Zone Configuration



Approach Configuration > Detector - NB RIVERSIDE >
Zone Operation

Name *
Detector - NB RIVERSIDE

MOVEMENTS

Left

DETECTOR INPUT

Detector Type
● Presence ○ Pulse

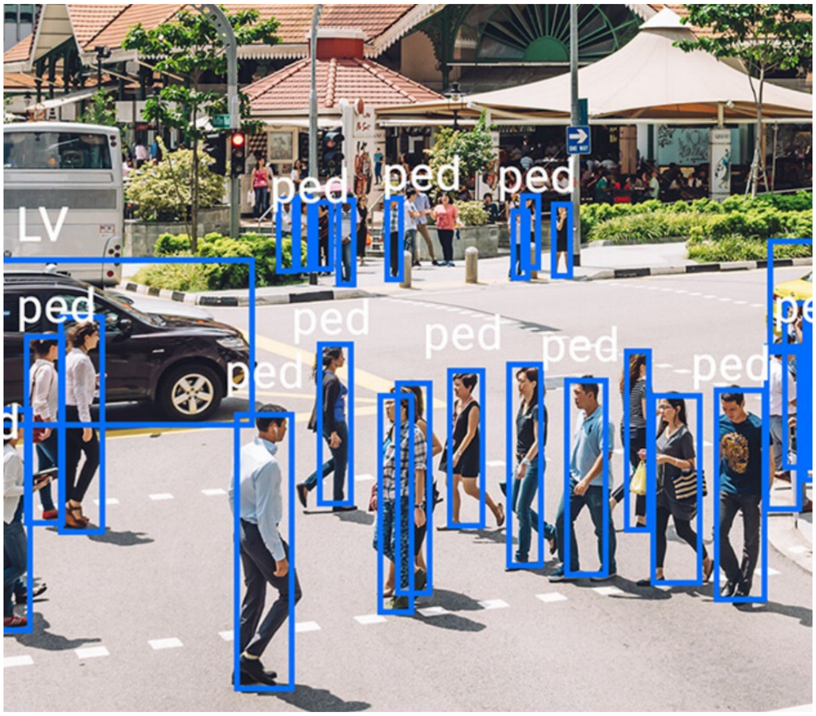
Vehicle Classifi...
All Vehicles

SDLC BIU 9

17 ○ 18 ○ 19 ○ 20 ○ 21 ● 22 ○ 23 ○ 24 ○ 25 ○

Some examples of how pedestrians (ped) and vehicles (LV) are detected within the Smartlink system (see Figure 21 below). Vehicle classification is also highlighted in the figure.

Figure 21. Miovision Detection Mechanism



4.3 Installation of Miovision Devices at the City of Mount Vernon

The following table shows the location and the hardware infrastructure that were installed in July 2018 and collected data for two years by Miovision.

Table 5. Miovision Hardware Locations

Location	Signal Controller	Miovision Hardware
Gramatan Ave South and Prospect	Peek	SmartLink + ABC Interface + SmartSense
Gramatan Ave South and Sydney	Transyt 1880	SmartLink + ABC Interface
Gramatan and Stevens/Fiske	Peek	SmartLink + ABC Interface + SmartSense
Gramatan Ave at North and Oakley	Peek	SmartLink + ABC Interface + SmartSense

Miovision cameras were installed at three intersections of Gramatan Avenue South intersecting Oakley Avenue/North Street, Prospect Avenue, and Stevens Avenue/Fiske Place. The intersection at Sydney Avenue was not equipped with the video camera due to budget constraints.

One issue that was faced during installation was how the detectors were tied to the phases in the controller. It was determined that one detection zone (one approach) was tied to a phase in the controller. However, existing in the field, these intersections had several approaches wired to a single phase in the traffic signal controller. To effectively collect data, additional equipment was needed. Miovision was able to provide D-cables that assisted with the detector calls that were made to the controller but it wouldn't fully resolve the issue without rewiring of the controller back panel and associated controller programming.

Figure 22. Intersection of Gramatan Avenue and Oakley Avenue/ North Street

Figure 23. Intersection of Gramatan Avenue and Prospect Avenue

Figure 24. Intersection of Gramatan Avenue and Stevens Avenue/Fiske Place

5 Live Traffic Data and Traffic System Incorporated Technology Specifications

5.1 Specifications

Live Traffic Data Corp (LTD) partners with traffic agencies, installing hardware to connect isolated signalized intersections with traffic management centers. They provide useful information to traffic engineers such as traffic counting, traffic visualization-like travel time diagram, green ban analysis, and congestion heat map. In this project, LTD and Traffic System Incorporated (TSI) coordinated their efforts to enhance the current city traffic signal field and help these intersections operate smarter. The intent of adding these technologies, the detection and ability to remotely monitor that detection, was an effort to increase the efficiency at the intersections as well as, decreasing delays in the corridor. The intention was to show an increase in flow of the traffic, which will result in a decrease in greenhouse emissions. In addition, the intent after completion of the study, was to make additional recommendations on technologies that should be implemented when additional funding becomes available.

LTD provides a comprehensive, best-supported Automated Traffic Signal Performance Measure tool, called SIGPAT™ (Signal Performance Analysis Toolbox). Some unique features of SIGPAT™ are as follows:

- Queue length and delay for each approach, each signal cycle.
- Generate email and text alerts based on performance measures.
- Maximum flexibility: Controller and detector-agnostic. Can collect high-resolution data from any signal controller and any detector system deployed in the U.S. or Canada today.
- Cloud-based architecture enable data sharing, maximum uptime, automatic data backup and access from any device via standard web browser.
- Reduce congestion, fuel consumption, and improve signal coordination.

Other features of the LTD SIGPAT system are: Real-time Performance Map, Split Monitor, Pedestrian Delay, Preemption, Turning Movement Counts, Purdue Coordination Diagram, Approach Volume, Approach Delay, Arrivals on Red, Approach Speed, Yellow and Red Actuations, Queue Length Number of Stops, Saturation Flow Rate, Arterial Travel Time, Vehicle Trajectory, Vehicle Classification, Retiming Benefits Analysis, Time-Space Diagram, Green Band Analysis, Arterial Congestion Map, Real-time Alerts, and Automatic Performance Reports.

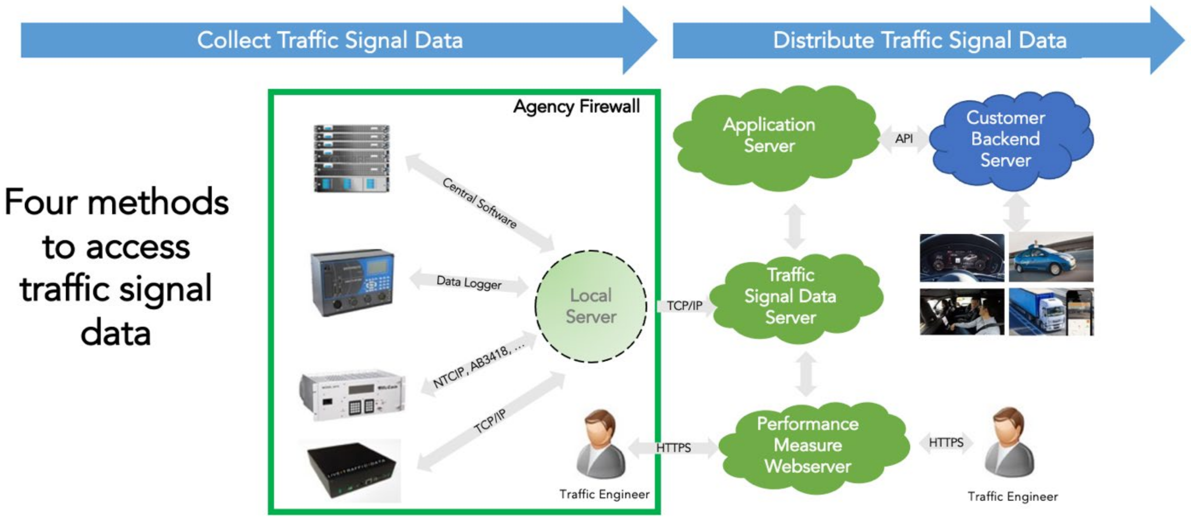
5.2 Live Traffic Data Corp and Traffic Systems Incorporated System Architecture and Installation Process

5.2.1 LTD and TSI System Architecture

To meet the scope of the project, TSI installed Sensys wireless in ground detection for counts and detection for the intersection along with Live Traffic Data's Remote Monitoring Central Cloud-based software to monitor each intersection. The Sensys network wireless vehicle detection system is embedded in the pavement and uses magneto-resistive wireless sensors to detect vehicle presence and movement. The intersections studied were on Gramatan Avenue in the City of Mount Vernon. The existing intersection controllers were Transyt Peek 3000 controllers. They were all operating on a fixed timed basis. The project sought to actuate these intersections and coordinate them on a Time-Based coordination scheme to allow vehicular traffic to efficiently progress from one end of the corridor to the other with minimal delays and/or stops. The Live Traffic Data remote monitoring software provided the city with full access to the real-time system. The software enables the city to monitor the intersections in real time and receive notifications of defects in operations. The system aimed to improve the flow of traffic along the corridor and decrease delays on side roads.

The following diagram is a composite system architecture, showing how the data is collected, processed, and distributed to various stakeholders.

Figure 25. LTD's system architecture



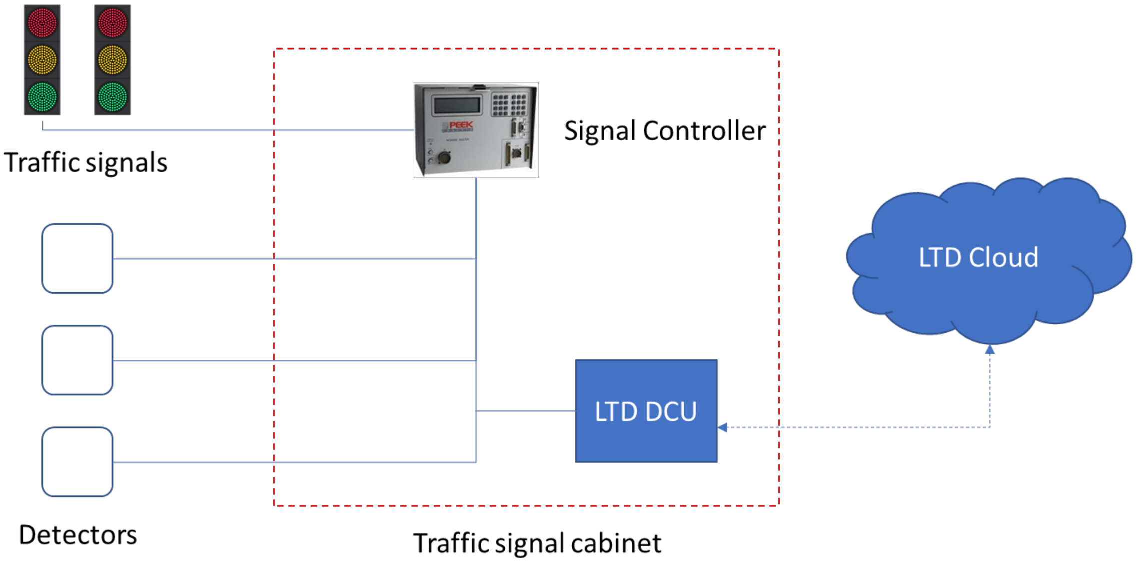
There are four methods by which LTD gathers the signal and vehicle detector data (shown on the left in above diagram):

1. Increasingly, central system software is making the traffic signal data available.
2. For newer controllers that support a Data Logger, LTD can upload the hi-resolution data.
3. For controllers supporting NTCIP, LTD can poll directly for the data.
4. At bottom, is an approach using hardware, which allows LTD to get data from all cabinets in the U.S. and Canada.

LTD provides a small (~1MB) executable "Local Server" service which pushes the data one way through an Agency Firewall to its cloud-based LTD Signal Data Server where the data is archived and Performance Measures computed. From there, the traffic signal data and performance measures are provided to the traffic agency via the cloud-based Performance Measure Webserver. The performance measures are accessed via web-browser. No software is required to be installed or maintained on the agency's workstations.

For the project at the City of Mount Vernon, the system architecture is shown on Figure 28, where the data collection units are used to collect traffic signal data directly from the signal controller and detector data output from the Sensys wireless detection system. The DA-300B hardware produced by EBERLE DESIGN INC is utilized as the data collection unit. During the project, the DA-300B has presented several issues like unstable communication connection, and data outage from time to time. However, these issues were overcome with the effort of all involved stakeholders.

Figure 26. LTD's System Architecture for the Project at the City of Mount Vernon



5.2.2 Traffic System Incorporated—Sensors Installation Process

TSI's approach for the installation at the City of Mount Vernon was as follows:

1. The Before Study—TSI evaluated each intersection after installation of LTD Remote Monitoring Software equipment prior to any addition of detection or coordination upgrades. All intersections operated in a non-coordinated and operating fixed time mode.
    - TSI gathered real time split data. This is the amount of green time for each approach (Phase)
2. Implementation Minor Street Phase—TSI installed wireless inground detection on the minor street approaches (Grand Avenue, Broad Street, and William Street) with the assistance of the City of Mount Vernon.
    - TSI gathered real time split data for major street (Gramatan Avenue) and minor street approaches.
    - TSI reviewed this data during peak periods to assist in determining a proper cycle length for daily pattern development.
    - TSI reviewed the delays/arrivals on red.
3. Implementation Major Street Phase—TSI installed major street wireless detection at the stop line and for advanced detection to monitor delays and arrivals on red and green.
    - TSI were to look at overall counts on the main line as well as arrival on red and on green.
4. TSI planned to develop basic coordination patterns to be implemented on a time-of-day basis with Time-Based Coordination.

The following pictures show the installation of sensors performed by TSI at their selected intersections on Gramatan Avenue (North) which are William Street, East Grand Avenue, and Broad Street East. (Figure 27, Figure 28, and Figure 29).

Figure 27. TSI Installation Diagram at Gramatan and Grand Avenue

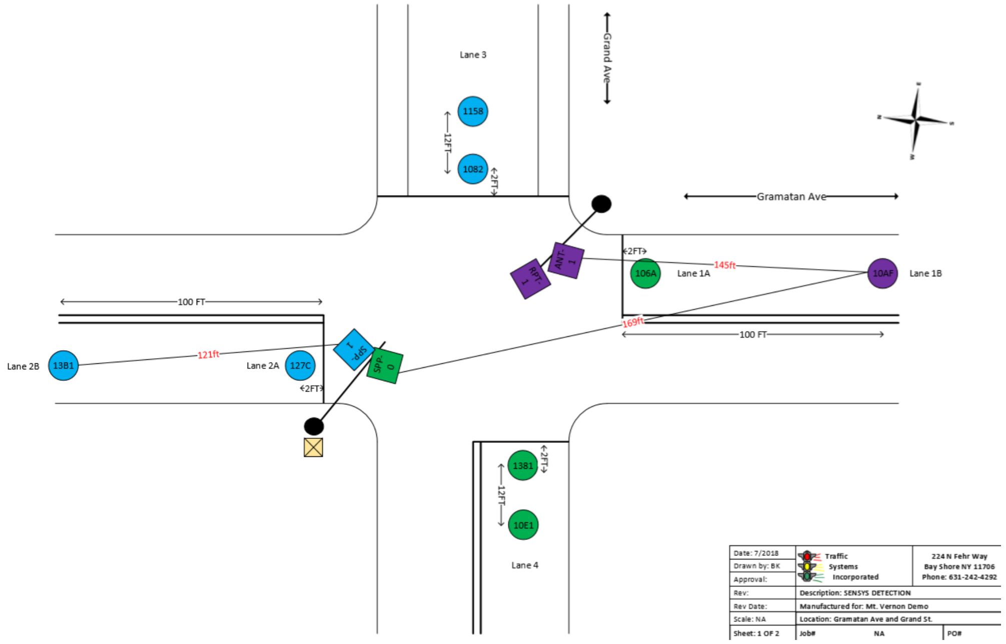


Figure 28. TSI Installation Diagram at Gramatan Avenue and Broad Street

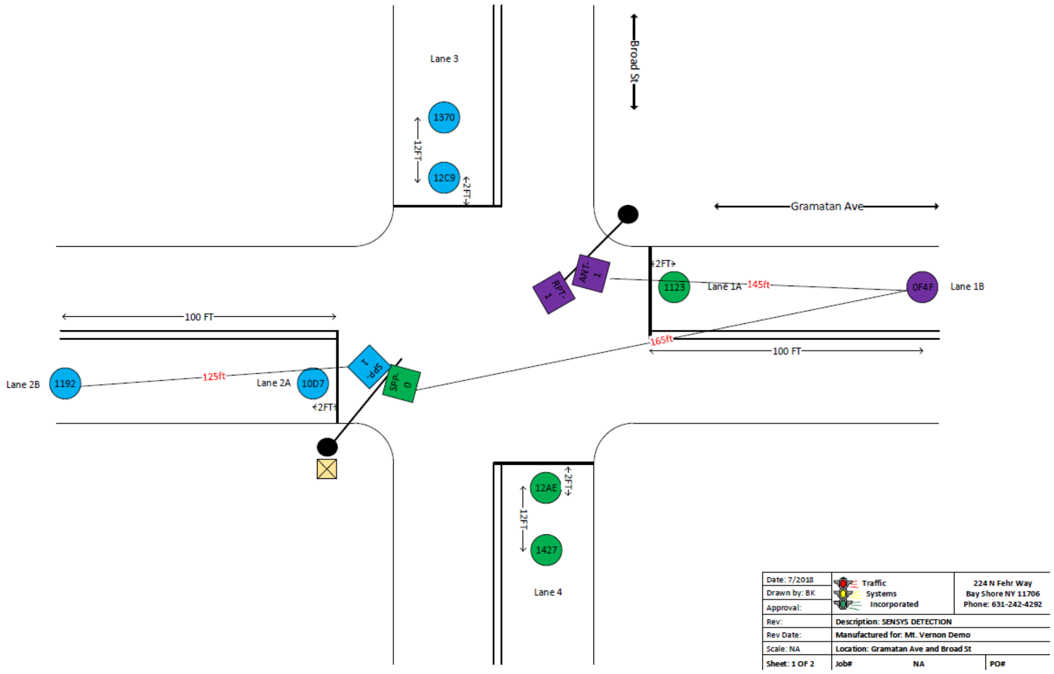
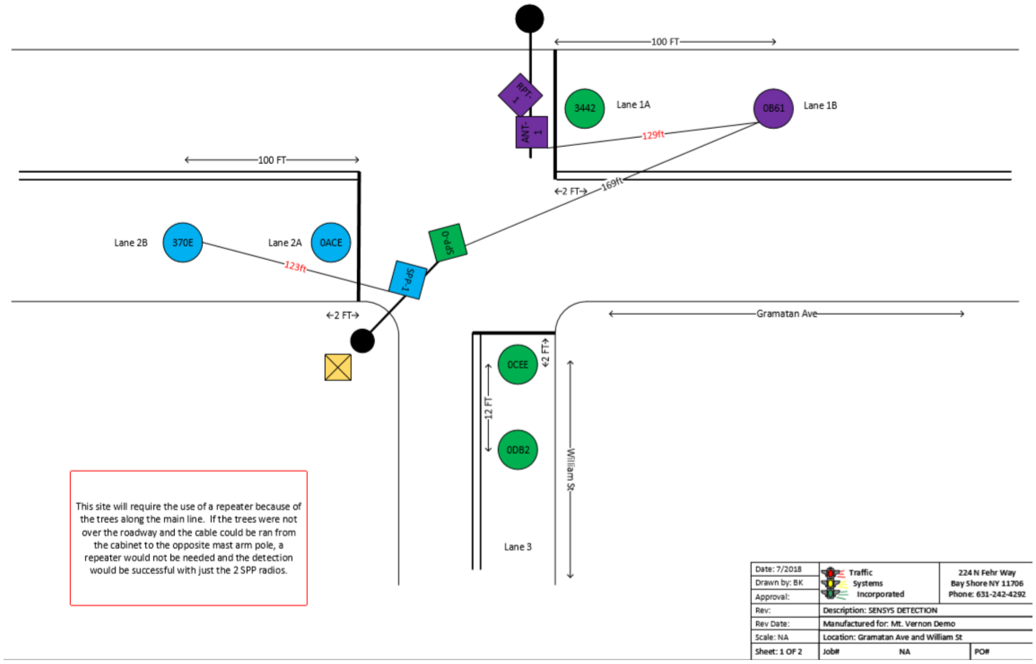


Figure 29. TSI Installation Diagram at Gramatan Avenue and William Street



This site will require the use of a repeater because of the trees along the main line. If the trees were not over the roadway and the cable could be ran from the cabinet to the opposite mast arm pole, a repeater would not be needed and the detection would be successful with just the 2 SPP radios.

Date: 7/2018
Drawn by: BK
Approval:
Rev:
Rev Date:
Scale: NA
Sheet: 1 OF 2

Traffic Systems Incorporated

224 N Fehr Way
Bay Shore NY 11706
Phone: 631-242-4292

Description: SENSYS DETECTION
Manufactured for: Mt. Vernon Demo
Location: Gramatan Ave and William St
Job# NA
PO#

6 Base Simulation and Calibration Process

6.1 Model Development

PTV VISSIM simulation software was utilized by the project team to simulate the vehicular traffic for the Gramatan Avenue in the City of Mount Vernon. PTV VISSIM is a microsimulation traffic software that takes the vehicles' volumes and signal control parameters as inputs. The network of the Gramatan Avenue was first created, then, traffic demand, vehicle routing, and many layers of traffic operational controls were added to the simulation model. VISSIM provides vehicle delay (time), travel times (time), queue length (distance), environmental impact outputs (NOx, VOC, and CO emissions in grams), for all classes of vehicles and for each segment of the simulated network.

Before beginning the optimization of the signalized corridor, the model needs to be calibrated for the current traffic conditions. To simulate the network, the following data is mainly required for the purposes of this project: (1) Throughput volumes of cars and trucks, (2) Turning movements (what proportion of cars moving right, through or left at each intersection), (3) Travel time along the arterial.

In this analysis, the team mostly focused on the southern part of the Gramatan Avenue equipped by Miovision due to installation issues and data collection issues at the intersections located on the northern portion of Gramatan Avenue. The issues resulted from legacy signal controller panels at the northern intersections, which prohibited accurate data transmission. Unfortunately, these problems were not addressed before the field data collection was halted due to the COVID-19 pandemic. The issues, as determined by the city, included existing controllers that were too old to handle the LTD system and faulty electrical installation of the controllers. Additional investigation was not considered as its was beyond reasonable time and budget scoped for this project. Thus, the project team collected the volumes from the cameras installed by Miovision. As stated above, the cameras were only installed on Stevens Avenue/Fiske Place, Prospect Avenue, and Oakley Avenue. Since Miovision had no camera installed on Sydney Avenue, the actual values were obtained from the site visit that took place on April 9, 2019. The intersection was filmed for 15 minutes and subsequently the corresponding vehicle movements (through movements (vehicles going straight through the intersection), right-turns, and left-turns) were counted for that time interval. The video allowed the team to not only count cars and trucks volume separately, but also provided the corresponding vehicle turning movement proportions. Given the observed intersection traffic flow count data, the VISSIM network could then be calibrated for the simulation runs. It is noted that the traffic flow demand from the far south signal of Gramatan Avenue, intersecting 1st Avenue and Gramatan Avenue, was also acquired from the site visit conducted by CED.

The following table (Table 6) provides the existing traffic signal timing conditions at all four intersections on the southern portion of Gramatan Avenue.

Table 6. Signal Control Parameters at Gramatan Avenue (Base Condition)

BASE MODEL					
	1st Street	Fiske Place	East Prospect	Sidney Avenue	Oakley Avenue
Cycle length (sec)	65	60	60	55	60
Offset (sec)	0	0	6	23	41
NB/SB split (sec)	30	35	35	30	35
EB/WB split (sec)	35	25	25	25	25

After acquiring all the required input, the network was developed in the PTV VISSIM microsimulation software to create the base conditions. Calibration was carried out in VISSIM in order to match the simulation with reality. Travel times were used as the performance measurement for calibration. Actual travel time data was acquired from Miovision's portal and Google API, and the corresponding simulated travel time was obtained from VISSIM.

Google API: The Google Maps API (application programming interface) allows users to retrieve some specific data from Google Maps through coding interface. We utilized Python to collect travel times for southern part of Gramatan Avenue. Then, the acquired travel time data from Google Maps was compared to the base travel time of our VISSIM simulation model to perform the calibration.

PTV VISSIM: For comparison, the base model was first developed in VISSIM; then, volume data from Miovision were used as inputs to VISSIM in order to calibrate the City of Mount Vernon network. The simulation emulated the traffic flow conditions for a weekday for 13 hours from 6:00 a.m. to 7:00 p.m. in order to better encapsulate the various levels of the underlying traffic flow demand. Also, point-to-point travel time was acquired from the Miovision portal, in both raw travel time and average of the past four weeks (historical travel time). The travel times estimated from VISSIM were then compared to the other sources (Google API and Miovision technologies). Figure 30 and Figure 31 below show the discrepancy of travel time from different sources in the northbound (NB) and southbound (SB) directions.

Figure 30. NB Travel Time Comparison

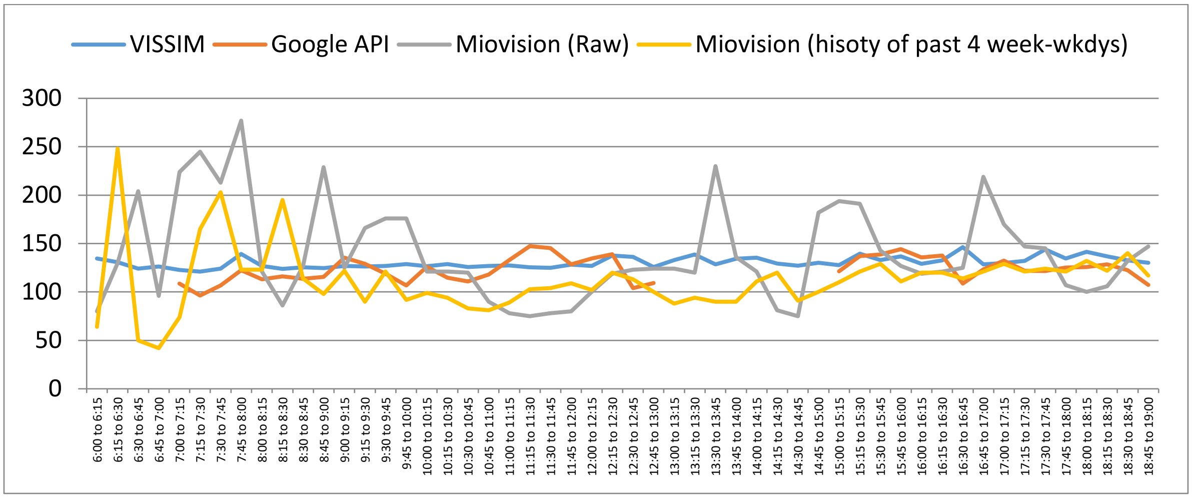
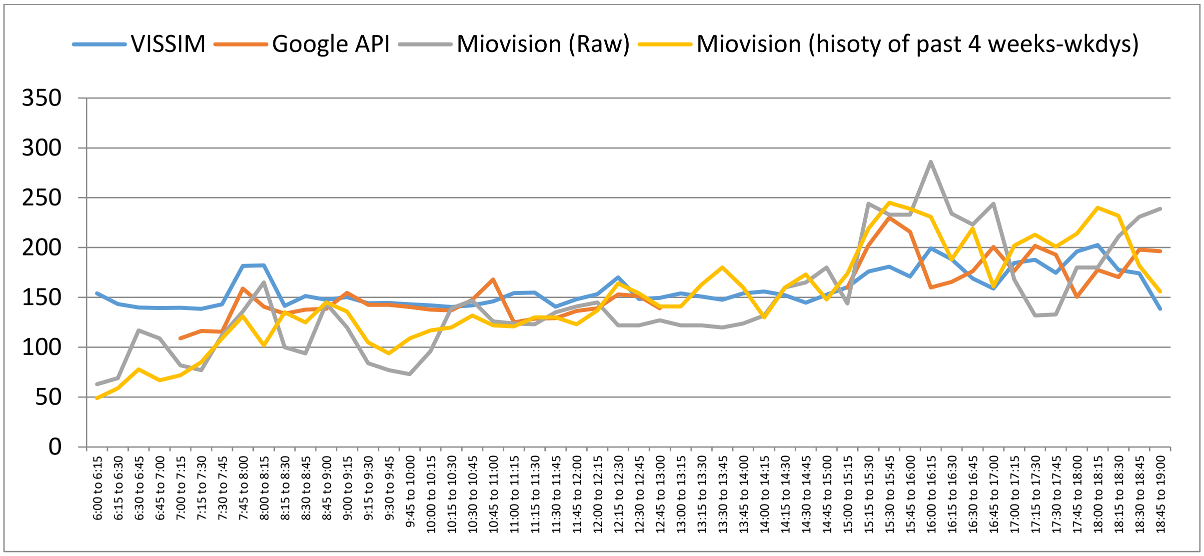
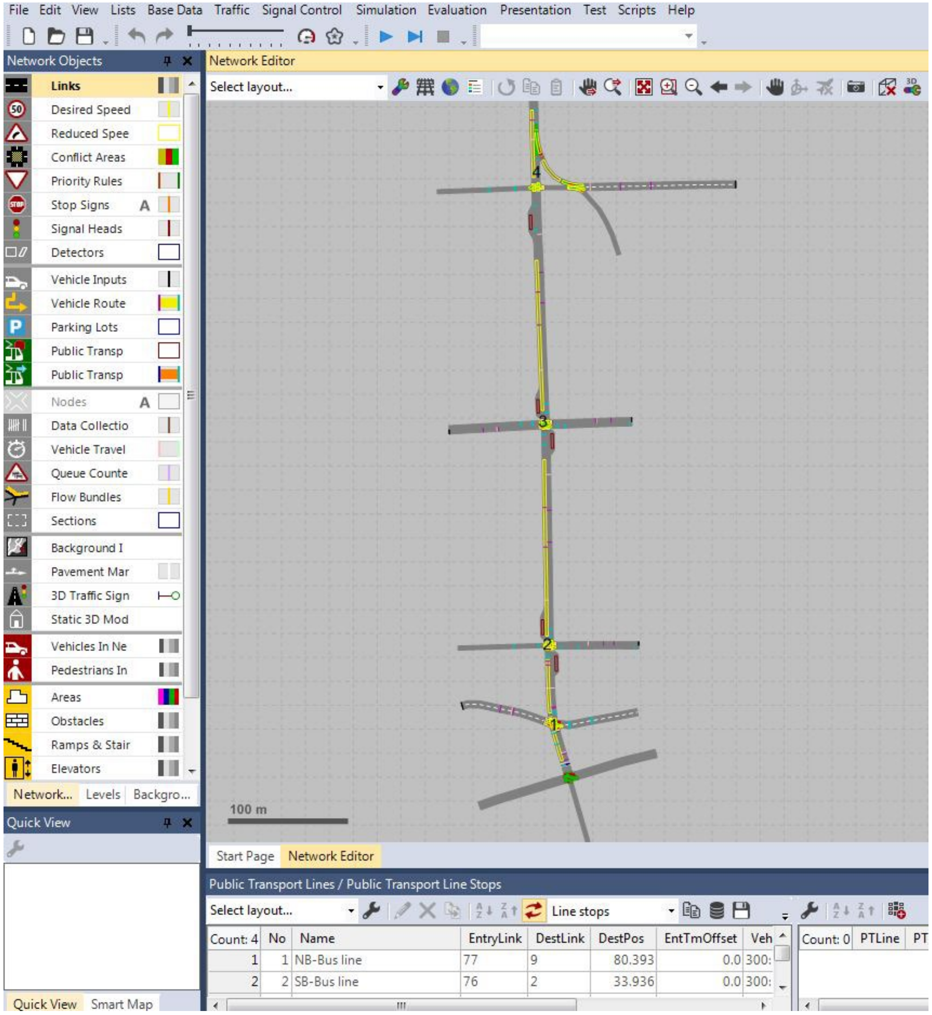


Figure 31. SB Travel Time Comparison from Various Sources



The average travel time difference of the VISSIM simulation to Google API was <10 percent (southbound direction) and <12 percent (northbound direction). Correspondingly, to the Miovision technologies the average difference in travel time was <15 percent (southbound) and <21 percent (northbound). Figure 32 shows the final simulated layout of the corridor in VISSIM. The next step involved the utilization of the VISSIM model for Gramatan Avenue to emulate various scenarios and conduct signal optimization.

Figure 32. Layout of the Simulated Corridor in VISSIM



Count: 4	No	Name	EntryLink	DestLink	DestPos	EntTmOffset	Veh
1	1	NB-Bus line	77	9	80.393	0.0	300:
2	2	SB-Bus line	76	2	33.936	0.0	300:

6.2 Different Signal Optimization Strategies

In this section, different traffic control models were applied and compared with the base signal model that was calibrated in the previous section. The different traffic control models simulated are as follows:

- One-signal program optimized model, which uses one fixed-time signal control timetable for a whole day. For the case study, the signal plan is based on PM peak.
- Three-signal program optimized model, which uses three fixed-time signal control timetables (AM, PM, MD) for the controlling traffic operations through the day.
- Actuated-coordinated signal control model, which is a signal control algorithm that enables the minor street phases to run as actuated and phases on the main arterial to run under coordination.

The research team utilized SYNCHRO 8 and PTV VISTRO 2 signal optimization software. In the following sections, the signal optimization results of the abovementioned signal timing schemes are presented.

6.2.1 Creation of One-Signal Program Optimized Model

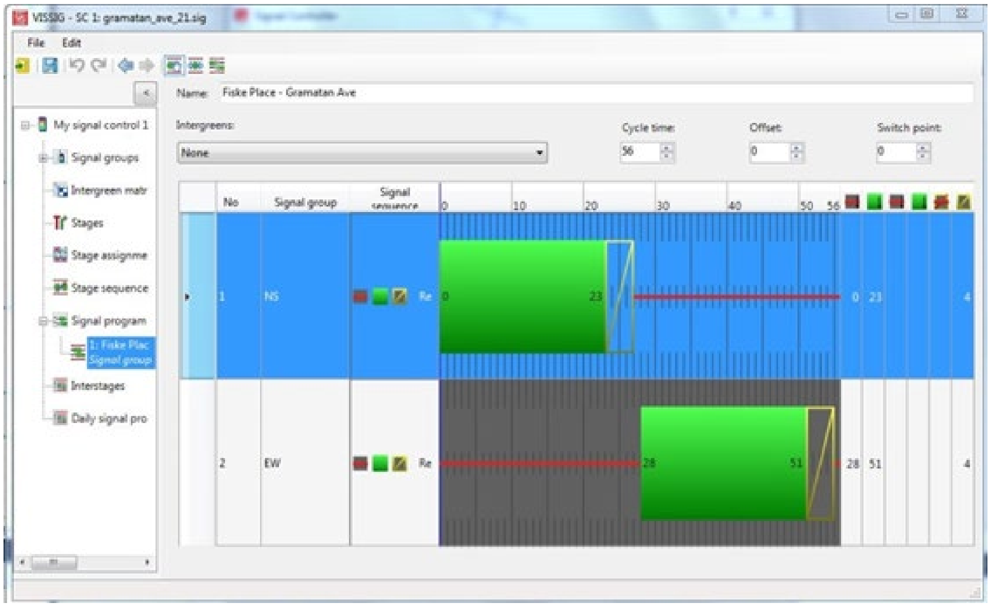
At this stage of the process, the team developed an optimized network in order to reduce the travel times and delays for vehicles along Gramatan Avenue. The main input data required by SYNCHRO 8 and PTV VISTRO 2 are:

- Arterial and intersection geometry.
- Intersection traffic flow data (through, right, left), including cars and trucks.
- Percentage of heavy vehicles (HGV's and buses).
- Peak hour factor.
- Speed limit for a given street segment.

The two-optimization software, Synchro and VISTRO, estimate the optimal values of various traffic control parameters including: cycle length, splits, and offsets. The PM peak hour demand was selected for analysis to obtain the optimized values in Synchro and VISTRO. The corresponding traffic volumes and other required input associated to the PM peak were gathered from field studies and were used as input to run the Synchro and VISTRO optimization software.

The signal optimization produced the following new traffic control values: cycle lengths, splits, and offsets, which were then used as input for the VISSIM microscopic simulation software. In this project, each signalized intersection consisted of two critical phases: north-south direction and east-west direction. The pedestrian signal phases were run concurrently with the associated vehicular signal phases.

Figure 33. Example of Signal Program for Stevens Avenue/Fiske Place



VISSIG - SC 1: gramatan_ave_21.sig

Name: Fiske Place - Gramatan Ave

Intergreens: None

Cycle time: 56

Offset: 0

Switch point: 0

No	Signal group	Signal sequence				
1	NS	Re	0	23		4
2	EW	Re	28	51		4

Table 7 displays the traffic signal information of one-program (only considering PM peak) optimization at all intersections.

Table 7. Signal Control Parameters at Gramatan Avenue (One-Program Model)

1-PROGRAM					
PM peak	**1st Street**	**Fiske Place**	**East Prospect**	**Sidney Avenue**	**Oakley Avenue**
Cycle length (sec)	65	65	65	65	65
Offset (sec)	0	5	10	26	44
NB/SB split (sec)	25	30	35	33	35
EB/WB split (sec)	30	25	20	22	20

To assess the optimized network performance, we used the average 15-minute—as estimated by VISSIM—travel times and delays values for Gramatan Avenue from 1st Street to Oakley Avenue for all 15-minute time intervals of the PM analysis period. The comparative simulation results for the two traffic flow parameters of travel time and delay, based on the base model and the optimized model—after Synchro optimization—are shown below (see Figure 34 and Figure 35). In Figure 35, the red line is the travel time (in seconds) for the base model, and the blue line is the travel time (in seconds) for the optimized condition using Synchro model. In Figure 35, the blue line is the delay measurement (in seconds) for the base model, and the red line is the delay measurement (in seconds) for the optimized condition using Synchro model.

Figure 34. Travel Time Comparison between Base Model and Optimized Model

(Northbound is the figure on the left, southbound on the right)

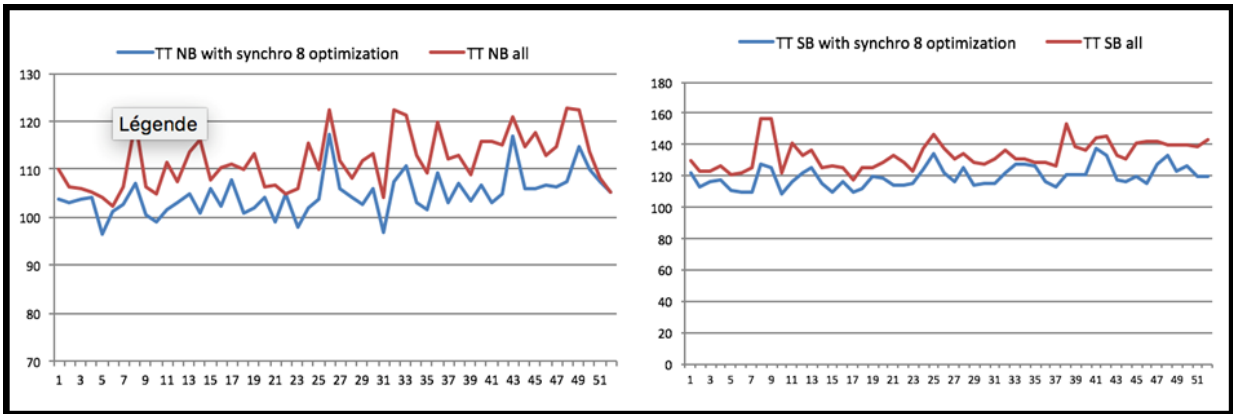
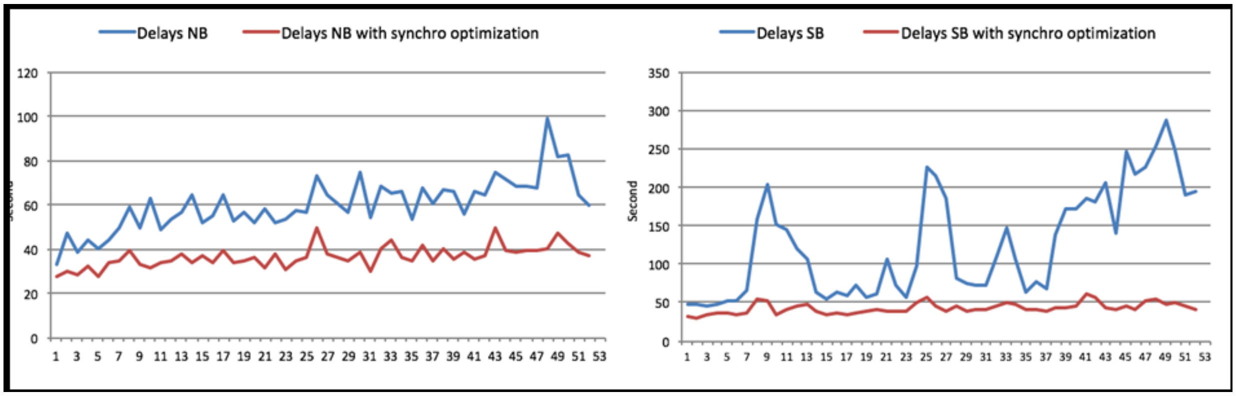


Figure 35. Delay Comparison between Base Model and Optimized Model

(Northbound is the figure on the left, southbound on the right)



The above figures highlight the optimized model (after the Synchro 8 optimization) and show that the optimized model is performing better than the base model. Delays and travel times of the optimized model are shorter than those of the base model.

This simulation was run and compared against the base to be more efficient. The timings for the optimized one-program model are shown in Table 7, and timing updates were attempted at each signal. Due to obstacles faced during this task, not all timings were correctly implemented to all intersections because of the lack of human resources at The City of Mount Vernon and the restrictions caused by the Covid-19 pandemic which added another layer of difficulty to implement the suggested timing phases.

6.2.2 Creation of Three-Signal Program Optimized Model

In the previous stage, we developed a solution to optimize the network, yet signal programs for all intersections were adapted to the PM peak (where the demand is the highest throughout a typical day). In order to represent the conditions throughout a typical day, signal programs for different time periods of the day were developed. Three signal timings were designed to include (a) the AM program for the morning peak, (b) the MD for the midday program, and (c) the PM program for the evening, which was already created in the previous step. The corresponding vehicle volumes associated to each time period of the day were selected as inputs in Synchro 8 (but not Vistro for this stage of the process) in order to obtain the optimized cycle lengths, splits, and offsets for the corresponding AM, MD, and PM peak periods of the day. The full results that include the three-signal program optimized model are summarized in section 6.4

6.3 Creation of the Actuated-Coordinated Model

In this model, we developed an actuated-coordinated signal control. In the two previous steps the models applied fixed control timing plans, meaning that signal timings were the same for every cycle and were not dependent on real-time conditions. In an actuated-coordinated model, detectors are installed at each intersection (on the cross/minor streets). This enables the cross streets to run as actuated with the "least loss time," and transfer all the unused time to the main streets (northbound and southbound in this project). In other words, if the minor (east/west) street has spare green time during a cycle, this time can be reallocated to the major (north/south) green time.

Using the same inputs from the previous stages and selecting the actuated-coordinated optimization model, the Synchro software returns the outputs of the optimized cycle length, splits, and offset for all given intersections. These outputs were then used as inputs for the RBC of the corresponding VISSIM simulation model.

6.4 Simulation Results of All Four Control Models

In this section, the results of all simulations are presented. The main traffic flow parameters, utilized to demonstrate the efficiency of the various undertaken signal optimizations, were the corresponding

15-minute average delays and travel times for the Gramatan South corridor (from Fiske Place to Oakley Avenue), which are depicted below in Figure 36 to Figure 41.

Figure 36. Average Delay of Gramatan Avenue of NB and SB in Four Signal Control Scenarios

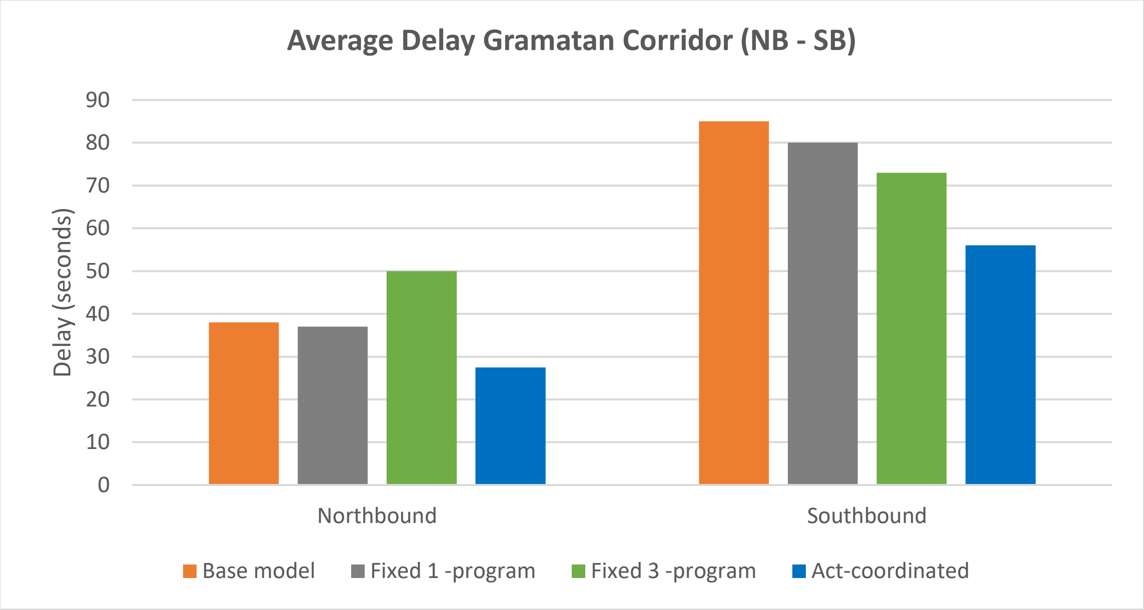


Figure 37. Average Bus Delay of Gramatan Avenue of NB and SB in Four Signal Control Scenarios

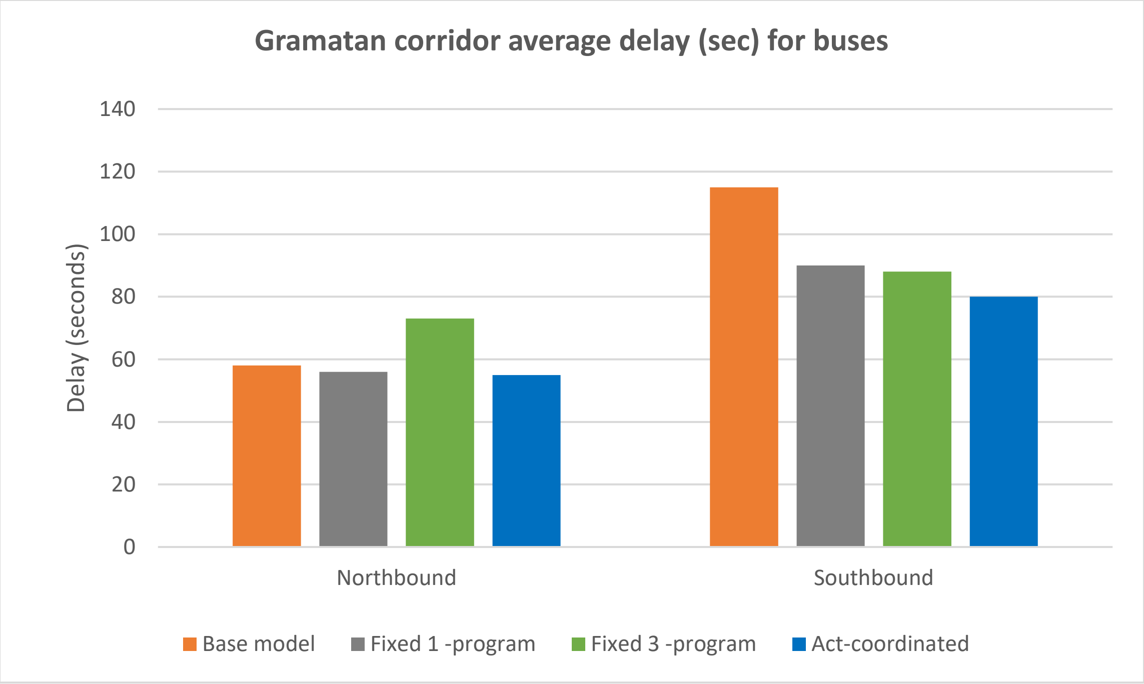


Figure 38. Average Delay of NB and SB at Each Intersection

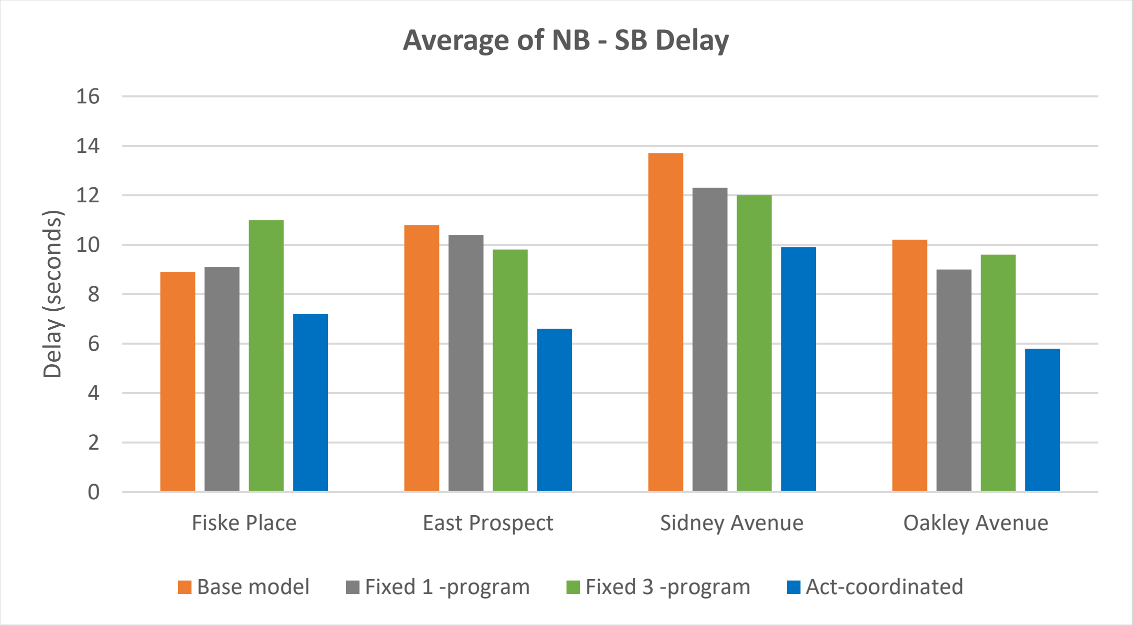
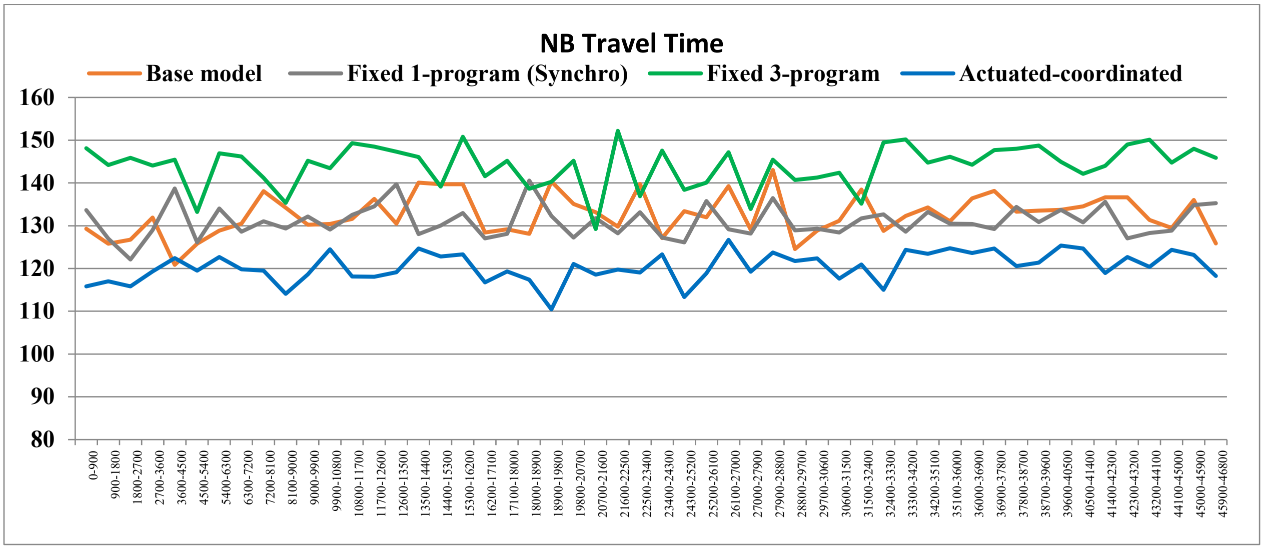


Figure 39. NB and SB Travel Time Comparison in all Levels of Signal Control Models

a) Travel time at the Northbound (NB) direction



b) Travel time at the Southbound (SB) direction

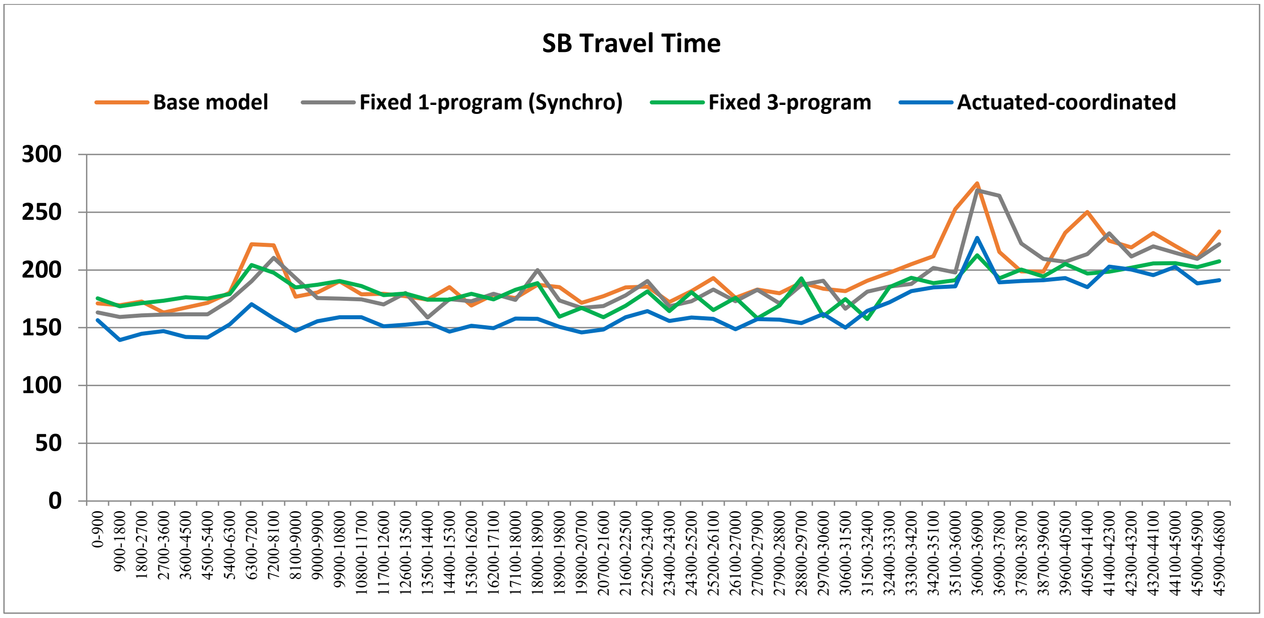
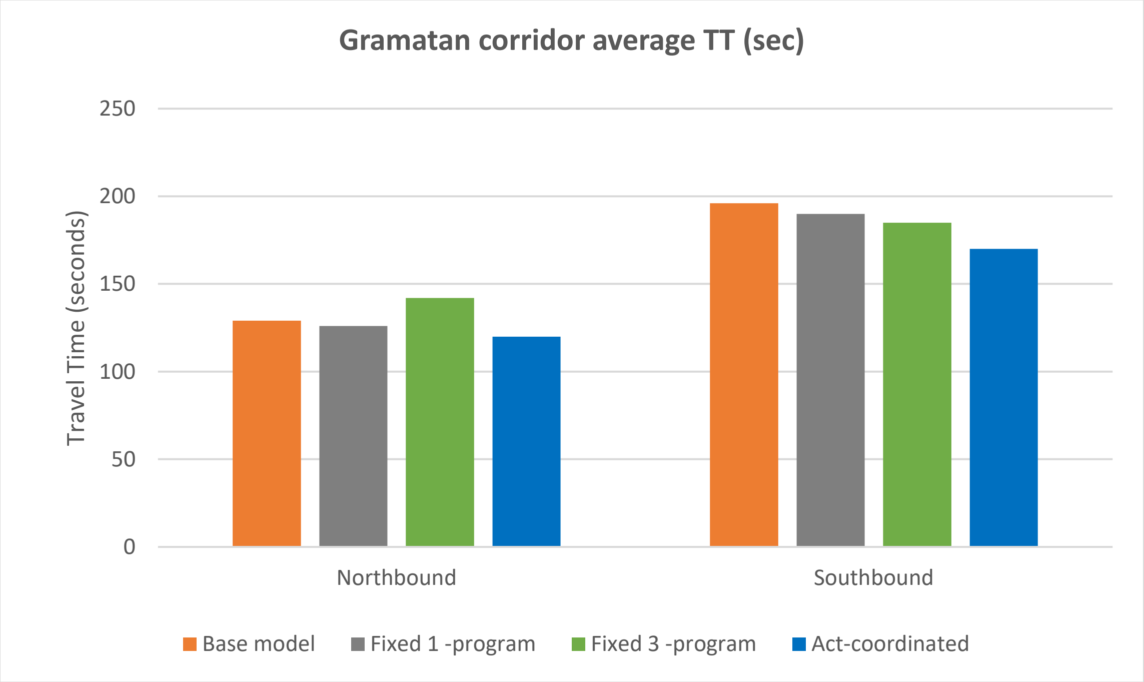


Figure 40. Average Travel Time (TT) Comparison for All Levels of Optimization

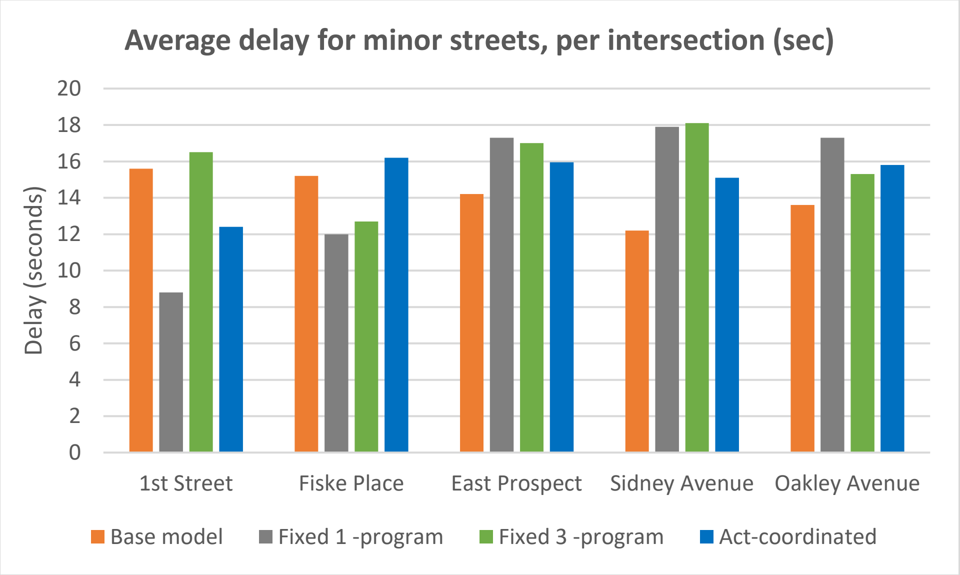


Graphs on Figure 40 and Figure 41 illustrate the change in traffic delay and travel time in the northbound and southbound directions. In both of these figures, we can observe that the actuated-coordinated results result in the least delay. In comparison to the base mode, the actuated-coordinated model reduces southbound delay by 62 percent and the corresponding travel time by 29 percent, which are significantly substantial.

6.5 Impact of the Signal Optimization on Cross Streets

In order to provide an overall assessment of the impact of the implemented signal optimization, the research team further examined its impact on the associated cross streets. The following figure (Figure 41) shows the corresponding 15-minute average cross-street delays per intersection (average value of eastbound and westbound).

Figure 41. Average Delay for Cross Streets at Each Intersection



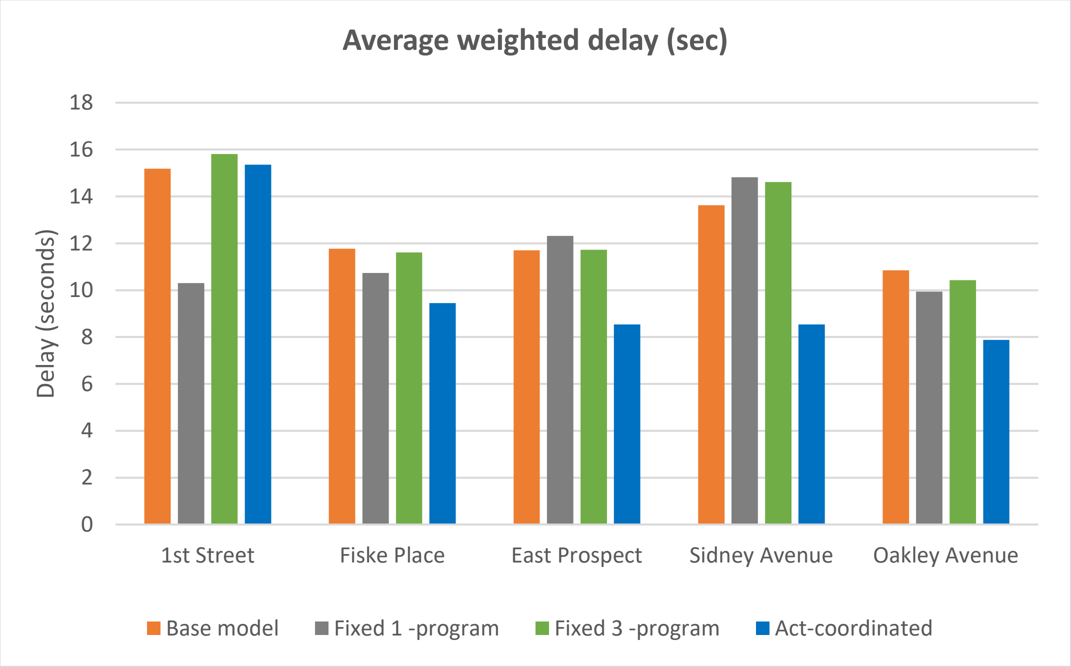
It is noted that while the actuated-coordinated control model reduced the 15-minute average delay on the main direction, it has increased the delay on some minor/cross streets (four out of five). The weighted average delay is another measure to determine the performance of different models.

Figure 42 shows the average weighted delay of the four intersections under different signal control models. The actuated-coordinated signal control has reached the least average weighted delay at each intersection among all control models except 1st street.

Table 8. Average Weighted Delay per Intersection for Each Model/Program

	Base Model	Fixed 1-Program	Fixed 3-Program	Act-Coordinated Model	Rate of Change (Act-Coordinated to base)
1st Street	15.18	10.30	15.81	15.35	1.11
Fiske Place	11.77	10.74	11.61	9.45	-19.71
East Prospect	11.70	12.32	11.73	8.54	-26.99
Sidney Avenue	13.63	14.82	14.62	8.54	-37.34
Oakley Avenue	10.85	9.94	10.43	7.88	-27.35

Figure 42. Overall Average Weighted Delay of Each Intersection (In Seconds)



The results from the traffic simulation reveal that utilizing the actuated-coordinated signal model has outperformed three other traffic control models.

While these are simulation results, they provide a strong argument to the engineers/planners and politicians to make a case for implementing such smart technologies in their cities.

6.6 Environmental Impact

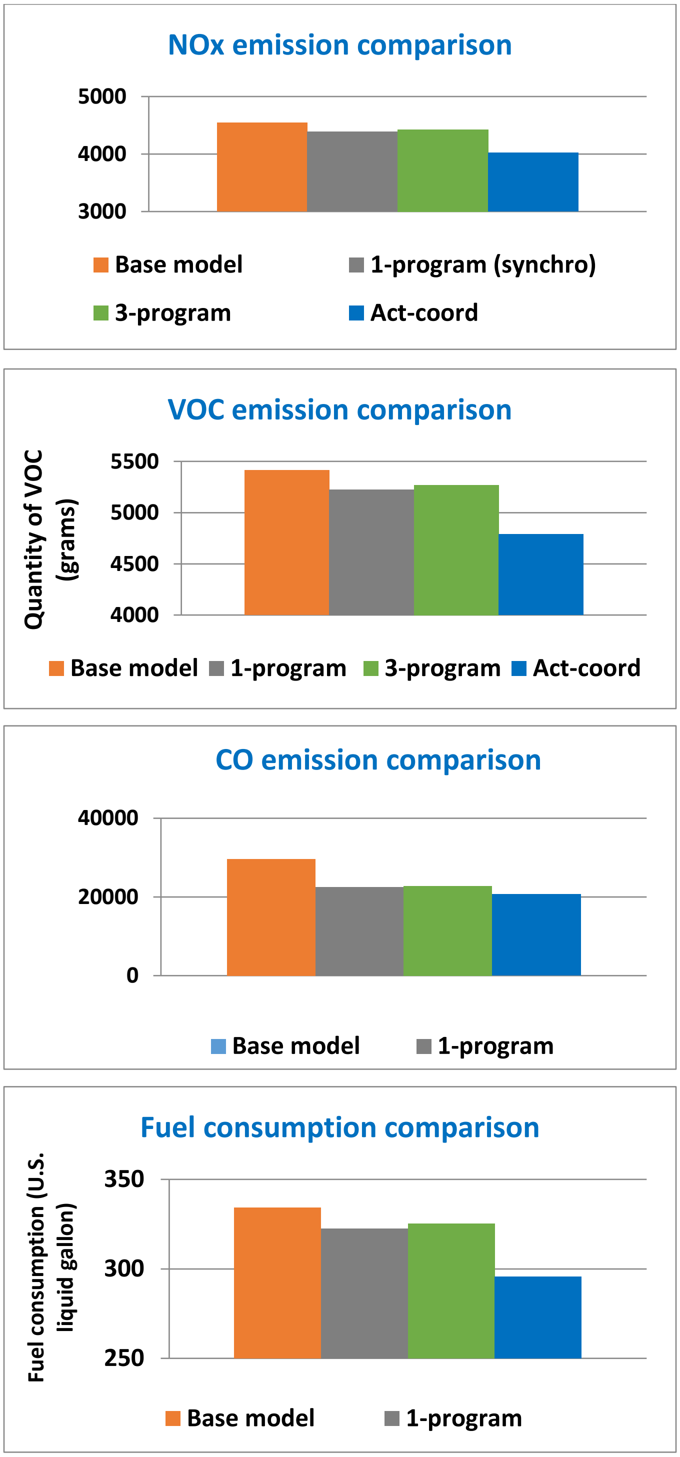
The main objective of this research project was to demonstrate the effectiveness of smart technologies to reduce traffic congestion. Given the capabilities of the VISSIM microscopic traffic simulator to also produce estimates of the fuel consumption and greenhouse gas (GHG) emissions, the corresponding parameters were estimated as they are readily available within the output of the traffic flow model. PTV VISSIM produces estimates of the following environmental parameters:

- Carbon monoxide (CO) emission (grams)
- Nitrogen oxides (NOx) emission (grams)
- Volatile Organic Compound (VOC) emission (grams)
- Fuel consumption (U.S. liquid gallons)

Correspondingly, the GHG emissions and fuel consumption were estimated for each of the four intersections (Stevens Avenue/Fiske Place, Prospect Avenue, Sidney Avenue, and Oakley Avenue) and for the Gramatan Avenue corridor (northbound and southbound) as a whole. Values by intersection were summed to obtain global numbers through the whole corridor from north to south and vice versa. Note that carbon monoxide (CO), nitrogen oxide (NOx) and volatile organic compound (VOC) emissions are given in grams, and that fuel consumption is given in U.S. liquid gallons.

Figure 43. Environmental Impact Analysis

GHG (NOx, VOC emission, CO) and fuel consumption under the different traffic control scenarios considered.



The Actuated Coordination Model produced the least GHG and fuel consumption from all other models. It produced a reduction of 11.5 percent in both GHG and fuel consumption versus the Base Model, respectively.

6.7 Analyses for Intersections at Gramatan Avenue North Instrumented by LTD and TSI

As noted above, the three intersections at Gramatan Avenue North were instrumented by LTD and TSI. Due to some technical issues with the traffic signal controllers at these locations, the project team couldn't gather the full set of data as expected. The following figures show some results for the intersection at Gramatan Avenue and Grand Street retrieved from the LTD analysis tool, including traffic volumes and signal coordination diagrams.

Figure 44. Traffic Volume from Two Detectors Installed in the Intersection Gramatan Avenue and Grand Street

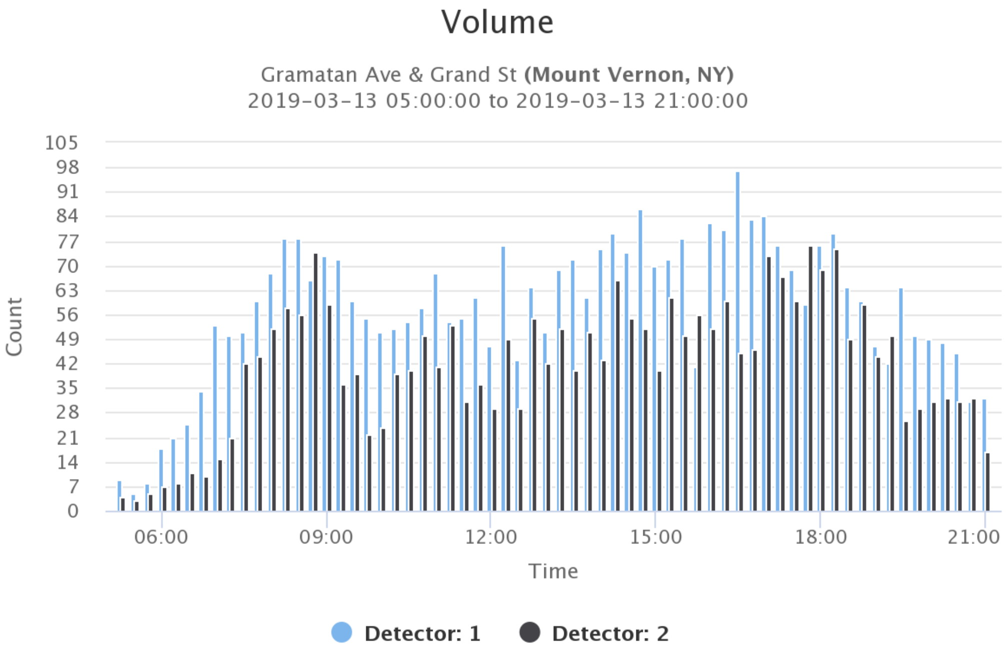


Figure 45. Purdue Coordination Diagram in the Intersection Gramatan Avenue and Grand Street

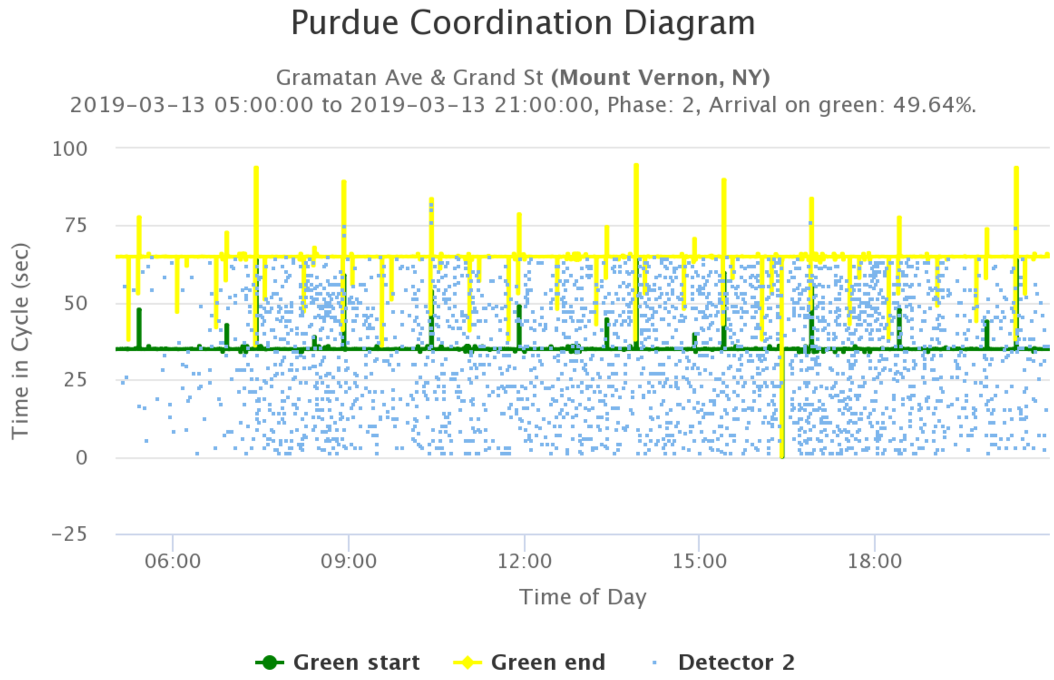


Figure 46. Re-identification Diagram

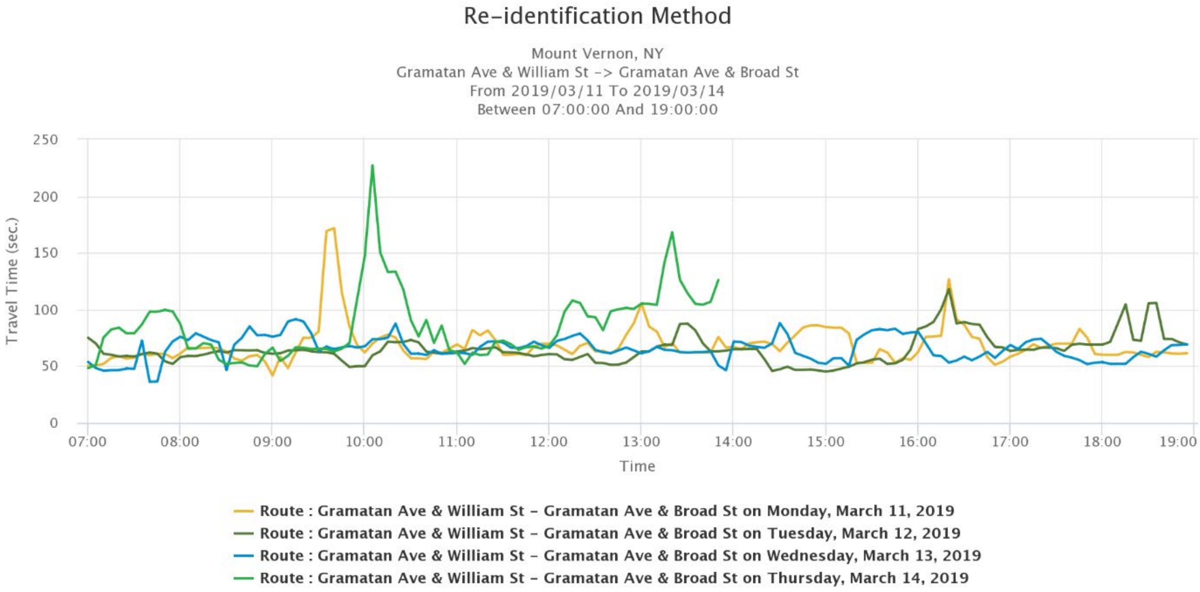


Figure 46 shows the travel time from Gramattan Ave to William Street for different work days of the week. This information is generated by Miovision technology for different segments of a corridor and for different time of the days of the week. This information shows how the travel time changes on different time of day, different days of a week, which is very useful for model calibration in the simulation process. Also, once the new signal timing is introduced and implemented, it can show how the travel time changes both in terms of the mean and the standard deviation.

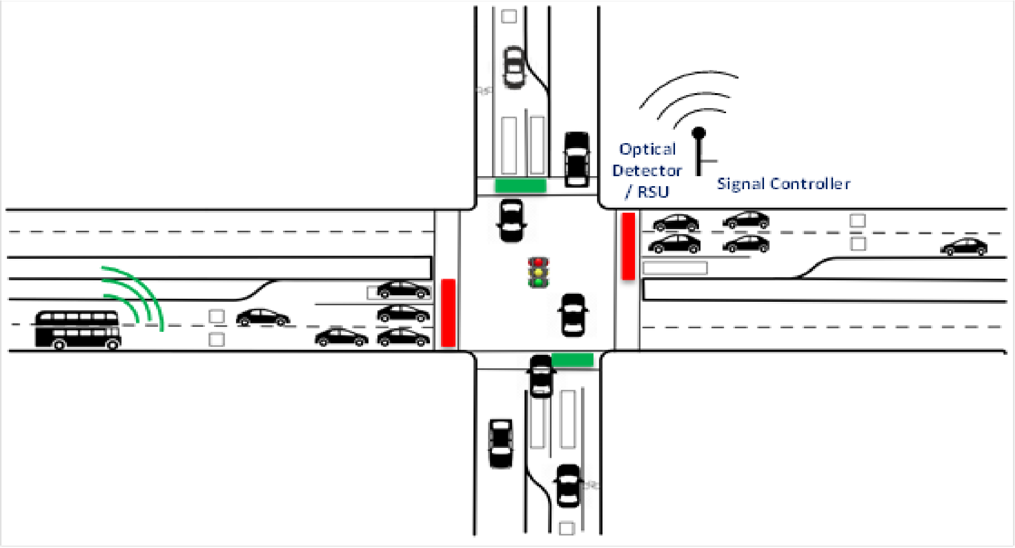
7 Pilot Test of the Optimization Scenarios

In the following sections, three different traffic operational scenarios are utilized to analyze the performance of a corridor. These scenarios are: (1) transit signal priority, (2) transit bus stop location, and (3) parking restriction.

7.1 Scenario 1: Transit Signal Priority

Utilizing connected vehicle technologies, vehicles can communicate with the infrastructure (V2I), through DSRC. A roadside unit (RSU) is installed at the intersection to broadcast traffic signal status, receive messages from surrounding vehicles, and share controlling parameters to another intersection through peer-to-peer communication. This way, the signal control system can facilitate the movement of transit vehicle and reduce its travel time significantly. Figure 47 shows a framework of transit signal priority model.

Figure 47. Transit Signal Priority Framework

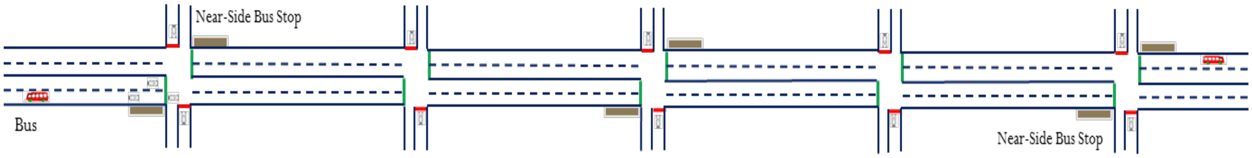


7.2 Scenario 2: Bus Stop Relocation

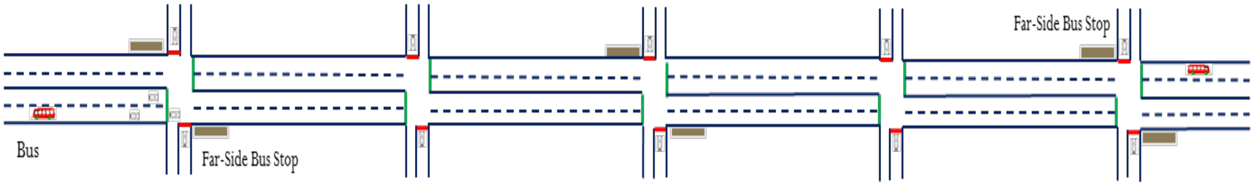
There are many bus stops located along Gramatan Avenue which are mostly near-side. In this scenario, the near side bus stops have changed to far-side bus stops. Figure 48 shows the schematic location of near-side and far-side stops along a corridor.

Figure 48. Bus Stop Location Scheme:

a) near-side bus stop versus



b) far-side bus stop



7.2.1 Simulation Results: Bus-Stop Relocation Strategy

Table 9 below shows the result of applying a bus-stop relocation strategy, relocating from a near-side to far-side stop. To evaluate the performance of this strategy, actuated-coordinated signal control with near-side and far-side was simulated in VISSIM. Simulation results have shown that vehicular delay has not changed much; however, the bus delays have significantly decreased (38.2 percent) on the Northbound (NB) and increased by a small fraction (6.3 percent) on the southbound (SB).

Table 9. Bus Stop Relocation Strategy/Relocating Stops from Near-Side to Far-Side

	Average Vehicular Delay	Average Bus Delay
	NB	SB
Base Act-Coord	21.48	53.49
Act-Coord with Bus Stop Relocation	20.44	53.96

However, the performance of bus stop relocation strategy can be further improved together with applying transit signal priority.

7.2.2 Bus-Stop Relocation Plus Transit Signal Priority (TSP)

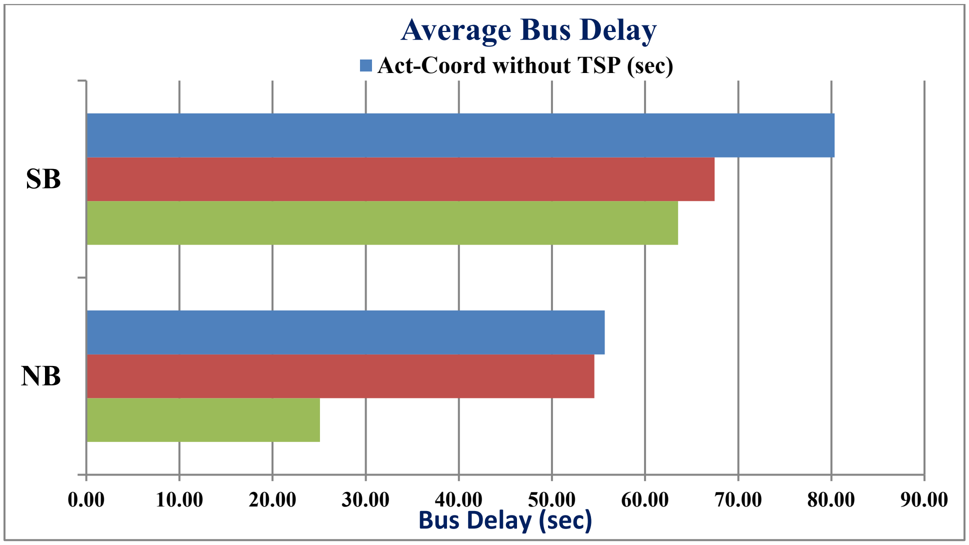
The VISSIM microscopic traffic simulation model has shown (see Table 10) that applying transit signal priority has further improved the bus-stop relocation strategy. The average bus delay reduced from 55.68 and 80.34 seconds to 25.08 (55 percent reduction) and 63.53 (20.9 percent reduction) seconds for the eastbound and westbound direction, respectively. It is further noted that the observed significant bus delay reduction did not impose a substantial negative impact on the general vehicular traffic delay.

Table 10. Average Vehicular Delay and Bus Delay Utilizing the Bus-Stop Relocation and Transit Signal Priority Strategy

	Average Vehicular Delay		Average Bus Delay	
	NB	SB	NB	SB
Base Act-Coord	21.48	53.49	55.68	80.34
Act-Coord with Only Bus Stop relocation	20.44	53.96	34.42	85.42
Act-Coord with TSP & Stop Relocation	19.00	50.21	25.08	63.53

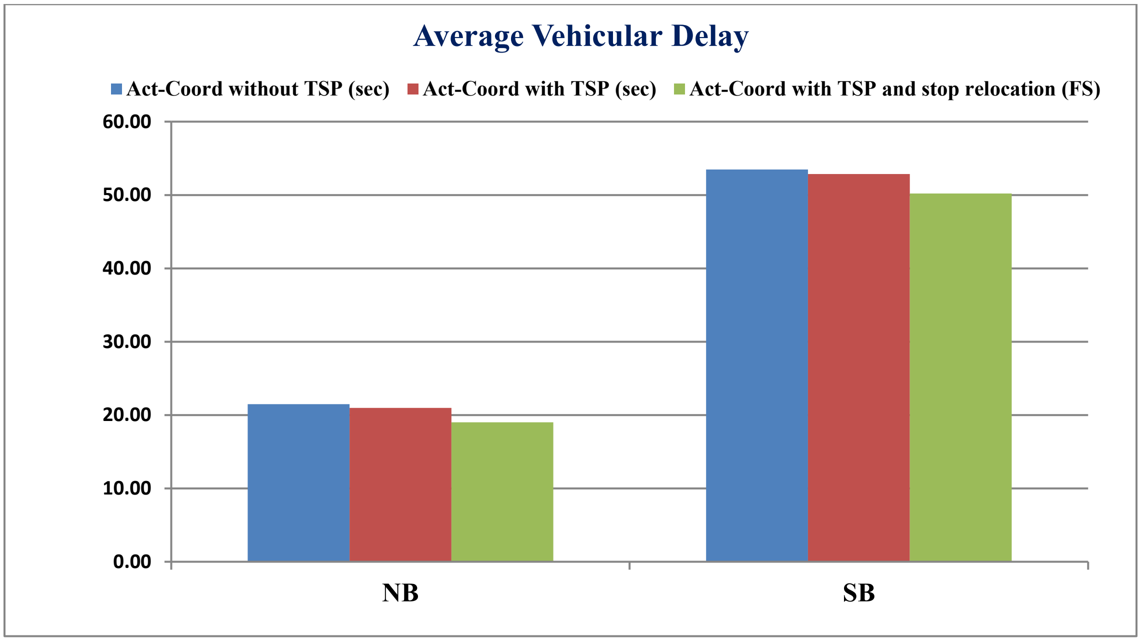
This section presents a comparative analysis of three models that utilized the Actuated Coordination Control (Act-Coord) model: The first model providing the best signal optimization which was reached from the previous section is the optimized Act-Coord model without transit signal priority. The second model is an optimized Act-Coord with transit signal priority (Act-Coord with TSP). The third model is an optimized Act-Coord model with transit signal priority together with bus stop relocation scenario (Act-Coord with TSP and Bus-Stop relocation).

Figure 49. Average Bus Delay of Three Scenarios in NB and SB Directions



It was observed (see Figure 50) that the average bus delays were reduced significantly when transit priority was applied, both on the northbound and southbound directions. Bus delays in the southbound direction were reduced from about 80 seconds from the Act-Coord without TSP to 67 seconds by the Act-Coord with TSP and were further reduced to 63 seconds when bus stop relocation was applied together with TSP, for an overall reduction in bus delay of (21.3 percent). The same pattern in bus delay reduction has been observed on the northbound direction, where the corresponding bus delays were reduced from 55 seconds (Act-Coord model) to 25 seconds utilizing the final model (Act-Coord with TSP and Bus-Stop relocation), for an overall reduction of (54 percent).

Figure 50. Average Weighted Vehicular Delay in Three Scenarios on NB and SB Directions



7.3 Scenario 3: Parking Restrictions on Gramatan Avenue

7.3.1 Restricted Northbound (NB) Parking Scenario

One approach to improve mobility and reduce congestion in urban areas is to increase the capacity of the road by restricting parking on one or both sides of the roadway. In this section, the eastern side of Gramatan Avenue has been restricted for parking and, therefore, one lane has been added to the northbound direction, making the northbound street function as a two-lane street. In order to accommodate the changes in the simulation network, all entry/exit connectors, paths, and bus routes are adjusted to work with the added lane. The simulation of this scenario runs for 13 hours, from 6:00 a.m. to 7:00 p.m. The simulation results of the Restricted NB Parking scenario, versus the base calibrated model (Base Model one lane per approach) are presented in Table 11 below.

Table 11. Base Model versus Restricted NB Parking (Gramatan Avenue)/Average Delay (seconds)

		Base Model	Restricted NB Parking
Average Vehicular Delay	North Bound	37.98	32.49
	South Bound	85.70	76.59
Average Bus Delay	North Bound	58.36	57.22
	South Bound	115.22	107.28

Utilizing the new scenario (Restricted NB Parking), the average vehicular delays were significantly reduced from 37.98 seconds to 32.49 seconds (15 percent) on the northbound; delays were reduced from 85.7 seconds to 76.59 seconds (10 percent) on the southbound direction, from the Base Model to the Restricted NB Parking model, respectively. The corresponding bus delay was slightly improved for both the northbound and southbound direction. Further, the average intersection delays were reduced with the introduction of the parking restriction scenario. Table 12 illustrates how the average intersection delays were significantly reduced at each signalized intersection, reaching up to 22 percent improvement.

Table 12. Base Model versus Restricted NB Parking Model: Average Intersection Delay (Seconds)

	Base model	Restriction on NB Parking	Rate of change
1st Street	18.67	14.50	22.3%
Fiske Place	14.15	13.92	1.6%
East Prospect	13.60	12.84	5.6%
Sidney Ave	17.73	13.97	21.2%
Oakley Ave	13.24	12.46	5.9%
Sum of delay	**77.38**	**67.69**	**12.5%**

7.3.1.1 Restricted NB Parking—Environmental Impact Analysis

The results of the environmental analysis (GHG and fuel consumption) using the corresponding VISSIM models are summarized in Table 13 and Figure 52 . The CO emissions has improved from 29,654 grams (gr) to 27,543 gr (7.1 percent reduction); NOx was reduced from 5,770 gr to 5,359 gr; VOC was reduced from 6,873 to 6,383 gr; and the fuel consumption has reduced from 424 to 394 liquid gallons. It is noted that the parking demand and its circulation to parking in the vicinity was not included in the simulation run, which would have worsened the Base model. However, such analysis could be undertaken in the future as it is an additional component of traffic congestion in urban areas.

Table 13. GHG Emissions (Grams) and Fuel Consumption (Liquid Gallons): Restricted NB Parking Scenario

	CO	NOx	VOC	Fuel Consumption
Base Model	29,654	5,770	6,873	424
Restriction on NB Parking	27,543	5,359	6,383	394

7.3.2 Restricted Southbound (SB) Parking Scenario

In this section, the western side of Gramatan Avenue has been restricted for parking which added one lane to the southbound direction, thus, enabling the southbound street to function as two lanes. Accordingly, all entry/exit connectors, paths, and bus routes have been adjusted to comply with the introduced modification. The simulation was executed for the same 13-hour time period from 6:00 a.m. to 7:00 p.m. and the corresponding summary results are depicted in Table 14.

Table 14. Base Model versus Restricted SB Parking (Gramatan Avenue)/Average Delay (Seconds)

		Base Model	Restricted SB Parking
Average Vehicular Delay	**North Bound**	37.98	35.70
	South Bound	85.70	52.14
Average Bus Delay	**North Bound**	58.36	57.44
	South Bound	115.22	83.63

Similar to the NB direction results, the restricted SB parking scenario of Gramatan Avenue, depicted a reduction in the average vehicular delays, from 37.98 seconds to 35.7 seconds on the northbound direction, and from 85.7 seconds to 52.14 seconds on the southbound direction. In addition, the reduction on the bus delays have been significant in the SB direction, dropping from about 115 seconds (Base Model) to about 84 seconds (Restricted SB Parking Model). Further, the corresponding bus delays were marginally reduced in northbound direction.

Correspondingly, the average intersection delays were also improved by implementing a parking restriction on the SB direction of Gramatan Avenue. Table 15 shows the average intersection delay of this scenario as compared to the base scenario. Four out of five intersections depicted reduced delays, where the overall delay reduction percentage for all five intersections was near 18 percent.

Table 15. Base model versus Restricted NB Parking (Gramatan Avenue)/Average Intersection Delay (Seconds)

	Base model	Restriction on SB Parking	Rate of change (%)
1st Street	18.67	19.00	-1.8%
Fiske Place	14.15	11.17	21.1%
East Prospect	13.60	11.00	19.1%
Sidney Ave	17.73	11.59	34.7%
Oakley Ave	13.24	10.82	18.2%
Sum of delays	77.38	63.58	17.8%

In parallel, the corresponding environmental analysis (GHG and fuel consumption) was undertaken as well to evaluate the performance of SB parking restriction. Table 16 Figure 53and Figure 60 summarize the environmental impact of the SB parking restriction for the south section of Gramatan Avenue. Utilizing new SB parking restriction scenario, CO was improved from 29654 gr to 26876 gr, NOx (5770 to 5229 gr, 9.4 percent reduction), VOC (6873 to 6229 gr), and the fuel consumption improved from 424 to 384 liquid gallons. Such a reduction confirms the benefit of parking restrictions in terms of emission and fuel consumption.

Table 16. GHG Emissions and Fuel Consumption: Restricted SB Parking Scenario

	CO	NOx	VOC	Fuel Consumption
Base Model	29654	5770	6873	424
Restriction on SB Parking	26876	5229	6229	384

7.3.3 Restricted Southbound (SB) and Northbound (NB) Parking Scenario

In this section, both the NB and SB of Gramatan Avenue have been restricted to parking, resulting in a four-lane roadway (two lanes per direction). Table 17 depicts the comparative analysis of the two-lane roadway (original base model) versus the new four-lane roadway in terms of average vehicle and bus delays, below.

Table 17. Base Model versus Restricted SB and NB Parking (Gramatan Avenue); Average delay (second)

		Base Model	Restricted NB & SB Parking
Average Vehicular Delay	**North Bound**	37.98	32.05
	South Bound	85.70	51.04
Average Bus Delay	**North Bound**	58.36	49.36
	South Bound	115.22	83.83

As predicted, the increase in capacity reduced traffic congestion and demonstrated substantial decreases in both vehicle and bus delay. Noteworthy, the average vehicle delay was reduced from 37.98 seconds to 32.05 seconds on the NB direction and from 85.7 seconds to 51.04 seconds on the SB direction. Similarly, the bus delays were reduced from 58.36 seconds to 49.36 seconds on the NB and from 115.22 seconds to 83.83 seconds on the SB.

The corresponding environmental analysis (GHG emissions and fuel consumption) for this scenario showed parallel results to the vehicular and bus delay. The results of the environmental analysis as estimated by the corresponding VISUM model are summarized in Table 18.

Table 18. GHG Emissions and Fuel Consumption: Restricted SB and NB Parking Scenario

	CO	NOx	VOC	Fuel Consumption
Base Model	29654	5770	6873	424
Restriction on NB-SB Parking	25430	4948	5894	364

The corresponding % reduction from the Base model to the Restricted SB and NB parking model in GHG are: CO (14.24 percent), NOx (14.24 percent), and VOC (14.24 percent). Similarly, the corresponding fuel consumption reduction was 14.15 percent.

The above results on the impact of parking restrictions in favor of increasing the travel through lanes— thereby favoring vehicular travel—were provided for illustration on how the traffic simulator could be used to evaluate various scenarios that the city engineers and planners could propose as well as politicians and other stakeholders. It is worth noting that parking restriction could cause negative impacts like attracting more trips from latent demand (potential trips constrained by congestion). Moreover, parking restriction could cause speeding problems in urban settings, imposing safety concerns to peds/bikes. Other potential scenarios could include the utilization of the parking lanes for pedestrians, micro-mobility vehicles (bicycles, scooters etc.), and exclusive bus lanes.

8 Travel Time and Vehicle Counts Comparison: Pre-COVID-19 and During COVID-19 Pandemic

While the COVID-19 pandemic certainly presents its challenges to the global community, including planned efforts under this project, it presented a unique opportunity to pivot the way we evaluated the data collected as part of this effort and further highlight the importance of the virtual aspects of this project, which allowed for continuation of operations despite the shutdown and restrictions.

In this section, a comparative analysis of travel time and vehicle counts is performed for pre-COVID-19 and during COVID-19 pandemic. The data was extracted from the Miovision platform covering the period from March 1 to September 28 for years 2019 and 2020, respectively. The comparisons are in the form of the mean of the travel time and vehicle daily counts for the periods before COVID-19 and during COVID-19 throughout different phases of the pandemic. The comparison is for both northbound and southbound directions in various times during the day (AM, PM, and MD).

8.1 Hourly Mean of Travel Time Median

In this subsection, the mean of the travel time median is compared on an hourly basis.

Figure 51 shows the hourly mean of the travel time median of Gramatan Avenue, from Fiske Street to Oakley Street, for weekdays (a) and weekends (b). The mean was estimated using data from March 1 to September 28, for the year 2019 and 2020, respectively. As shown in Figure 54, the mean travel time during the pandemic is consistently below that of the pre-COVID-19 value, and this, for each hour of the day. The same conclusion is observed on Gramatan Avenue from Oakley to Fiske; see Figure 52.

Figure 51. Fiske Place to Oakley Street Hourly Mean of Travel Time Median from March 1 to September 28, 2019 and 2020

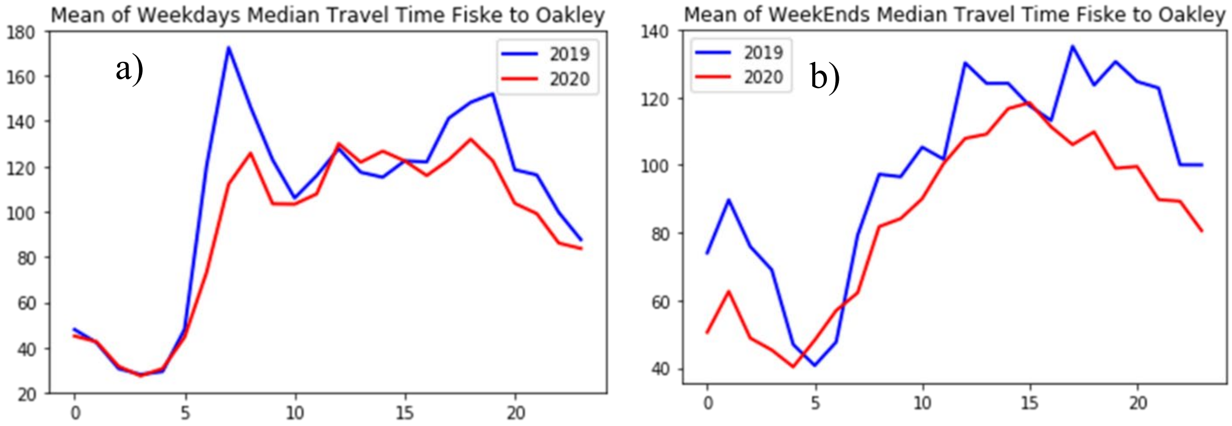


Figure 52. Oakley Street to Fiske Place Hourly Mean of Travel Time Median, from March 1 to September 28, 2019 and 2020

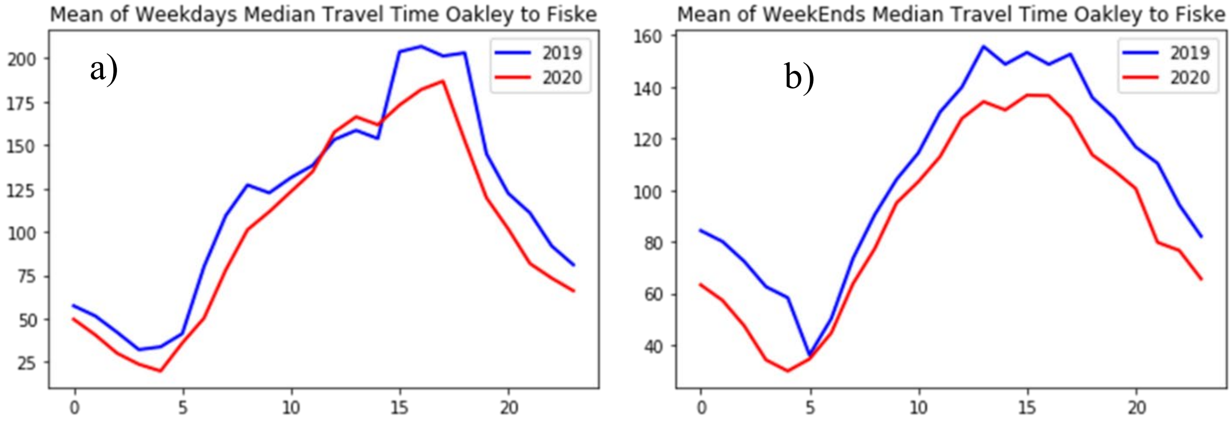


Table 19 shows the travel time statistics comparison for pre-COVID-19 and during COVID-19, broken by time periods am-peak, pm-peak, off-peak and midday-peak (mid-peak). As it can be observed, the mean and standard deviation consistently dropped in 2020, for all time periods resulting from the reduction in the traffic volume along the corridor.

Table 19. Peak Period Travel Time Statistics Comparison: Pre-COVID19 in 2019 and COVID19 in 2020

	AM_PEAK		PM_PEAK		OFF_PEAK		MID_PEAK	
	2019	2020	2019	2020	2019	2020	2019	2020
mean	124.83	102.04	120.24	117.92	87.9	74.31	119.35	117.82
std	85.66	74.9	71.41	68.67	88.39	81.95	100.62	71.14
min	0	0	15	0	0	0	0	0
25%	64	50	78	79	30	0	76	79
50%	96	90	101	105	68	55	97	107
75%	156	123.25	132	135	120	107	128	134
max	559	524	601	541	2630	601	2985	843

8.2 Hourly Mean of Travel Time Median: Based on COVID-19 Opening Phases

In this section, the hourly mean of the travel time median is analyzed for each COVID-19 opening phases. Phase 1 spanned from June 8 to June 21 2020, Phase 2 spanned from June 22 to July 5, 2020, Phase 3 spanned from July 6 to July 19 2020, Phase 4 started from July 20 until the next lockdown. We compared the travel time during these phases with the travel time during these same times in 2019. Figure 53 shows the mean of hourly travel time median, of Gramatan avenue from Fiske to Oakley broken down per each phase. The mean hourly travel time of Phase 1 is clearly below that of its corresponding counterpart in 2019. As we move from Phase 1 to phase 4, we observe that the travel time during the pandemic slowly takes over the pre-COVID travel time:

- In Phase 1 few businesses were allowed to open: construction, agriculture, forestry, fishing, hunting, manufacturing, etc. resulting in few vehicles on the roads and speed increases and travel time decreases.
- In Phase 2 and Phase 3 the travel time during the pandemic is greater than the pre-COVID travel time, from 12 p.m. to 4 p.m.
- In Phase 4 the travel time during pandemic is greater than the pre-COVID travel time from 12 p.m. onwards.

As more businesses reopened during Phases 2, 3 and 4, we observe more congestion, hence, travel time increases. Of particular note is the increase in travel time of Phase 4—compared to the corresponding one of 2019—which supports the theory that more people were traveling in single occupancy, privately owned vehicles, rather than higher exposure modes such as ridesharing and using mass transit.

Figure 53. Fiske Place to Oakley Street Hourly Mean of Travel Time Median, Broken Down by Phases

The observation for Fiske to Oakley travel direction is the expected one. However, for the southbound direction, Oakley to Fiske, we observed an abnormal situation. As shown in Figure 54, from 10 a.m. to about 7 p.m., we observe a surge in travel time during phase 1 and phase 2; the same observation is made from 10 a.m. to about 4 p.m., during phase 3. During phase 4, the mean travel time in 2020 was almost the same as that of 2019. The rise in travel time on the southbound, Oakley to Fiske, can be accounted by the fact that, more vehicles travel on the southbound as compared to the northbound direction, Fiske to Oakley.

Figure 54. Oakley Street to Fiske Place (SB) Hourly Mean of Travel Time Median, Broken Down by Phases

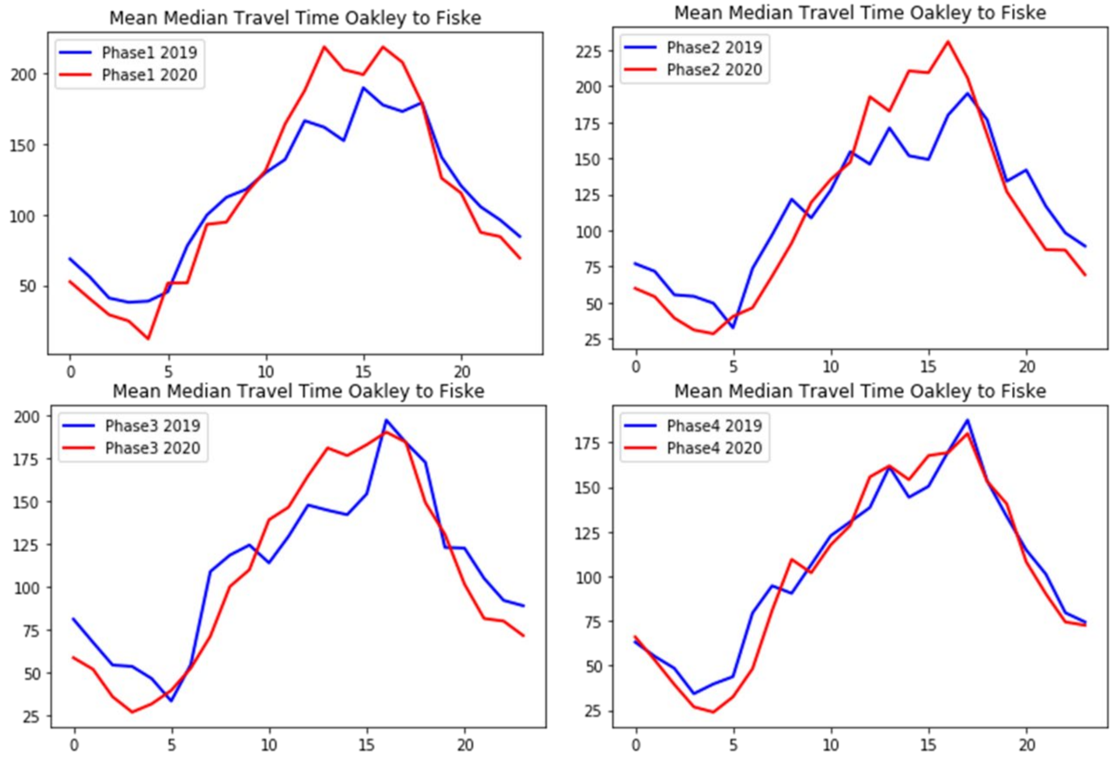
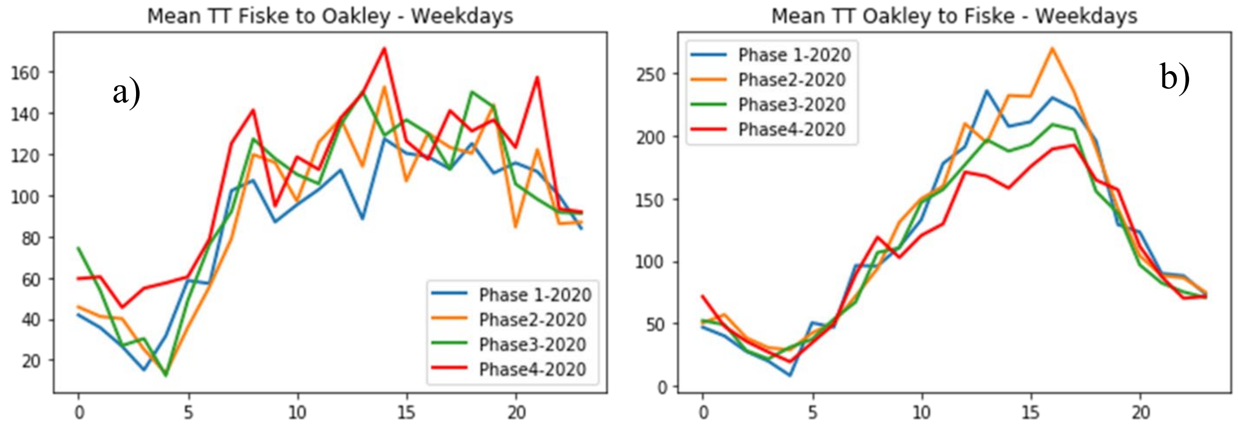


Figure 55 shows the weekdays hourly mean of travel time median, for each phase, for Fiske to Oakley (a) and Oakley to Fiske (b). The direction from Fiske to Oakley, the travel time tends to increase as the phase number increases, which is what is normally expected, as compared to the abnormality observed in the Oakley to Fiske direction.

Figure 55. Weekdays Hourly Mean of Travel Time Median, for Each Phase



8.3 Vehicle Daily Counts

Figure 56 shows the vehicle daily counts for intersection at Gramatan Avenue and Fiske Street, North-East, North-South, South-East, and South-North direction. As observed, most of vehicles flow through the main direction, North-South and South-North. At Gramatan Avenue and Fiske Street intersection, the vehicle count drastically decreases by about 96 percent, during the Phase 1 lockdown, for the North-East direction, and by about 98 percent for the South-East direction, and 99 percent for the West-East direction. For other directions, namely, North-South, South-North, West-North and West-South, the decrease was not as noticeable. On the contrary, at some directions like West-North, the vehicle count is even higher during the phase 1 lockdown than during the same time in 2019. This is probably due to a road closure in the Eastern direction. See Figure 58. The road closure rerouted the vehicles along other routes.

Figure 56. The Vehicle Daily Counts for Fiske Place; NE, NS, SE, and SN Directions

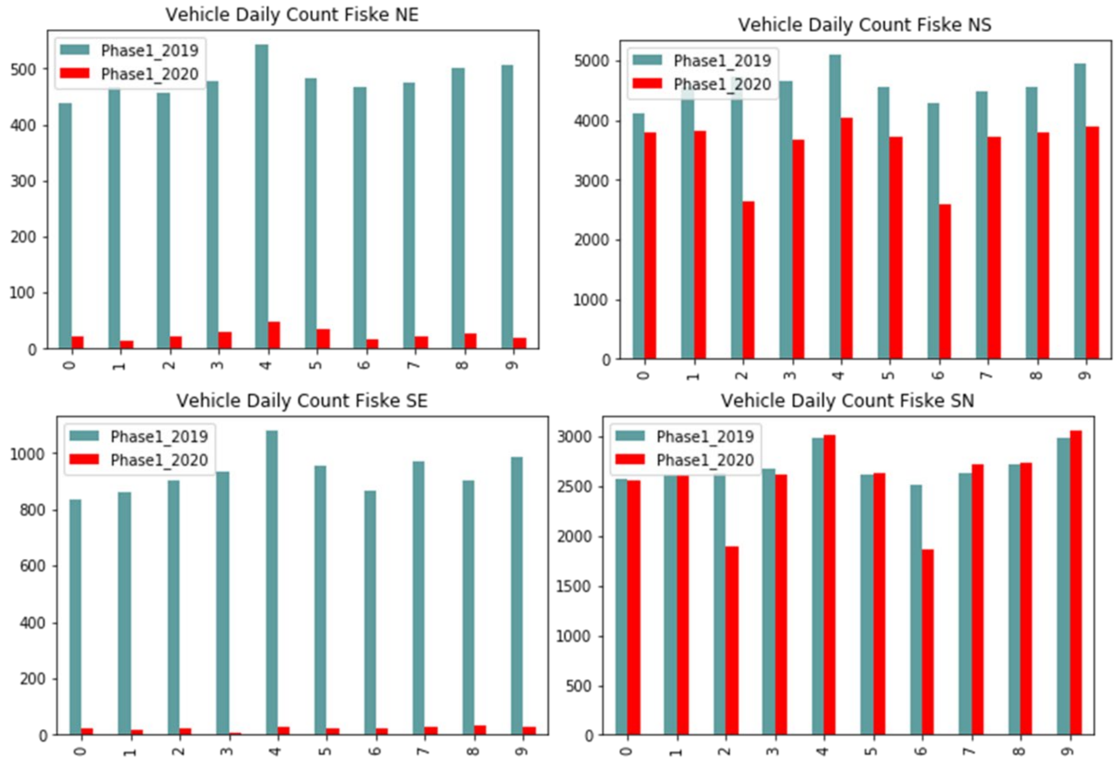


Figure 57. The Vehicle Daily Counts for Fiske Place; WE, WN, and WS Directions

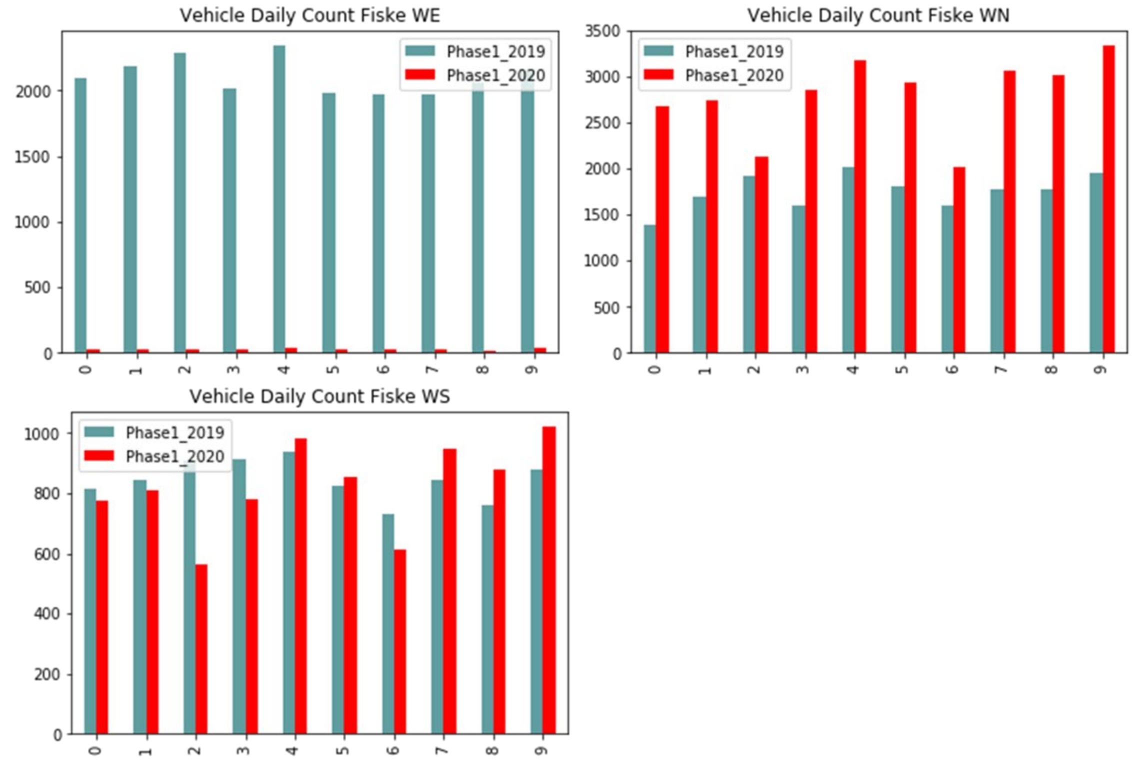


Figure 58. Map of Study Locations Going from Oakley Street to Fiske Place through Sydney Avenue and Prospect Avenue Intersections

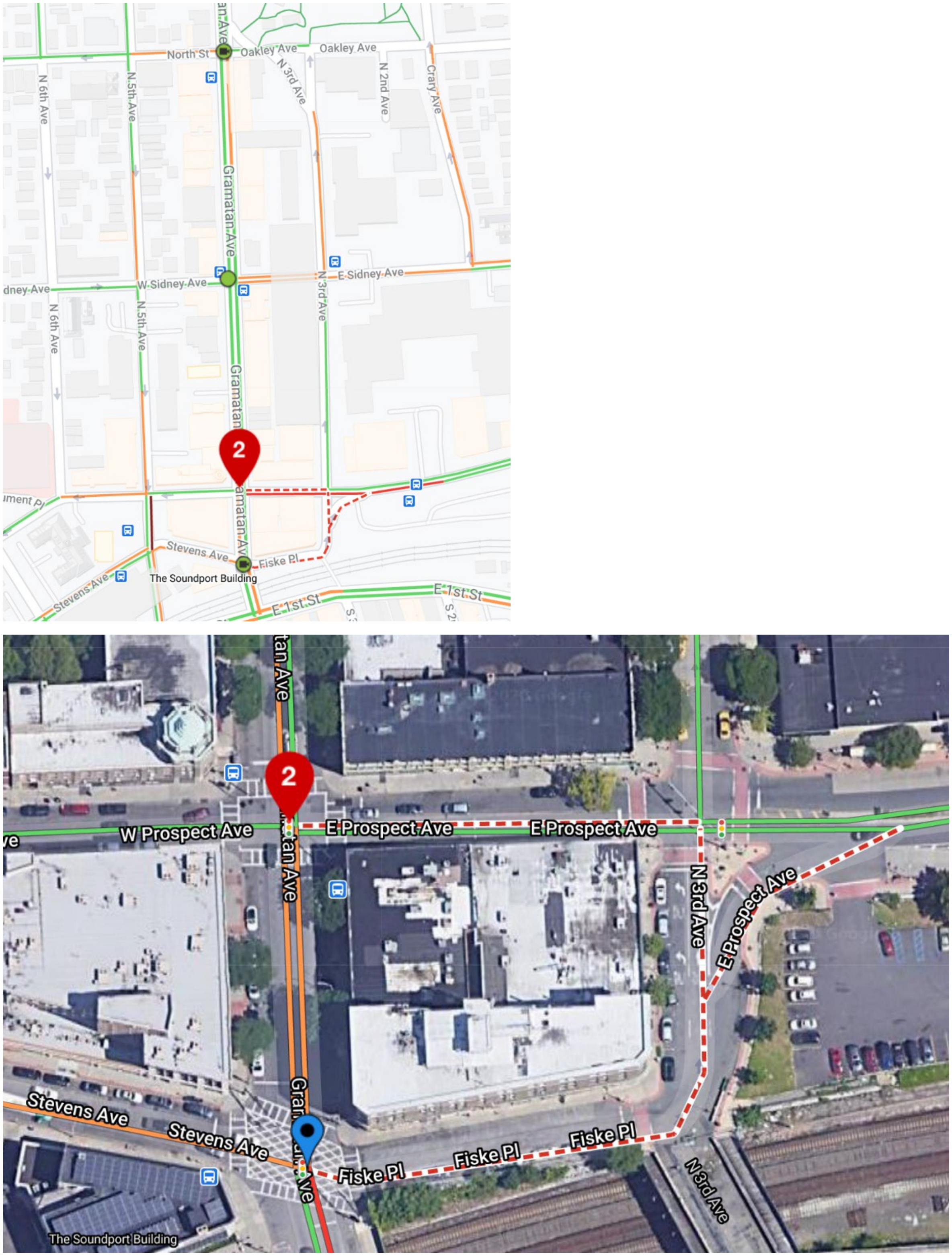
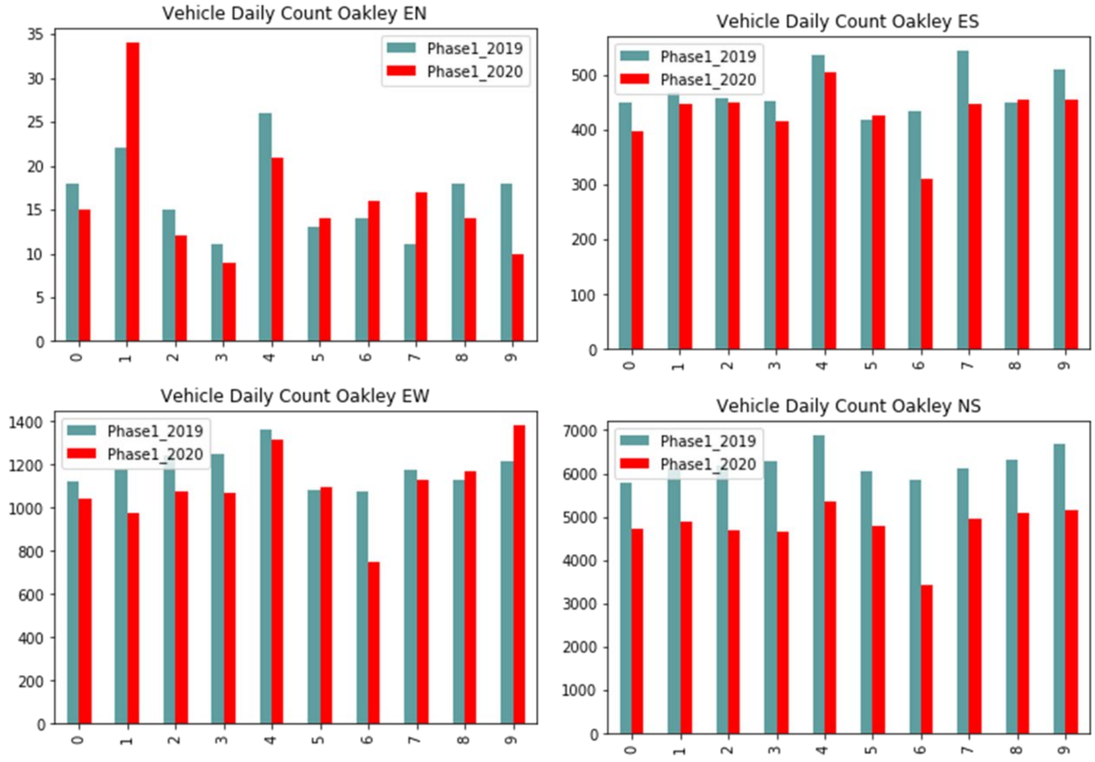


Figure 59 shows the vehicle daily counts for the intersection at Gramatan Avenue and Oakley Street, East-North, East-South, East-West, and North-South, North-West, South-North and South-West directions. As observed, most of vehicles flow through the main directions, North-South, and South-to-North. In contrast to the Fiske intersection, the decrease in vehicle count during Phase 1 lockdown was not as high at Oakley. This reinforced the idea that a huge part of the vehicle count decrease at Fiske was mainly due to the surrounding road closures. The decrease of vehicle count due to the pandemic lockdown can be estimated from the North-South and South-North direction at Oakley, which are the main travel directions. In the North-South direction, we observed a decrease of about 32 percent and about 25 percent decrease in the South-North direction. We also depicted an obvious outlier day at Oakley, June 12, 2020, in the North-West direction.

Figure 59. The vehicle daily counts at Oakley Street; EN, ES, EW, and NS directions



Vehicle Daily Count Oakley EN

Vehicle Daily Count Oakley ES

Vehicle Daily Count Oakley EW

Vehicle Daily Count Oakley NS

Figure 60. The Vehicle Daily Counts at Oakley; NW, SN, and SW Directions

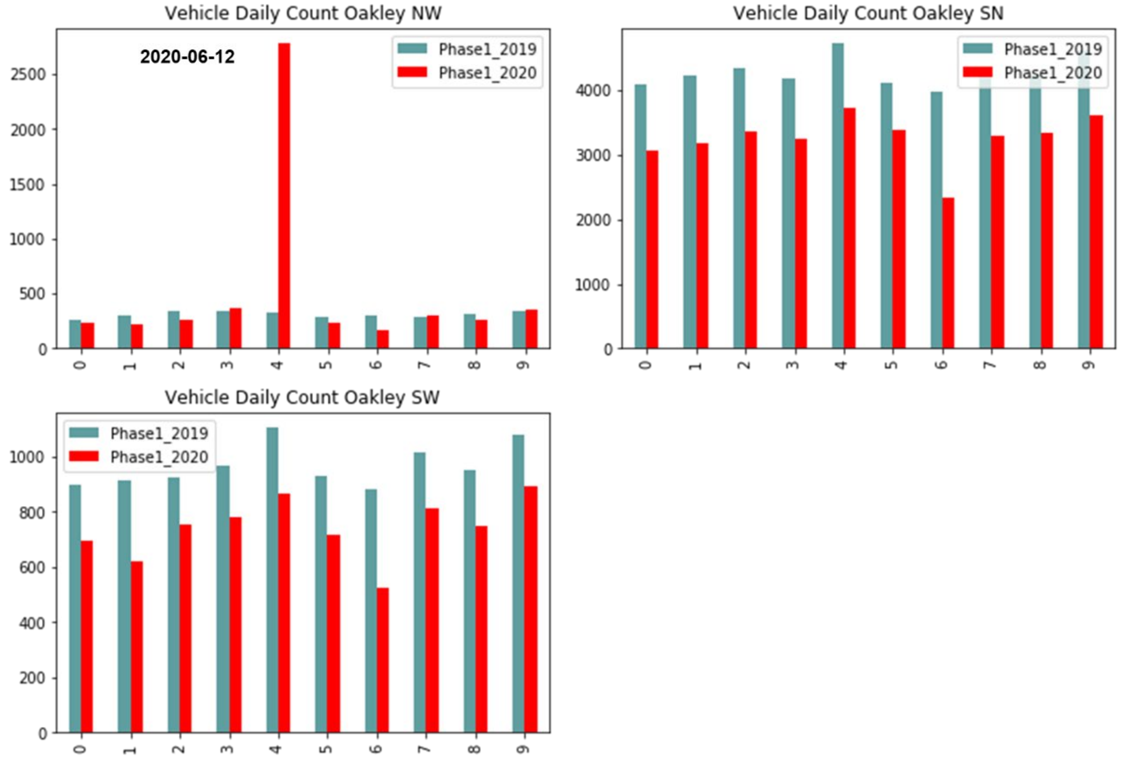


Figure 61 shows the vehicle count comparison for Phase 1 to Phase 4 at Fiske, North-East, North-South, South-East, and South-North directions. As mentioned previously, in order to check the effect of the phases' lockdown to the vehicle count, the focus should be on the main direction, North-South and South-North. As observed in the main directions, the vehicle count increases as the lockdown gets released from Phase 1 to Phase 4.

Figure 61. Vehicle Count Comparison for Phase 1 to Phase 4 at Fiske Place; NE, NS, SE, and SN Direction

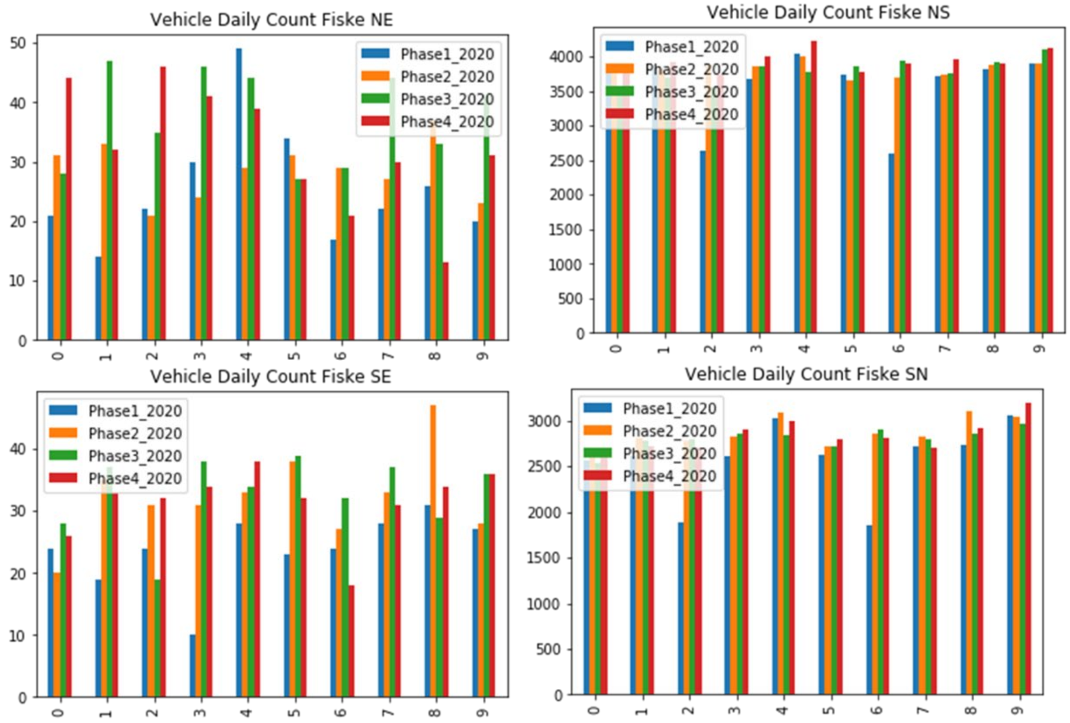
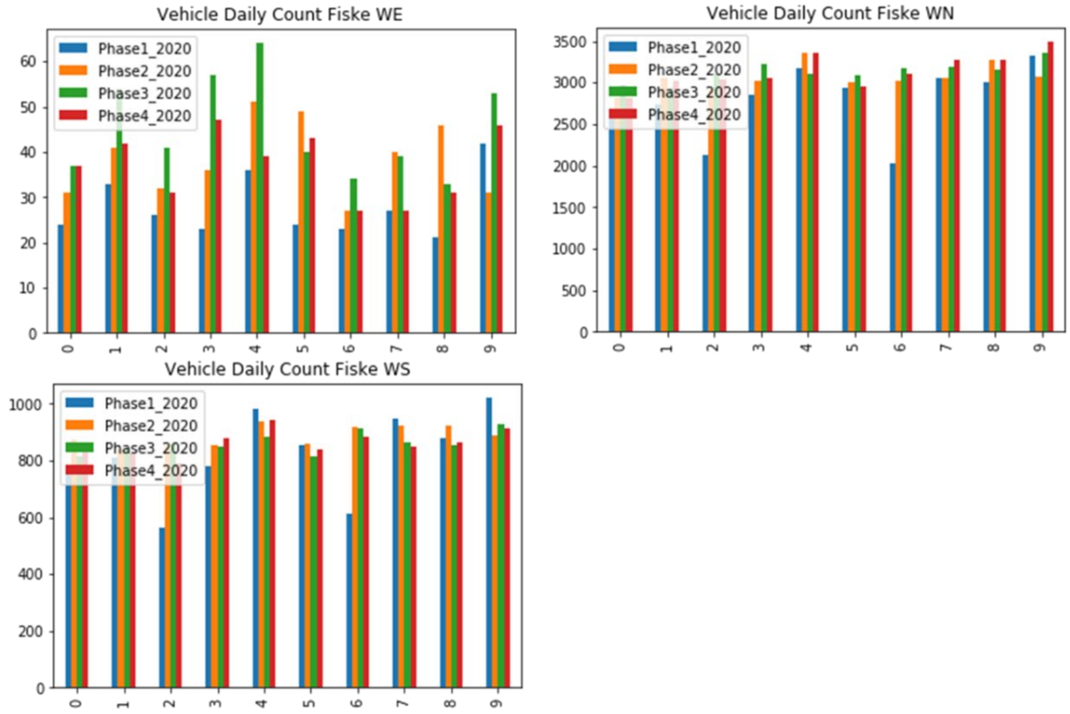


Figure 62. Vehicle Count Comparison for Phase 1 to Phase 4 at Fiske Place; WE, WN, and WS Directions



9 Conclusion

9.1 Summary

The main objective of this project was to design a Virtual Traffic Management system and implement it in the City of Mount Vernon to demonstrate its main characteristics, while experiencing the various institutional issues in implementing these technologies. During the performance of this project, the project team has brought together government agencies, private technology providers, and an academic institution to design, implement, and demonstrate the VTM strategy for the City of Mount Vernon. This project tried to highlight the benefit of considering smart technologies to actively control a medium size jurisdiction's traffic operation and monitor ITS components.

The main characteristics of the VTM as implemented at the City of Mount Vernon are the following:

- The virtual monitoring of various sensors and real-time traffic flow model implementation based on the prevailing traffic flow conditions (using the various traffic flow sensors), including the monitoring of various components of the traffic control systems.
- The off-line/online monitoring of traffic flow conditions for research purposes and subsequent recommendations to make changes to the corresponding models of the VTM.

Active traffic management includes a broad array of nontraditional solutions that cities can deploy to increase the efficiency of their transportation systems. Utilizing advanced transportation management systems, which provide capability to move from static approaches to more actively and dynamically managed traffic operations, cities can improve the efficiency of their transportation network. As demonstrated in the City of Mount Vernon, by monitoring the arrivals and adjusting signal timings based on the detected inputs, the city's current traffic control systems have improved, both in terms of congestion mitigation and reduced traffic pollution as a direct result of the reduced vehicle delays and stops at intersections.

Traffic monitoring devices provided by Miovision and LTD & TSI have been installed at multiple intersections along the Gramatan Avenue corridor. The project team performed the assessment of traffic flow through the corridor by uploading traffic count data collected by the field devices and analyzing that data to provide better progression along the corridor. The installed systems feature a tool that allows for visualization of the performance of the corridor in terms of travel time, delay, and congestion. The remote monitoring capability of the devices installed along with the vehicle detection system allowed the team to understand the overall system performance for the Gramatan Avenue corridor. Unfortunately, with the COVID-19 pandemic, the project activities at the field were suspended and the project team relied solely on data collected and generated by the installed ATMS to perform the data analyses. To further demonstrate the functionality of the ATMS, the project team has simulated many traffic scenarios. These scenarios include controlling the corridor for different time of day plans, changing transit stop locations, applying transit signal priority, restricting parking lane on different approaches, etc. Any of these simulated scenarios can be tested quickly in the field with ATMS performance tools to evaluate for permanent or temporary operational treatments. Such tool enables the city to lively monitor the performance of traffic at different times and locations.

The main functions of the City of Mount Vernon VTM as implemented:

- Monitoring the status of each component of the system.
- Data gathering from the various sensors.
- Offline and online signal optimization.
- Offline and online data warehousing and data analysis.

The main components of System Architecture are:

1. The Traffic Operations Center (TOC) is equipped with all necessary data processing and modelling hardware and software:
    - Hardware: communication system (wired, wireless), computers, data storage devices (on-site, Cloud?)
    - Software: VISSIM, VISTRO, SYNCHRO, data gathering/warehousing/processing
2. The TOC is connected to the field traffic control devices through a hybrid wired and wireless communication system: co-axial, fiber optic, Wireless (cell phone based).
3. The field components of the TOC include: the corresponding communication system (see item 2 above), the traffic flow sensors, the traffic controllers, and the signal timing.

The City of Mount Vernon VTM installed and utilized the following sensors (and estimated the corresponding traffic flow parameters):

1. Miovision:
    - Intersection overhead 360 cameras: traffic flow—vehicles (passenger cars, buses, trucks), pedestrians, bicyclists, per movement (vph), occupancy (vpm), queue length (vehicles), delay (seconds).
    - Intersection Wi-Fi sensors: vehicle probe-based travel time/speed: Link-based, path-based.

2. LTD and TSI:
    - Sensys in-pavement wireless vehicle detection system (detect vehicle presence and movement): traffic flow—vehicles (passenger cars, buses, trucks), pedestrians, bicyclists, per movement (vph), saturation flow rate (vph), occupancy (vpm), queue length (vehicles), number of stops, Delay (seconds), Pedestrian delay (seconds), approach speed (vph), arterial travel time (minutes), vehicle trajectories

The research team of CCNY in cooperation with Colliers Engineering & Design CT, P.C. implemented the following software along the Gramatan Avenue corridor: The microscopic traffic simulator PTV VISSIM that was utilized to simulate the following scenarios, where the PTV VISTRO and SYNCHRO were utilized to estimate the capacity and level of service (LOS) and optimize the signal timing. The research team conducted the following scenarios: Transit Signal Pre-emption (TSP), Bus-stop Relocation (near-side, far-side), Bus-stop relocation plus TSP, Parking restrictions in combination with increases in the number of travel lanes. The research team utilized the data gathered by the implemented technologies of Miovision and LTD, Google API travel time data and manual traffic counts to calibrate the abovementioned software.

Unfortunately, due to various issues, adjustments were not made to the existing timings during the project. Ultimately administrative challenges between the project team, local agency, and the consultant/vendor used for timing adjustments didn’t permit new timings to be implemented as part of this research effort. Namely, the uncertainty in the variability of the data given the COVID-19 pandemic occurring amidst the project timeline and not being representative of stable traffic conditions was cause for concern amongst stakeholders.

With the COVID-19 pandemic, the project team was not able to perform all the tasks that were initially anticipated. However, data collected during the pandemic has provided a unique opportunity to perform a quick before (COVID-19) and after (COVID-19) analysis of the impact of the COVID-19 pandemic at the Gramatan Avenue corridor and demonstrate once of the functionalities of the VTM. The vehicle counts were drastically decreased during the height of the pandemic compared to the same period for the previous year. The reduction in vehicular counts has brought some positive effect in terms of improved traffic flow, reduced delays, congestion, and emissions from vehicles.

9.2 Recommendations

9.2.1 VTM System Architecture

The principal functionality of the system architecture of VTM once fully implemented is envisioned to offer:

1. Online monitoring of the status of each component of the system:
   - Computing hardware
   - Communication system
   - Sensors
   - Computing software
2. Online data gathering from various sensors:
   - Infrastructure based: video cameras, inductive loop detectors, radar detectors, air quality sensors, parking sensors, flooding sensors, other,
   - Automated vehicle location sensors: (GPS, low jack, other)
3. Offline and online data gathering, warehousing, analysis:
   - Data warehousing
   - Data analysis
   - Web data-analysis publications
   - Signal optimization
   - Scenario analysis

Research: The establishment of such a VTM offers the opportunity for research entities to gather data to calibrate existing models and assist in the evaluation of various scenarios, develop new models, and assist in the teaching environment using real data and real case studies in a synergy between the private and public sector.

9.2.2 Deployment of VTM

One of the objectives of this project is to evaluate the main characteristics of the ATMS through the demonstration and to provide some recommendations for its implementation to jurisdictions in New York State which are struggling with growing congestion and have fewer available funds to add roadway capacity and to develop a full-fledged transportation management center. Although the planned activities in the field were stopped with the COVID-19 pandemic, valuable insights were gathered during the preparation, selection, procurement, installation, and deployment of the technologies and discussions with the stakeholders. Following are some practical and technical considerations for the deployment of VTM systems based on information collected during the performance of this demonstration project, lessons learned from past ATMS implementation, and expert knowledge from the members of the project team.

- Planning for VTM deployment:
  - In order for the VTM to be successful, it requires the cooperation and partnership of the following stakeholders to work in a cooperative and synergistic manner: Public officials, engineers, planners, consulting firms, research entities, various special organizations, and the general public.
  - Due to budgetary constraints, several municipalities may not be able to install all the elements of a fully deployed VTM, therefore, an incremental approach can be planned and implemented.
  - A structured approach to the planning of VTM deployment is important in order to justify the transportation investment of the system. The planning process should start with a review of the existing traffic conditions that will lead to the development of needs and objectives. The development of a database to inventory traffic devices installed on the road network will also be helpful. Analysis should include a review of traffic volume data, variations over the day, principal land use (i.e., shopping, schools, etc.).
  - Budgetary considerations must be reviewed to ensure that the jurisdiction has adequate fund to sustain the deployment throughout its life cycle. They should consider both the short- and long-term financial implications of implementing VTM systems.
  - Involvement of other stakeholders in the planning process should be contemplated to gather other transportation needs from them. Stakeholders may include transit operators, commercial vehicle operators, public work, police, emergency services, public, etc.
- Establish VTM deployment goals and objectives that aim to provide a positive societal impact by improving safety, increasing the attractiveness of a community for business, encouraging a more balanced use of all modes of travel, reducing environmental and energy impacts by producing higher average network speeds and fewer stops.
- Pursue strong partnerships and relationships between government agencies with the technology providers to deliver VTM services as effectively and efficiently as possible giving the fact that many local jurisdictions lack the resources to hire and adequately train operational support staff to keep up with technology needs leaving much of this advanced equipment inadequately monitored and staffed. This will also facilitate engaging ITS experts to assist with strategy development. Emphasis should also be made for the intellectual property as collaboration with commercial vendors developing proprietary software, processes, and the collection of data may raise intellectual property and ownership issues.
- When deploying VTM strategies, it is suggested for jurisdictions to focus on strategies and products that are proven and readily available. Testing for the strategies should be rigorously performed before implementation. One should also contemplate phasing new strategies into current systems to minimize any disturbance the changes may create. A performance monitoring of the VTM strategies should also be considered in order to determine how well the strategies meet its initial goals and objectives.

- Promote the concept of open architecture and integration of new systems with legacy systems of field control equipment in use at signalized intersections. One should recognize that the field equipment represents a significant investment for a jurisdiction and emphasis must be to use new systems that will not necessarily require their upgrade. An open technology framework is important to prevent vendor lock-in and to also encourage further innovation and development for new applications and benefits going forward.
- Implementing VTM systems will require the deployment of complex hardware and devices. The jurisdiction should develop a full-maintenance program that incorporates maintenance life-cycle costs in order to protect the significant investment made and to ensure that it remains fully operational throughout the life of the systems.
- Jurisdictions are encouraged to seek collaboration with neighboring jurisdictions and other transportation agencies since congestion issues on roadway networks are not usually bound by the organizational or geographic boundaries. Many VTM strategies may benefit from or require data, cooperation, and agreements that span multiple jurisdictions and agencies. Jurisdictions may consider the use of pooled fund to procure VTM services for corridors that traverse multiple jurisdictions. They will need some degree of flexibility and autonomy in their procurement practices to pursue these innovative solutions.
- Furthermore, the establishment of synergism between the public agencies, the private sector, the research institutions, and the public under the umbrella of the VTM, can expand the capabilities of all these stakeholders to be up to date with the advancements in technologies and methods in order to make more informed decisions on the methods and technologies that will be best to implement.

Endnotes

[1] FHWA Briefing Room: U.S. Driving Tops 3.1 Trillion Miles In 2015, New Federal Data Show; www.fhwa.dot.gov/pressroom/fhwa1607.cfm

[2] 2019 Urban Mobility Report; https://static.tti.tamu.edu/tti.tamu.edu/documents/umr/archive/mobility-report-2019.pdf

[3] Freight Activity in the U.S Expected to Grow Fifty Percent by 2050; https://www.bts.gov/newsroom/freight-activity-us-expected-grow-fifty-percent-2050

[4] Traffic Signal Benchmarking and State of the Practice Report; https://transportationops.org/trafficsignals/benchmarkingreport/

[5] Mount Vernon Comprehensive Plan, November 2011

[6] Westchester County Association Announces Smart Tech Pact With Four Cities; https://dailyvoice.com/new-york/harrison/business/westchester-county-association-announces-smart-tech-pact-with-four-cities/684545/

[7] While initially planned, environmental sensors were not installed throughout the corridor to capture and demonstrate the potential to reduce transportation GHGs/energy consumption due to the cost and effort to install equipment and analyze captured data.

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and support to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

To learn more about NYSERDA's programs and funding opportunities, visit nyserda.ny.gov or follow us on Twitter, Facebook, YouTube, or Instagram.

New York State
Department of Transportation

50 Wolf Road
Albany, NY 12232

telephone: 518-457-6195

dot.ny.gov

New York State
Energy Research and
Development Authority

17 Columbia Circle
Albany, NY 12203-6399

toll free: 866-NYSERDA
local: 518-862-1090
fax: 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov

NYSERDA

Department of Transportation

State of New York
Kathy Hochul, Governor

New York State Energy Research and Development Authority
Richard L. Kauffman, Chair | Doreen M. Harris, President and CEO

New York State Department of Transportation
Marie Therese Dominguez, Commissioner