Final Report

New Jersey Traffic Signal Retiming

Broadway Road (CR 551)
Warren Street to Koehler Street

Prepared for:
Delaware Valley Regional Planning Commission (DVRPC)

And

Gloucester City, NJ

Camden County, NJ

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EXECUTIVE SUMMARY

Iteris, Inc. was contracted by the Delaware Valley Regional Planning Commission (DVRPC) through the New Jersey Traffic Signal Retiming Program to provide engineering services for the full retiming of nine intersections in Camden County, New Jersey on Broadway (CR 551). These signals are all located within Gloucester City, New Jersey. Imperial Traffic & Data Collection was a subconsultant on this project responsible for data collection.

Following the NJ Signal Retiming Regional Corridor Prioritization project completed in 2022, this signal system was identified to be a high priority corridor in Camden County utilizing a scoring system developed to rank signal systems throughout the region. The goal of the retiming program is to optimize signal timings along critical corridors given current conditions and utilizing existing equipment, with a focus on optimizing signal operations at the study intersections while considering all users of the system. This system was selected due to the density of signals on the network, the high heavy vehicle volumes and that this corridor is regularly utilized as a detour or diversion route when there are incidents Interstate 76/Interstate 676, which generally runs parallel.

Project Vision

- **Goal:** Optimize traffic operations and timings throughout the system utilizing existing equipment.
- **Goal**: Improve air quality through decreased motor vehicle emissions and fuel consumption.
- **Goal**: Improve reliability and predictability of travel along arterials.
- **Goal**: Improve the safety of motorists, pedestrians, and bicyclists.
- **Goal**: Identify equipment issues, report them to the maintaining agency and recommend improvements.

The majority of the traffic signals included in this project had not been retimed within the last 10 years according to the available documentation within the traffic cabinets and most were not operating as shown on the existing conditions timing directives. Several signals were running in free operation, or non-coordinated, and clocks were not consistent, so there was no signal timing coordination prior to this project along Broadway (CR 551). With the signal density in this area, the high percentages of buses and heavy vehicles, along with the volume growth that has occurred over that time, coordinated signal timings along this network is clearly appropriate as it provides progression between signals for high volume movements. There is significant commuter traffic, largely driven by the shipping port just north of the system, along with heavy pedestrian volumes on this system, also making this a high priority corridor for signal timing analysis.

This system has no functional vehicle or pedestrian detection, which is common for a downtown type system, but several operational issues were identified and reported to the municipalities and Camden County. These issues were generally related to inconsistency in signal and pedestrian delays. There were some locations with vehicle detection in the traffic cabinet but were not operating, so all modeling and programming for this project assumed there was no detection through the network and all signals will run pretimed for the near future. The noted issues and observations are included within this report and suggested recommendations are also provided.

This project was developed to evaluate signal timing coordination needs given current conditions and equipment throughout the network and to reduce traffic signal delay and stops to help improve system performance.

Project Accomplishments

As part of this project, the Iteris team developed and implemented three unique time-of-day patterns through the network. Additional time periods were modeled and analyzed, but based on data collected and corridor observations, three patterns were sufficient to handle the needs of this system during a typical week. So, the following are the patterns that were developed and analyzed for this project:

Pattern Number	Time-of-Day	Abbreviation For Figures
1	Off-peak	MD
2	Weekday AM Peak	AM
3	Weekday PM Peak	PM

Through the completion of this project, all clearance intervals for both vehicle and pedestrian movements were brought up to standard utilizing the NJDOT methodology for vehicles and the Manual on Uniform Traffic Control (MUTCD). Pedestrian crosswalks were manually measured for these calculations and all issues were documented and reported to Gloucester City and Camden County. Pedestrians have a significant impact on this corridor and there are several Gloucester City schools with crossing guards at traffic signals during school ingress and egress periods, so accurately programming the pedestrian clearance times will improve safety throughout the network and ensure each movement has sufficient crossing time.

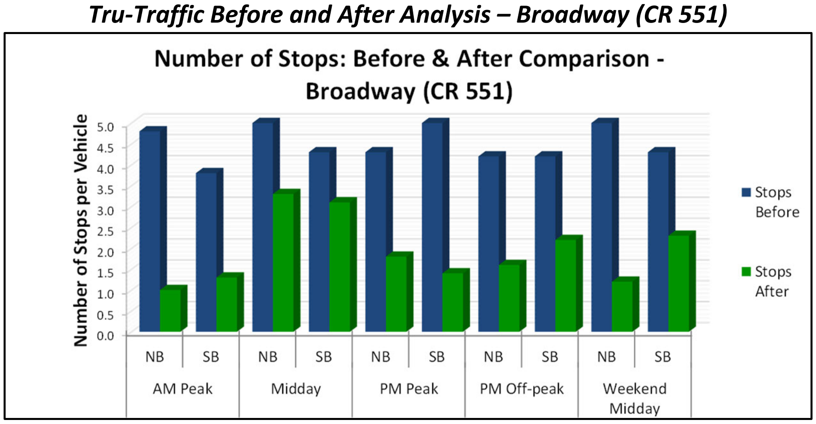
The highest congestion area within this network was at the intersection of Broadway (CR 551) & Market Street (CR 634), specifically during the AM and PM peak periods. The congestion is largely due to there being a single lane servicing each movement, so each direction would fail intermittently throughout the day. The largest issue under existing conditions was the westbound movement at this intersection during the AM peak period, where queues would extend up to approximately three hundred feet and experience cycle failures. The implemented signal timings eliminated that issue as average queues were observed to be much shorter phase failures were no longer observed.

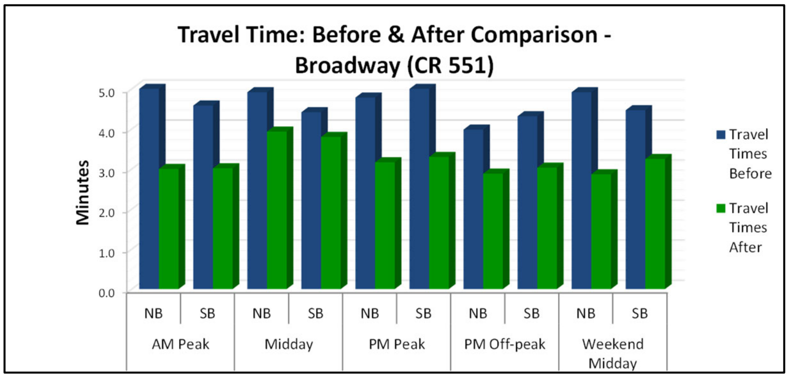
Three of the traffic signals on this network were running in free operation at the start of this project and all of the controller clocks were either never set or differed from GPS time. Free operation means the signal considers its own inputs and controller programming only while servicing the various movements throughout the day and there is no coordination between that signal and those to either direction. Signal timing coordination requires a consistent time for each signal along a network, so when controller clocks do not match, there is no effective timing coordination. So under existing conditions, there was inconsistent operations and travel times through this network, which led to unnecessary delays and added stops. At the conclusion of this project, the nine included signals run consistent coordinated cycle lengths throughout the network for both weekday and weekend operations and each signal is consistently programmed with all necessary safety functions properly programmed. Controller clocks were set to GPS time several times during this project and were noted to hold time relatively well, significantly improving travel times and reducing delay.

Traffic Operations Analysis Summary

Field measured travel time runs were conducted on Broadway (CR 551) between Burlington Street/Warren Street and Koehler Street. Though three patterns were implemented, travel time runs were conducted for several additional time periods to gauge the improvements for other time periods as well. The off-peak pattern is called in the scheduler during all times other than the weekday AM and PM peak periods. So that pattern operates during the weekday midday peak, PM off-peak, overnight and all day on weekends. In the northbound direction, weekday travel times decreased by up to 120 seconds (40.0%) and weekend travel times decreased by up to 123 seconds (41.7%). In the southbound direction, weekday travel times decreased by up to 108 seconds (35.3%) and weekend travel times decreased by up to 73 seconds (27.2%).

Tru-Traffic Before and After Analysis – Broadway (CR 551)

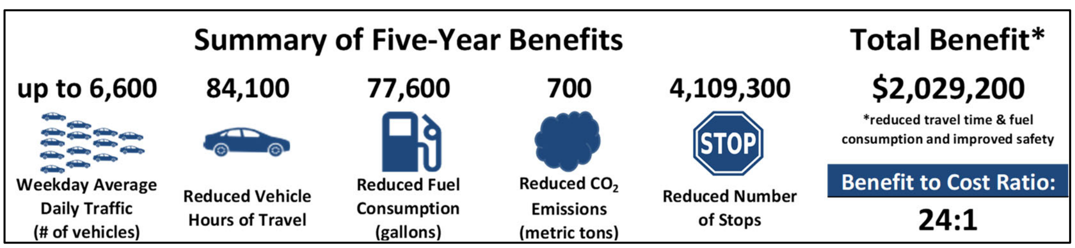




Before and After Analysis – Broadway Rd (CR 551)

Though there are many benefits to signal retiming projects, two general benefit types were focused on to quantify the improvements experienced through this project. The first is user benefits, which are enjoyed directly by travelers and are determined by a reduction in travel time costs and operating costs. Crash costs are generally improved through signal retiming projects but require a comparison of crash data over at least three years, so could be considered and measured in the future. These costs measures are explained in more detail in the body of this report, but travel time and number of stops comparisons were measured using Synchro and operating costs are estimated using a combination of vehicle occupancy, heavy vehicle percentages, the average cost of fuel within the region according to the US Energy Information Administration (EIA) and the current Consumer Price Index. The second type of benefit used in this report is non-user benefits, which include environmental impacts, air quality, and reduced motorist frustration. The emissions estimate shown is calculated using an equation provided by the US Environmental Protection Agency (EPA).

The various values and assumed benefit lifetime utilized are all conservative, so actual improvements are likely much higher than estimated in this report. The figure below summarizes the numerous benefits measured for this project.



Recommendations for Safety Improvements

Safety, operational and capacity related recommendations are provided and analyzed in the body of this report. The potential high impact recommendations are summarized below to highlight areas where there could be significant benefit in making certain improvements to this traffic network.

General Recommendations

- Consider adding vehicle detection and pedestrian pushbuttons throughout the network. Neither were present throughout this project, but significant benefits could be realized by adding both to strategic locations. Adding vehicle detection and pedestrian pushbuttons would allow cycle time to be distributed more appropriately at some critical intersections throughout this network instead of the full allotment each cycle regardless of demand and would significantly reduce stops and travel times during off-peak periods.
- Consider installing GPS units to each cabinet to maintain consistent controller time throughout the network or developing a regular routine of setting controller clocks every six to eight weeks or as often as possible. Controller clocks were noted in this project to maintain time well generally but over time, the clocks will slowly drift apart, and the coordinated timings will gradually lose effectiveness until set consistently again.
- As this system continues to develop in the future, consider the impact to the signal timings for activities such as replacing controllers, upgrading equipment, new developments, or any roadway adjustments.

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1.0 INTRODUCTION

1.1 Purpose

Iteris, Inc. was contracted by the Delaware Valley Regional Planning Commission (DVRPC) to provide engineering services for the full retiming of nine intersections in Camden County, New Jersey on Broadway (CR 551). These signals are all located within Gloucester City, New. The goal of the project was to optimize signal timings given current conditions and utilizing existing equipment, with a focus on optimizing signal operations at the study intersections while considering all users of the system.

The tasks involved in this analysis were:

- Collected existing geometric, volume, and traffic signal timing data and existing timing directives.
- Conducted field visits to develop understanding of intersection and corridor issues.
- Conducted travel time runs to benchmark existing conditions.
- Updated and developed existing traffic operations models to benchmark existing capacity analysis.
- Updated basic timing parameters for both vehicle and pedestrian movements.
- Developed three unique timing patterns for weekday and weekend operations.
- Modified day plan schedules and implemented new signal timing plans.
- Performed post-implementation observation and fine-tuning of timing and conducted travel time runs.
- Developed implemented operations models to compare and measure improvements.
- Updated timing directives to reflect new timings and placed final copy in each traffic cabinet.
- Documented all work performed and summarized findings in this technical report.
- Updated project website to include all deliverables and project material.

1.2 Traffic Signal Locations

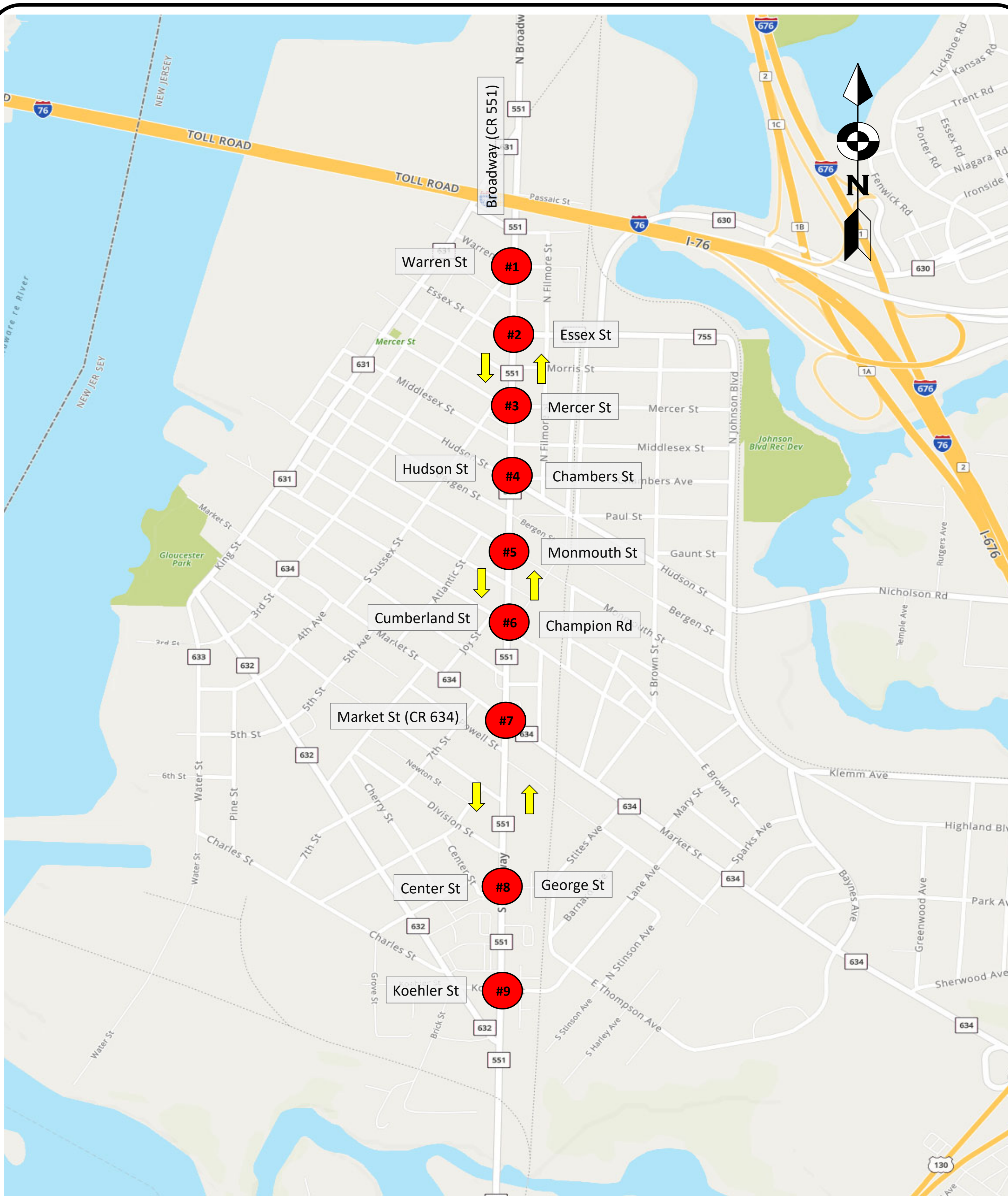
The traffic signals included in this project are:

No.	Intersection
1	Broadway (CR 551) & Burlington St/Warren St
2	Broadway (CR 551) & Essex St
3	Broadway (CR 551) & Mercer St
4	Broadway (CR 551) & Hudson St/Chambers Ave
5	Broadway (CR 551) & Monmouth St
6	Broadway (CR 551) & Cumberland St/Champion Rd
7	Broadway (CR 551) & Market St (CR 634)
8	Broadway (CR 551) & Center St/George St
9	Broadway (CR 551) & Koehler St

Note that throughout this report, Broadway Rd (CR 551) is considered North-South in directionality. The models, timing sheets and timing directives developed for this project will also reflect this assumption consistently.

Broadway Rd (CR 551) is a two-lane undivided roadway that spans approximately 1.1 miles within the limits of this project. The posted speed limit for both directions is 25 mph throughout. The network is a downtown system and consists of both residential and commercial areas along with several schools just off Broadway (CR 551). A large shipping port is just north of this corridor and heavily drives commuter traffic during the AM and PM peak periods. Also, Interstate 76/Interstate 676 runs parallel to this corridor, so Broadway (CR 551) is used as a diversion route when there are incidents along that roadway.

Figure 1 on pages 2 illustrate the locations of the signals included in this report.



Camden County Study Intersection:

7-day, 24-hour Count Location (Directional):

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Figure 1

Traffic Signal Locations
Broadway (CR 551)

2.0 DATA COLLECTION

2.1 7-Day, 24-Hour Volumes

24-hour segment counts were conducted by Imperial Traffic & Data Collection (ITDC) during January of 2023 while Gloucester City schools were in session. Counts were collected at three locations on Broadway (CR 551) and these counts were collected to illustrate the various traffic patterns that occur during a typical day on the various roadways at the count locations.

The Average Daily Traffic (ADT) volume on Broadway (CR 551) from the locations counted was as high as 6,500 on weekdays and 4,800 on weekends.

Figure 2 through Figure 5 on pages 5 – 8 illustrate the average weekday, Saturday and daily hourly volume data for the counts collected for this project.

2.2 Turning Movement Counts

Turning movement counts (TMCs) were collected by ITDC at all nine locations throughout the project limits.

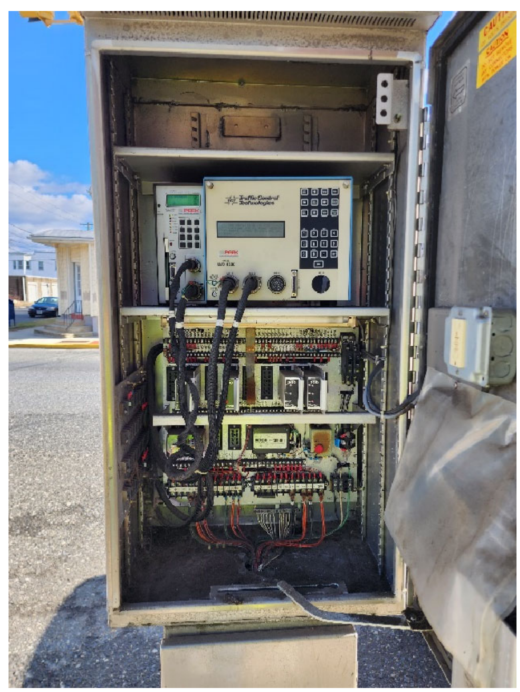
TMCs for all signals in the network were collected from 7:00 am – 9:00 am, 11:30 am – 1:30 pm, 2:30 pm – 5:30 pm, and 6:30 pm – 7:30 pm on weekdays. Turning movement counts were not collected on weekends for this project because of the low volumes on Broadway (CR 551). The weekday midday period was determined to be similar to weekend volumes.

These volumes were then increased by a growth factor to account for fluctuations in daily traffic volumes and to factor in some future volume growth and potential diversion traffic from Interstate 76/Interstate 676. TMC diagrams illustrating hourly volumes for each developed timing pattern can be found on Figure 11 through Figure 19 on pages 28 – 36. Raw TMC data can be found on the project website.

2.3 Traffic Signal Timing and Phasing Data

There were two traffic controller types on this corridor, Econolite and LMD. The Econolite controllers are more modern equipment, so for those locations, existing data files were uploaded via Aries Zone Manager, an Econolite direct connect software, directly from each local controller. For the LMD locations, timings were manually documented from each controller.

2.4 Field Notes



Field notes were collected by Iteris, Inc. staff during January 2023 at each intersection on various signal and traffic characteristics to assist in model development and signal optimization. The field notes contain information on various intersections, signal, and traffic characteristics. Diagrams within the field notes contain lane geometry at the stop bar, measured lane storage lengths, number of signal heads, and cabinet locations. Posted speed limits, left turn types (protected only, protected/permissive, or permissive only), turn restrictions, and the presence of roadway lighting and signal back plates were noted.

For each approach, vehicle and pedestrian clearance distances and median widths were measured. Vehicle detection and pedestrian pushbuttons, where present, were reviewed and tested for proper operation. Other unusual or unique characteristics were also recorded. The summary of findings can be found in the Field Notes folder on the project website. The Appendix of this report contains the status of those observations at the end of the project, since some of the observations had changed since the field reviews. The final table will be accurate as of June 27, 2023, when detection was last reviewed for this project.

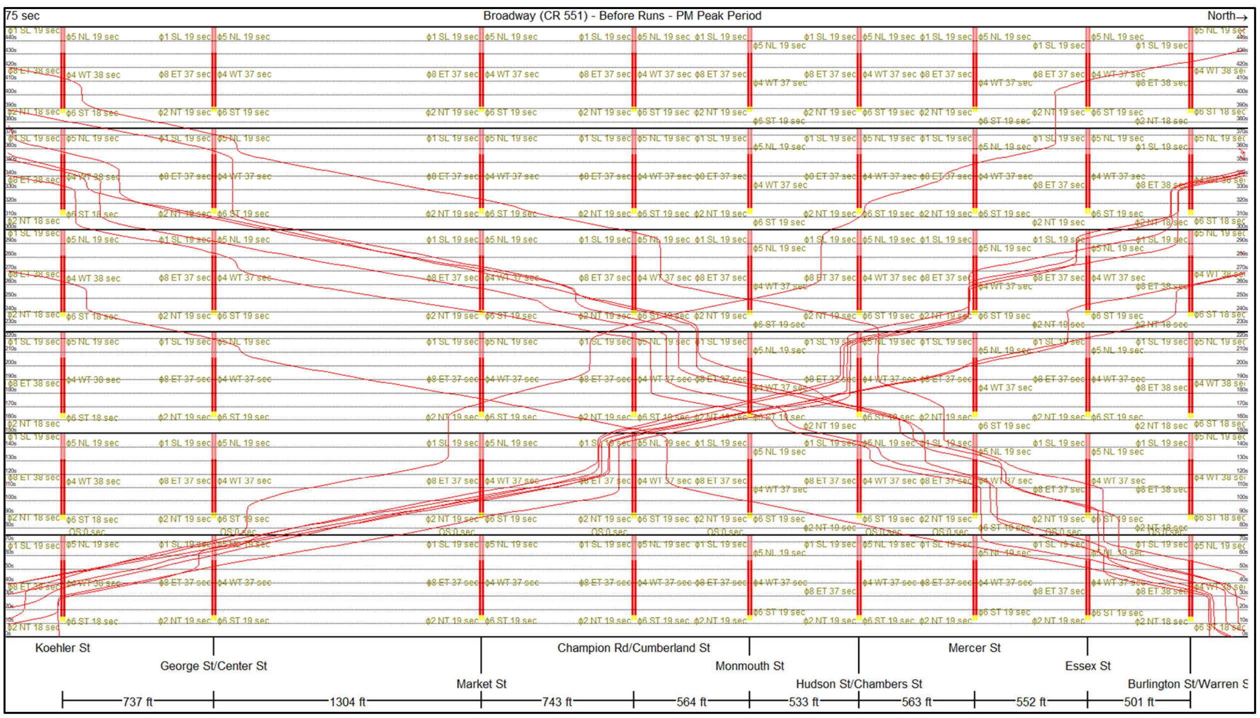
Photographs were taken within every traffic cabinet and approach photos were also collected for all intersections. The photographs are a record of the current geometrics and other intersection, signal, and roadside characteristics. Field notes and intersection photographs can be found within the project website.

A Saturation Flow Rate study was also performed for this project, which is a large factor in the modeling and analysis of the signals along this network. Since this is a downtown system with a lot of conflicting turns and pedestrians, low speeds and has a high percentage of heavy vehicles, the saturation flow rate is significantly lower on this system than what is found on more typical arterial roadways.

2.5 Travel Time Runs

Travel time runs were conducted under both existing and implemented signal timings on Broadway (CR 551). These data were collected to both fine-tune implemented signal timing as well as provide a field-measured metric by which existing and implemented signal timing can be compared using floating car studies. Travel time data is presented and analyzed in Section 6.4 of this report.

Video was collected during both the existing and implemented conditions travel time runs to be used in developing comparison videos. Complete travel time data can be found in the Tru-Traffic folder on the project website.

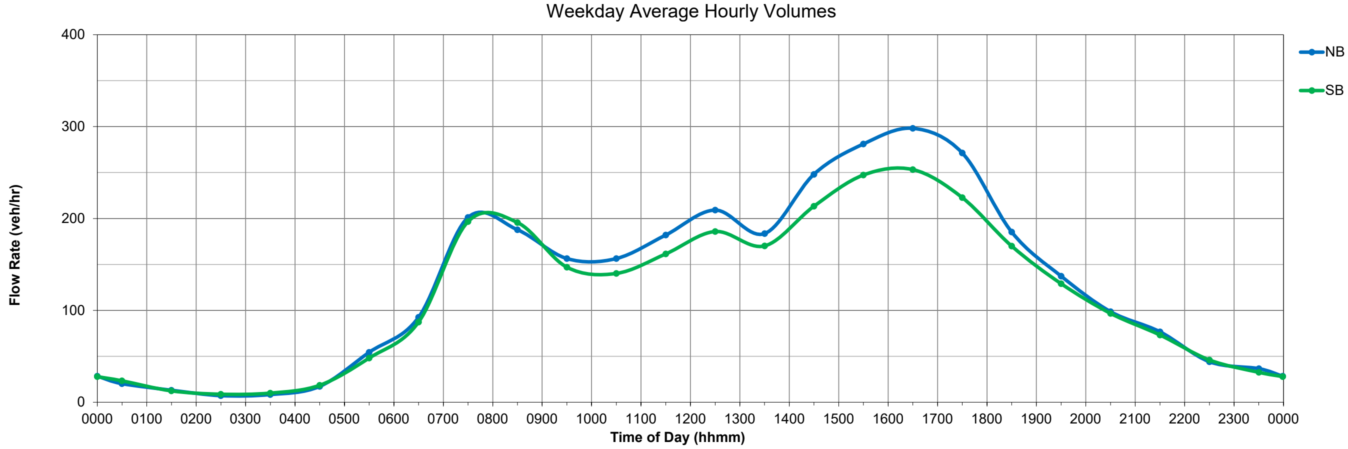


Sample Time-Space Diagram from Tru-Traffic Software – Broadway (CR 551) - PM Peak Period

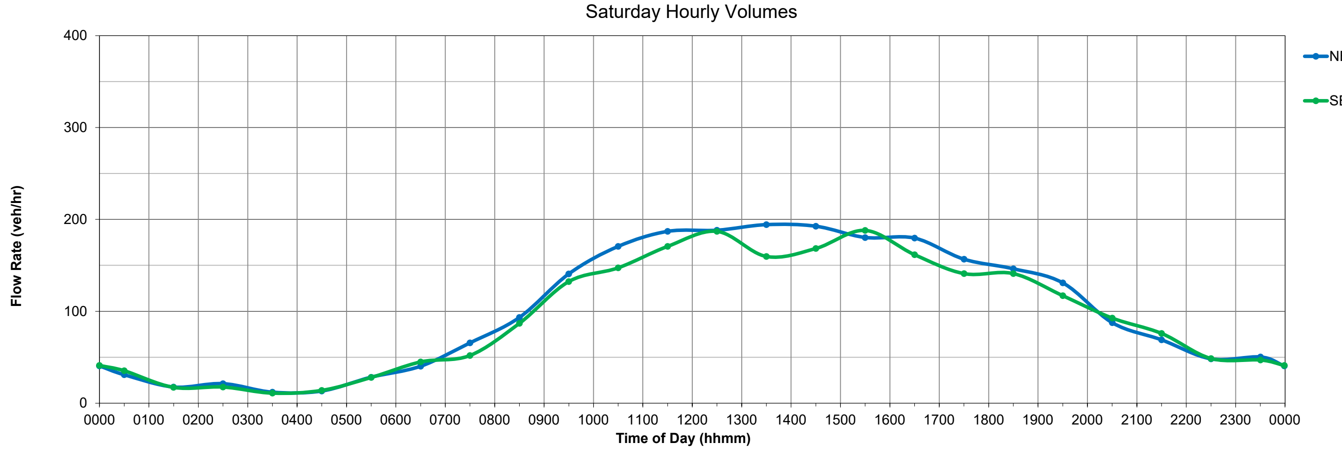
Hourly Volumes - Average for Count Locations on Broadway (CR 551) between Essex St and Center St/George St

From	To	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday		Avg. Weekday		Avg. Weekend	
		NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB
0000	0100	21	19	20	24	26	25	15	22	20	27	31	35	40	37	20	23	36	36
0100	0200	10	12	13	10	10	10	16	16	16	14	18	17	26	23	13	12	22	20
0200	0300	8	9	5	4	8	8	8	11	7	12	21	18	16	16	7	9	19	17
0300	0400	9	11	9	10	9	13	8	8	6	7	12	11	12	13	8	10	12	12
0400	0500	18	21	17	15	17	18	18	22	17	17	13	14	9	10	17	19	11	12
0500	0600	54	41	54	50	53	51	56	48	55	51	28	28	19	17	54	48	24	23
0600	0700	90	90	90	82	89	82	100	96	93	87	40	45	26	35	92	87	33	40
0700	0800	200	200	190	188	207	209	199	199	209	187	66	52	44	35	201	197	55	44
0800	0900	191	198	206	223	180	184	182	192	180	181	93	87	64	60	188	196	79	74
0900	1000	154	144	145	146	166	150	157	144	160	152	141	132	116	94	156	147	128	113
1000	1100	149	135	147	136	153	129	157	157	175	144	171	147	136	128	156	140	153	138
1100	1200	182	153	186	172	178	163	180	152	184	167	187	171	153	143	182	161	170	157
1200	1300	200	177	212	179	204	191	197	182	232	201	188	187	169	154	209	186	179	170
1300	1400	188	181	191	166	169	146	163	170	206	188	194	160	176	151	184	170	185	155
1400	1500	233	192	245	212	254	210	249	209	260	244	193	168	177	148	248	213	185	158
1500	1600	239	232	259	233	317	264	290	251	300	258	180	188	154	128	281	247	167	158
1600	1700	229	208	311	259	319	252	339	276	293	271	180	162	134	130	298	253	157	146
1700	1800	215	182	264	221	287	222	306	246	283	243	157	141	133	125	271	223	145	133
1800	1900	167	153	167	164	165	157	245	191	182	185	146	141	108	116	185	170	127	128
1900	2000	135	127	144	134	144	137	121	112	143	135	131	117	87	81	137	129	109	99
2000	2100	89	86	105	115	99	87	95	93	105	103	88	93	82	86	99	97	85	89
2100	2200	72	70	75	71	70	68	66	70	100	88	69	76	53	49	77	73	61	62
2200	2300	33	40	47	40	43	45	37	39	60	66	48	49	50	52	44	46	49	50
2300	0000	36	34	30	31	40	33	30	27	46	38	50	47	24	26	37	33	37	37
	Sub-total	2,923	2,713	3,134	2,884	3,208	2,852	3,235	2,932	3,333	3,065	2,446	2,286	2,006	1,855	3,166	2,889	2,226	2,070
	Total	5,635		6,018		6,060		6,167		6,398		4,732		3,861		6,056		4,296	

Weekday Average Hourly Volumes



Saturday Hourly Volumes



Hourly Volumes by Day

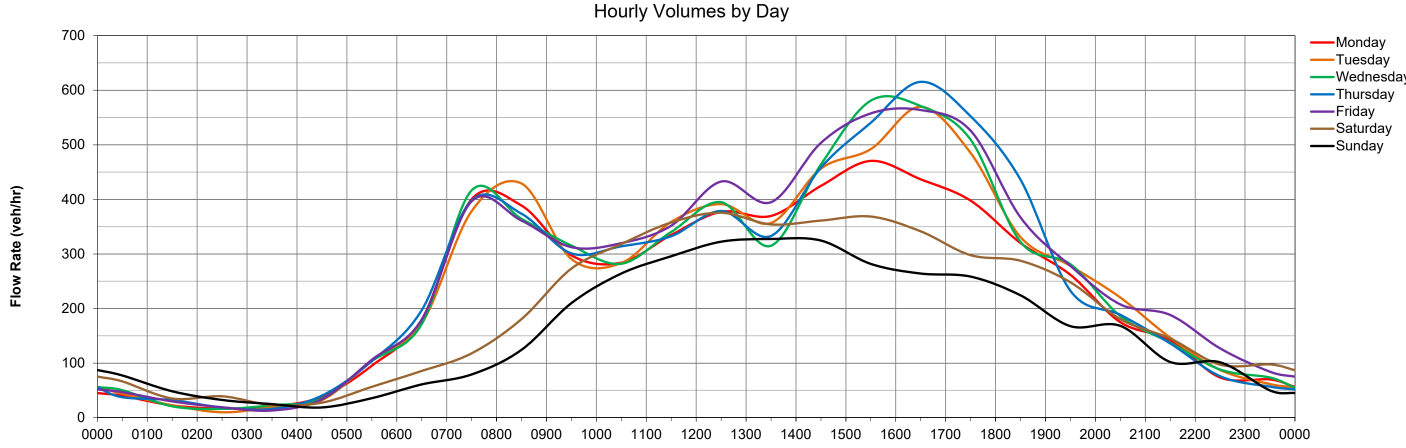


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Figure 2

7-Day, 24-Hour Volumes

Average for Count Locations on Broadway (CR 551) between Essex St and Center St/George St

Hourly Volumes - Broadway (CR 551) between Essex St and Mercer St

		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday		Avg. Weekday		Avg. Weekend	
From	To	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB
0000	0100	26	24	22	31	30	27	25	20	23	30	29	43	41	47	25	26	35	45
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0200	0300	7	11	3	4	13	14	11	15	9	15	23	15	21	21	9	12	22	18
0300	0400	8	14	11	9	11	10	4	6	7	7	13	17	10	16	8	9	12	17
0400	0500	17	20	19	17	25	16	21	22	20	10	15	16	6	11	20	17	11	14
0500	0600	50	39	65	52	55	39	55	44	50	49	31	34	12	25	55	45	22	30
0600	0700	92	68	82	70	84	64	102	64	100	59	40	42	23	45	92	65	32	44
0700	0800	174	160	182	155	200	172	188	158	204	139	50	49	38	32	190	157	44	41
0800	0900	170	147	234	145	177	132	173	143	173	152	93	75	59	43	185	144	76	59
0900	1000	133	127	118	138	135	129	125	140	140	149	92	121	62	74	130	137	77	98
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1700	1800	123	200	142	273	168	301	133	384	189	287	125	142	81	121	151	289	103	132
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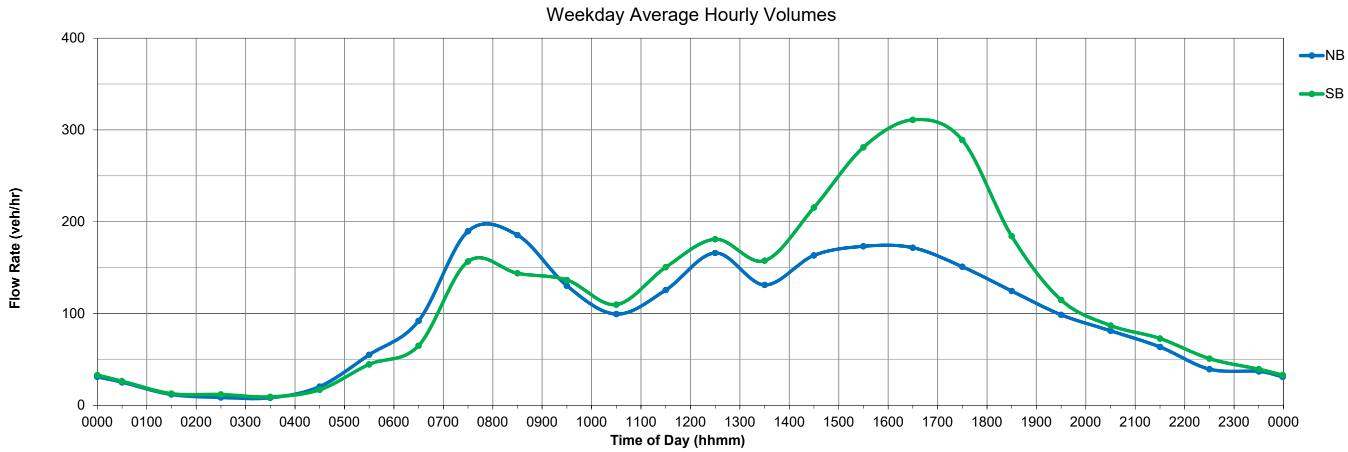
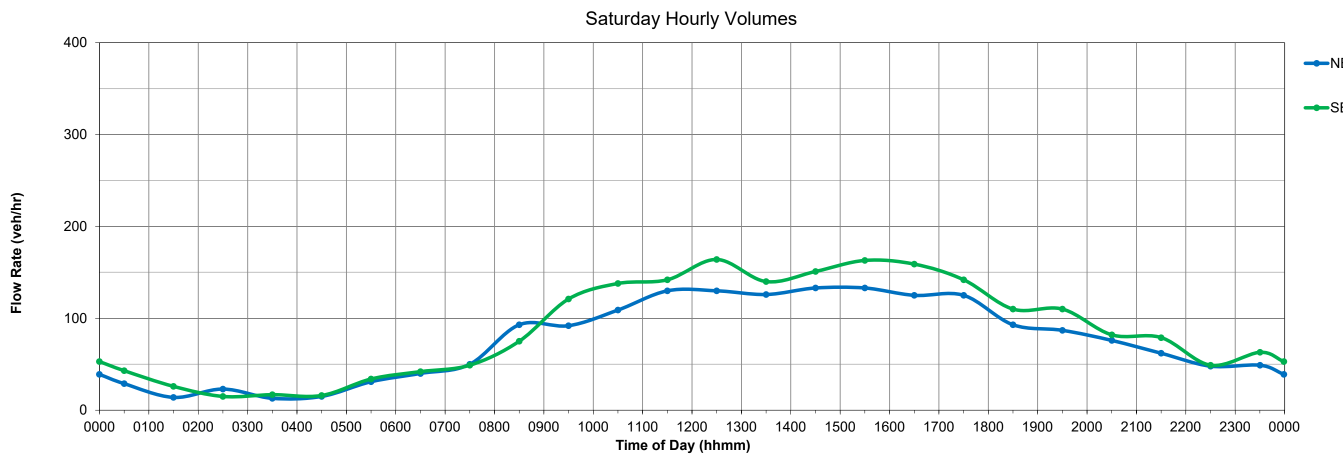
1900	2000	81	104	101	99	113	141	85	96	113	134	87	110	57	86	99	115	72	98
2000	2100	81	81	86	96	84	76	72	94	83	88	76	82	66	80	81	87	71	81
2100	2200	65	73	52	67	62	69	52	59	87	96	62	79	43	59	64	73	53	69
2200	2300	32	38	46	49	30	57	35	37	54	73	48	49	32	66	39	51	40	58
2300	0000	36	43	30	33	38	35	29	35	52	51	49	63	17	36	37	39	33	50
	Sub-total	2,144	2,611	2,385	2,778	2,380	2,758	2,313	3,037	2,540	3,157	1,826	2,130	1,374	1,702	2,352	2,868	1,600	1,916
	Total	4,755		5,163		5,138		5,350		5,697		3,956		3,076		5,221		3,516	





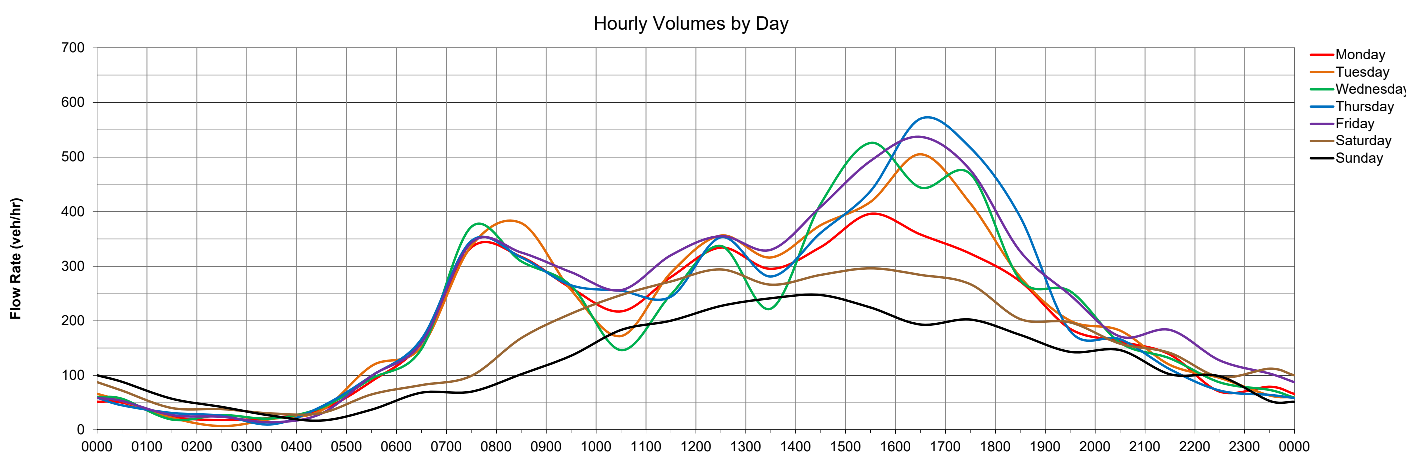
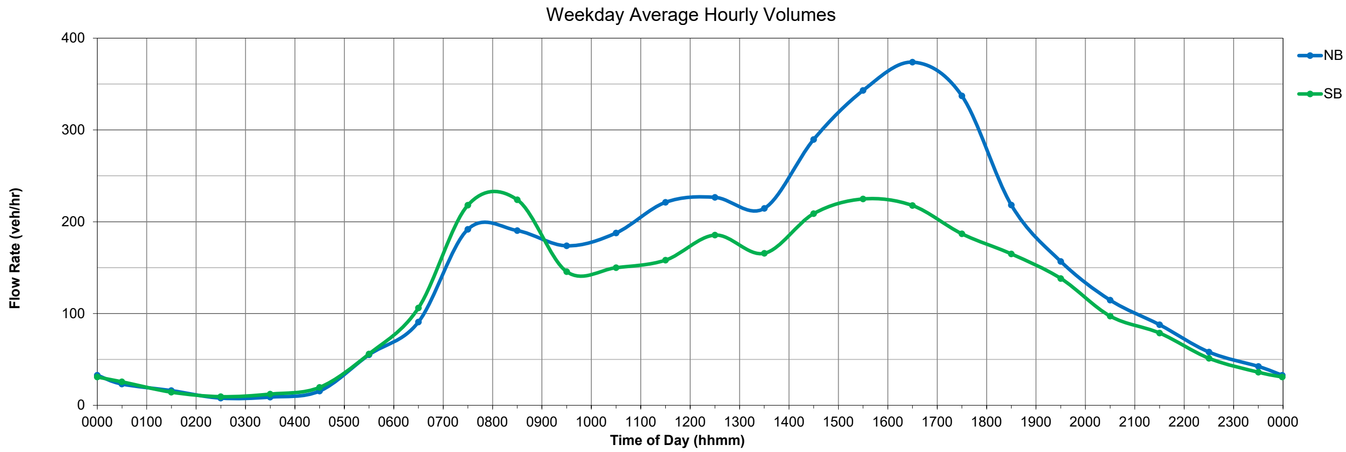
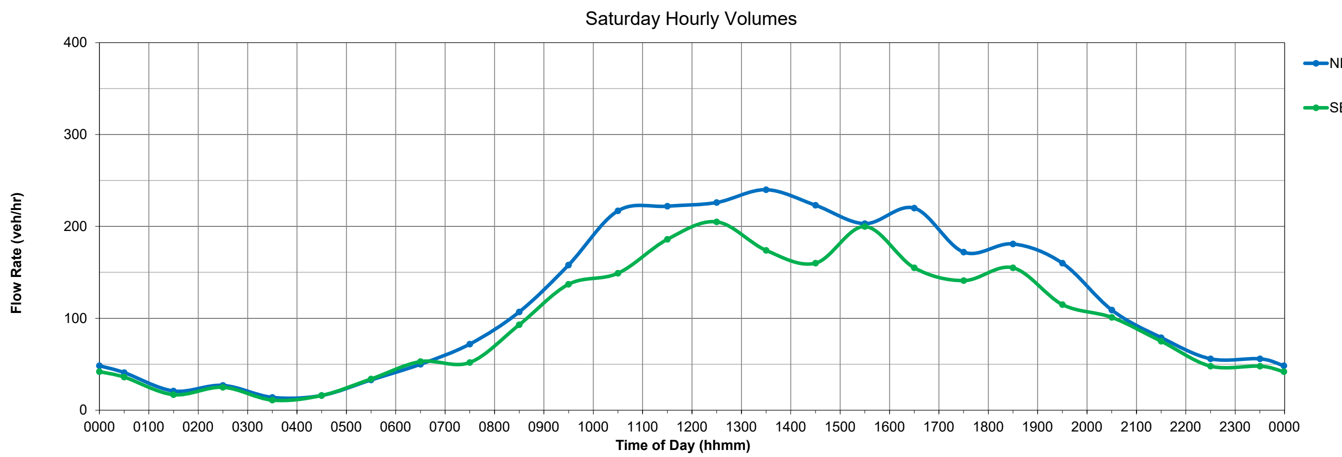


Figure 3
7-Day, 24-Hour Volumes
Broadway (CR 551) between Essex St and Mercer St

Hourly Volumes - Broadway (CR 551) between Monmouth St and Cumberland St/Champion Rd

		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday		Avg. Weekday		Avg. Weekend	
From	To	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB
0000	0100	28	26	27	21	24	29	15	25	22	27	41	36	47	40	23	26	44	38
0100	0200	14	8	16	11	12	13	17	26	21	14	21	17	30	25	16	14	26	21
0200	0300	9	11	8	4	6	7	8	12	8	13	27	25	14	19	8	9	21	22
0300	0400	12	13	9	11	8	17	12	12	4	8	14	11	18	15	9	12	16	13
0400	0500	17	21	17	14	11	18	19	24	14	21	16	16	13	10	16	20	15	13
0500	0600	55	47	52	54	51	61	57	53	60	65	33	34	24	18	55	56	29	26
0600	0700	90	113	89	97	87	98	101	112	87	110	50	53	35	37	91	106	43	45
0700	0800	198	219	177	193	188	238	197	220	199	220	72	52	41	39	192	218	57	46
0800	0900	197	223	189	282	193	212	185	213	188	190	107	93	64	74	190	224	86	84
0900	1000	160	150	165	134	186	152	179	145	179	147	158	137	147	93	174	146	153	115
1000	1100	174	136	176	165	189	151	183	161	217	137	217	149	174	144	188	150	196	147
1100	1200	227	140	226	185	224	167	211	151	218	148	222	186	191	166	221	158	207	176
1200	1300	214	177	230	183	222	203	203	180	264	184	226	205	203	170	227	185	215	188
1300	1400	227	167	215	150	199	149	177	180	255	182	240	174	196	162	215	166	218	168
1400	1500	278	190	271	224	297	197	281	211	321	222	223	160	201	150	290	209	212	155
1500	1600	284	218	324	221	371	230	355	228	381	227	203	200	176	123	343	225	190	162
1600	1700	280	192	372	209	415	237	435	199	367	251	220	155	154	134	374	218	187	145
1700	1800	264	161	313	184	334	191	433	176	342	222	172	141	166	133	337	187	169	137
1800	1900	188	161	186	165	185	150	310	157	222	192	181	155	136	128	218	165	159	142
1900	2000	169	143	155	156	170	133	137	123	153	136	160	115	116	78	157	138	138	97
2000	2100	95	92	128	113	109	92	117	87	124	102	109	101	97	93	115	97	103	97
2100	2200	81	82	93	69	73	72	84	82	108	89	79	75	65	46	88	79	72	61
2200	2300	44	51	59	47	70	45	45	44	72	69	56	48	68	48	58	51	62	48
2300	0000	42	39	34	34	51	39	36	29	49	39	56	48	34	28	42	36	45	38
	Sub-total	3,347	2,780	3,531	2,926	3,675	2,901	3,797	2,850	3,875	3,015	2,903	2,386	2,410	1,973	3,645	2,894	2,657	2,180
	Total	6,127		6,457		6,576		6,647		6,890		5,289		4,383		6,539		4,836	





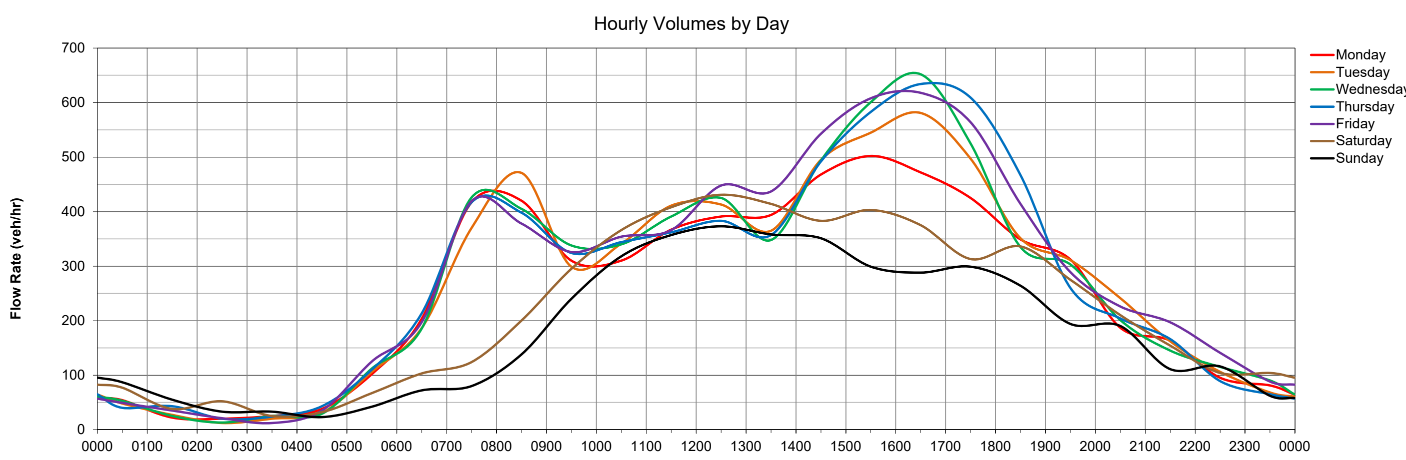
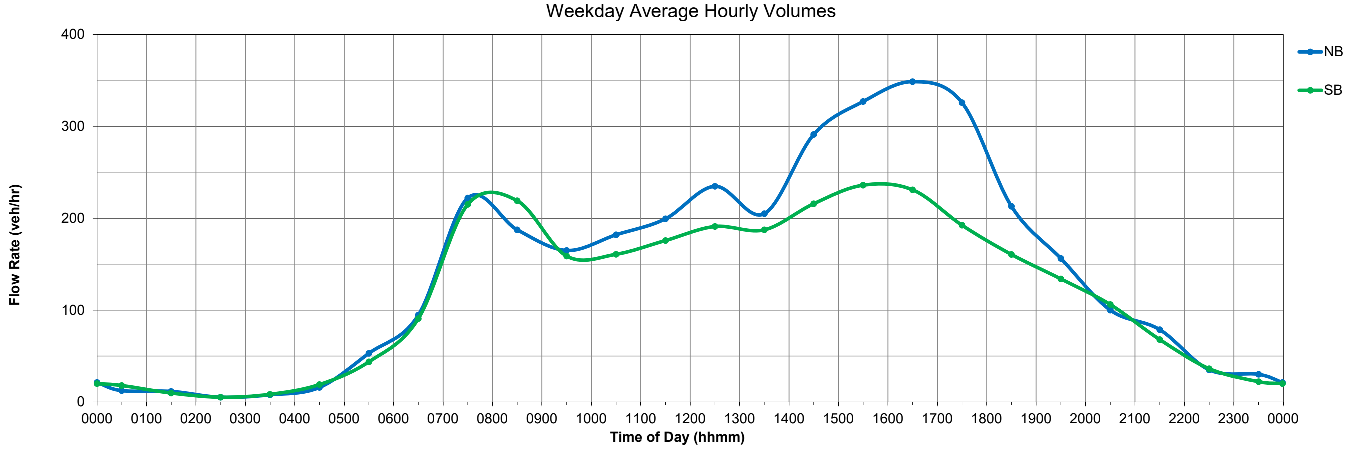


Figure 4
7-Day, 24-Hour Volumes
Broadway (CR 551) between Monmouth St and Cumberland St/Champion Rd

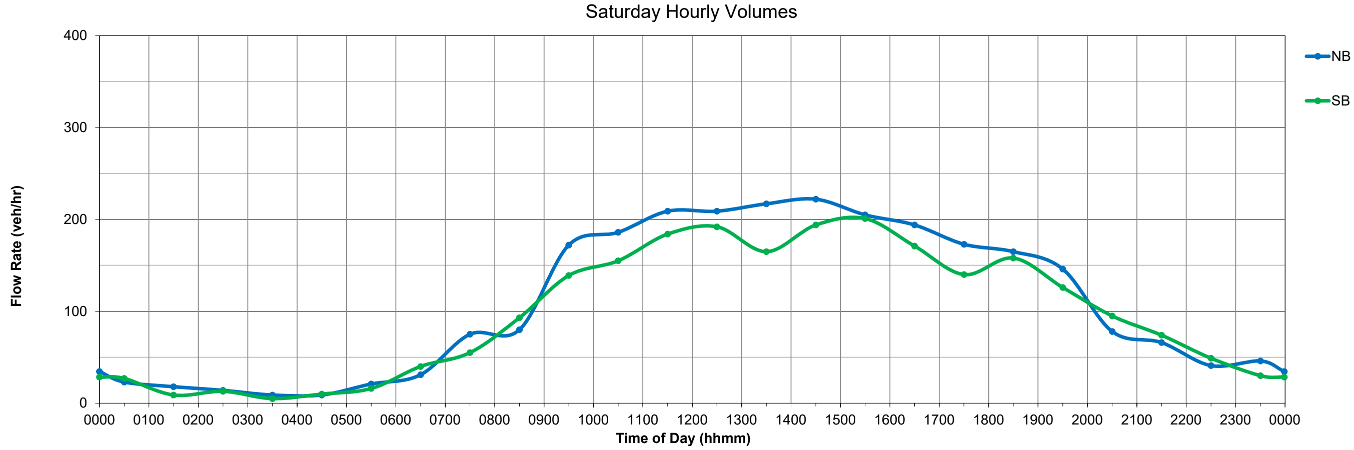
Hourly Volumes - Broadway (CR 551) between Market St (CR 634) and Center St/George St

		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday		Sunday		Avg. Weekday		Avg. Weekend	
From	To	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB	NB	SB
0000	0100	8	8	11	19	23	18	5	22	15	23	23	27	32	25	12	18	28	26
0100	0200	9	12	13	6	9	9	11	11	16	11	18	9	18	15	12	10	18	12
0200	0300	7	5	5	5	4	4	5	5	5	7	14	13	13	9	5	5	14	11
0300	0400	8	7	8	9	9	13	7	7	7	6	9	5	7	8	8	8	8	7
0400	0500	19	21	14	15	15	19	15	20	16	20	9	10	8	8	16	19	9	9
0500	0600	56	38	46	43	53	52	56	46	54	40	21	16	20	8	53	44	21	12
0600	0700	87	88	100	79	97	83	98	113	91	91	31	40	20	22	95	91	26	31
0700	0800	229	220	211	216	233	218	212	219	225	202	75	55	53	34	222	215	64	45
0800	0900	206	223	194	243	170	209	188	219	179	201	80	93	68	64	187	219	74	79
0900	1000	168	154	152	165	176	168	168	146	161	161	172	139	138	115	165	159	155	127
1000	1100	183	142	177	160	188	172	165	178	197	152	186	155	144	147	182	161	165	151
1100	1200	193	164	196	181	201	181	215	176	192	177	209	184	168	162	199	176	189	173
1200	1300	237	170	231	174	220	202	207	193	279	216	209	192	199	168	235	191	204	180
1300	1400	215	205	212	177	200	175	176	185	222	195	217	165	218	165	205	187	218	165
1400	1500	281	190	288	211	281	203	300	222	306	253	222	194	219	156	291	216	221	175
1500	1600	273	240	293	220	378	238	356	245	335	237	205	201	189	133	327	236	197	167
1600	1700	273	207	381	242	377	240	400	242	312	224	194	171	151	160	349	231	173	166
1700	1800	259	186	338	205	360	174	353	178	319	219	173	140	152	122	326	192	163	131
1800	1900	194	145	196	166	187	169	303	148	185	175	165	158	124	110	213	161	145	134
1900	2000	155	133	175	148	148	138	140	116	163	135	146	126	87	79	156	134	117	103
2000	2100	92	84	101	136	104	93	96	99	107	118	78	95	84	84	100	106	81	90
2100	2200	71	54	81	77	74	62	63	68	105	79	66	74	52	41	79	68	59	58
2200	2300	24	31	36	25	30	32	30	36	55	57	41	49	49	41	35	36	45	45
2300	0000	30	20	26	27	32	25	25	16	38	23	46	30	20	14	30	22	33	22
	Sub-total	3,277	2,747	3,485	2,949	3,569	2,897	3,594	2,910	3,584	3,022	2,609	2,341	2,233	1,890	3,502	2,905	2,421	2,116
	Total	6,024		6,434		6,466		6,504		6,606		4,950		4,123		6,407		4,537	

Weekday Average Hourly Volumes



Saturday Hourly Volumes



Hourly Volumes by Day

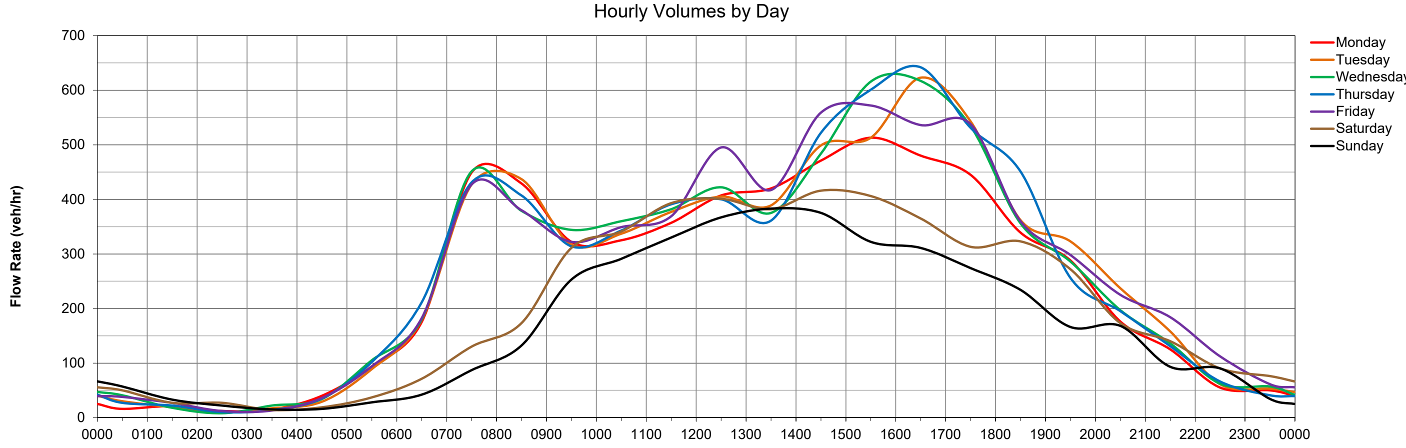


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Figure 5
7-Day, 24-Hour Volumes
Broadway (CR 551) between Market St (CR 634) and Center St/George St

3.0 SITE SURVEY

Prior to conducting any analysis, a site survey was performed to observe the signal equipment in the cabinet and operation of the traffic signal as well as the geometric, traffic, and signal timing characteristics of each intersection.

3.1 Intersection Observation

A general observation of the interaction between traffic, the signal, and intersection design was also made during the site survey. The purpose of these observations was to note any characteristics (such as low lane utilization) that may not be inferred from any other available data sources but could significantly affect the performance of the new signal timings. Any potential safety hazards observed during the site survey, such as missing, damaged, or obstructed signs, signals, or pavement markings were also noted. All vehicle and pedestrian detectors were observed and tested for proper operation. A summary of those detection issues is included in this report on Figure 8 on page 25. An observation of all signals was conducted during daytime operation under normal weather conditions.

3.2 Summary of Field Observations

The following observations were noted during the site survey:

General Observations

- Under existing conditions, most signals within this network were running in free operation or the controller clocks were either not set or were off by different amounts of time through the network. This resulted in inconsistency throughout the network and unpredictable arrivals at intersections, creating scenarios where a platoon of vehicles could be arriving at a signal and the indications would go to the yellow and red intervals on the main street at the most inopportune time. This increased the number of dilemma zone conflicts along the network, resulting in more rear end crashes, hard braking and red light running throughout the network. Also, vehicles could stop at several signals in a row and experience significant delays while travelling down the Broadway (CR 551).
- None of the existing traffic cabinets were equipped with any way to maintain a consistent time source, such as a GPS. Also, several controller clocks were never set under existing conditions, so even though coordinated timings were programmed in the traffic controller, signals were operating in free operation due to the controller clocks not being set.
- There were a number of pedestrian display issues noted during the field notes and observations. Those issues found at the time are summarized in Figure 8 on page 25. These issues ranged from the pedestrian indications not displaying properly to signal heads being tilted away from the crosswalks in a manner that the intended path could not interpret the intended indication.
- In general, the controller clocks hold time well with a few exceptions. When clocks were set, they were observed to drift together, so two weeks after being set, most clocks would be fast by three seconds, but at least all signals would be off the same amount.
- Heavy pedestrian volumes were noted for all time periods throughout the network and there are crossing guards present at all signals between Market Street (CR 634) and Hudson Street/Chambers Street during Gloucester City schools’ ingress and egress periods.
- Volumes were directionally unbalanced by time of day along this network, with northbound being much heavier during the AM peak period and southbound being much heavier during the PM peak period. This was caused by commuter traffic and likely heavily impacted by the port just north of this system.
- There was a high percentage of heavy vehicles, such as buses and large trucks noted along Broadway (CR 551) through all time periods. There were a number of bus stops along the network and not much area for buses to pull off, so would occasionally block main street traffic to pick up and drop off passengers at certain stops along the roadway.

Broadway (CR 551) & Burlington Street/Warren Street

- During the midday and PM periods, southbound queues extended up to approximately 300 feet, resulting in cycle failures. This was largely due to the side streets using a significant amount of cycle time even though there was little vehicular or pedestrian traffic.

Broadway (CR 551) & Mercer Street

- The traffic cabinet had clearly been struck by a vehicle at some point since the top portion of cabinet is very loose. The Field Notes were completed on a very windy day and the cabinet portion was bouncing off the bottom portion of the cabinet.
- During the midday and PM periods, westbound queues extended up to approximately 300 feet, which would service in one cycle but was noted as likely Interstate 76/Interstate 676 diversion traffic. When this was noted, southbound traffic through the network was heavier and would increase travel times and phase failures through the network.

Broadway (CR 551) & Hudson Street/Chambers Street

- During the midday and PM periods, southbound queues extended up to approximately 500 feet and resulted in cycle failures. This was largely due to the side streets using a significant amount of cycle time even though there was little vehicular or pedestrian traffic.

Broadway (CR 551) & Monmouth Street

- The controller screen was not responsive initially during the field notes. Eventually it started to work properly after a good portion of field notes, but the controller still had issues and black screen would appear and not go away for extended periods of time.

Broadway (CR 551) & Market Street (CR 634)

- During the AM and PM periods, westbound queues extended up to approximately 300 feet, resulting in phase failures.
- During the PM peak period, southbound queues extended up to approximately 400 feet and experienced cycle failures. This was generally due to southbound left turn queues blocking the area for through traffic to pass through.
- During the AM peak period, northbound queues extended up to approximately 250 feet and experienced cycle failures. This was generally due to heavy vehicles with long start up times being paired with a short cycle length and green allocation for that movement.

Broadway (CR 551) & Center Street/George Street

- There is ‘STOP’ painted in the pavement for a signalized eastbound (phase 4) movement, which runs sequentially following the westbound (phase 3) movement. Vehicles do not abide by this direction as the signal seems to dictate driver behavior.

4.0 SIGNAL TIMING IMPLEMENTATION

4.1 Model Development

The basic link-node structure of the roadway network was built in Synchro on a coordinate-specific, Bing Maps image of roads provided within Synchro. This type of reference ensures precise intersection placement as well as proper link curvature and length. Node numbers (intersection IDs) were assumed based on the proposal provided at the beginning of this project.

Once all existing geometric, volume, and signal timing data were coded into the models and general field observations were completed, new signal timings were developed.

4.2 Basic Signal Timing Parameters

The basic timing parameters, such as minimum green, yellow change, red clearance, vehicle extension, recall mode, walk time, and pedestrian clearance (flashing don't walk), were reviewed and updated as necessary for each traffic signal phase. These parameters are discussed in greater detail below. All clearance intervals were calculated for all intersections.

Minimum Green

Minimum values were reviewed and updated, as necessary. In general, the following were used:

- Main Street through movements: 15-20 seconds depending on detection layout and pedestrian operation.
- Left turn movements: 5 seconds.
- Side street through movements: 7-10 seconds depending on side street volume and detection layout.
- In many cases, existing minimum greens were not reduced but all were reviewed for appropriateness.

Yellow Change and Red Clearance Intervals

The yellow change and red clearance intervals were calculated from equations provided by the NJDOT Traffic Engineering Division as follows:

$$\text{Total Clearance (TC)} = t + \frac{V}{2a} + \frac{w+L}{V}$$

t = perception-reaction time (s)
V = approach speed (ft/sec)
a = deceleration rate (ft/sec^2)
w = width of intersection (stop bar to furthest conflict point)
L = length of vehicle

Yellow time for each movement is calculated based on the approach posted speed limit, with one second per 10 mph and rounded up to the nearest whole number. If speeds vary on the concurrent approaches, the higher value is utilized, and the concurrent phases have matching yellow and red intervals. The red interval is then calculated by subtracting the yellow interval from the Total Clearance equation shown above and rounded up the nearest whole number.

Walk Time

Generally, a value of seven or more seconds based on 2009 MUTCD requirements and engineering judgment was used if pedestrian phases were present. All pedestrian phases on this network were pretimed, so serviced every cycle regardless of demand. There were several movements where a value under seven seconds was utilized, and each was done only in situations where the system significantly benefited from a shorter walk time. At those locations, the existing value was not reduced and the MUTCD minimum of four seconds was not violated. Pedestrian movements along Broadway (CR 551) were programmed to hold in Walk until there is just enough time to service the required pedestrian clearance time. At key locations with heavy pedestrian volumes, additional time was added to side street movements by time of day to allow for additional Walk time as well.

Pedestrian Clearance (Flashing Don't Walk)
The length of this interval is a function of the crosswalk length, pedestrian push button distance from the curb, and a standard pedestrian walking speed of 3.5 ft/s. MUTCD guidelines were utilized in calculating appropriate flashing don't walk times.

For specific information, the existing and implemented timing sheets can be found on the project website. All clearance measurements and calculations for both vehicle and pedestrian movements are provided on the project website.

4.3 Phasing

During the optimization process, it may be determined that the basic phasing structure of an intersection should be changed or further evaluated to improve the operation and/or safety of the intersection or corridor. No such recommendations are being presented for this system.

4.4 Day Plan Schedules

The process of determining the day plan schedule is primarily based on the 7-day, 24-hour traffic volume counts and engineering judgment. Figure 6 on page 13 illustrates the existing and implemented day plan schedules.

EXISTING SCHEDULES
Broadway (CR 551)
Weekday (Monday-Friday)

		12 am – 12 am
1	Burlington St/Warren St	1 [75]
2	Essex St	[Free]
3	Mercer St	1 [75]
4	Hudson St/Chambers St	[Free]Note 1
5	Monmouth St	1 [75]
6	Champion Rd/Cumberland St	1 [75]
7	Market St	1 [75]
8	George St/Center St	[Free]Note 1
9	Koehler St	1 [75]

Notes: 1 - Programmed in scheduler to run a 75 second cycle coordinated plan but runs free to programming error

PROPOSED SCHEDULES
Broadway (CR 551)
Weekday (Monday-Friday)

1	Burlington St/Warren St	1 [75]	2 [90]	1 [75]	3 [90]	1 [75]
2	Essex St	1 [75]	2 [90]	1 [75]	3 [90]	1 [75]
3	Mercer St	1 [75]	2 [90]	1 [75]	3 [90]	1 [75]
4	Hudson St/Chambers St	1 [75]	2 [90]	1 [75]	3 [90]	1 [75]
5	Monmouth St	1 [75]	2 [90]	1 [75]	3 [90]	1 [75]
6	Champion Rd/Cumberland St	1 [75]	2 [90]	1 [75]	3 [90]	1 [75]
7	Market St	1 [75]	2 [90]	1 [75]	3 [90]	1 [75]
8	George St/Center St	1 [75]	2 [90]	1 [75]	3 [90]	1 [75]
9	Koehler St	1 [75]	2 [90]	1 [75]	3 [90]	1 [75]

Notes:

EXISTING SCHEDULES
Broadway (CR 551)
Saturday

		12 am – 12 am
1	Burlington St/Warren St	1 [75]
2	Essex St	[Free]
3	Mercer St	1 [75]
4	Hudson St/Chambers St	[Free]Note 1
5	Monmouth St	1 [75]
6	Champion Rd/Cumberland St	1 [75]
7	Market St	1 [75]
8	George St/Center St	[Free]Note 1
9	Koehler St	1 [75]

Notes: 1 - Programmed in scheduler to run a 75 second cycle coordinated plan but runs free to programming error

PROPOSED SCHEDULES
Broadway (CR 551)
Saturday

		12 am – 12 am
1	Burlington St/Warren St	1 [75]
2	Essex St	1 [75]
3	Mercer St	1 [75]
4	Hudson St/Chambers St	1 [75]
5	Monmouth St	1 [75]
6	Champion Rd/Cumberland St	1 [75]
7	Market St	1 [75]
8	George St/Center St	1 [75]
9	Koehler St	1 [75]

Notes:

EXISTING SCHEDULES
Broadway (CR 551)
Sunday

		12 am – 12 am
1	Burlington St/Warren St	1 [75]
2	Essex St	[Free]
3	Mercer St	1 [75]
4	Hudson St/Chambers St	[Free]Note 1
5	Monmouth St	1 [75]
6	Champion Rd/Cumberland St	1 [75]
7	Market St	1 [75]
8	George St/Center St	[Free]Note 1
9	Koehler St	1 [75]

Notes: 1 - Programmed in scheduler to run a 75 second cycle coordinated plan but runs free to programming error

PROPOSED SCHEDULES
Broadway (CR 551)
Sunday

		12 am – 12 am
1	Burlington St/Warren St	1 [75]
2	Essex St	1 [75]
3	Mercer St	1 [75]
4	Hudson St/Chambers St	1 [75]
5	Monmouth St	1 [75]
6	Champion Rd/Cumberland St	1 [75]
7	Market St	1 [75]
8	George St/Center St	1 [75]
9	Koehler St	1 [75]

Notes:

LEGEND
A white box indicates FREE operation, a shaded box indicates coordinated operation.
The first number specifies the pattern, the second number [in brackets] is the cycle length (s).
Darker shades represent a longer cycle length.

Figure 6
Day Plan Schedules
Broadway (CR 551)

4.5 Pattern Optimization

The list below summarizes each time period that was modeled and analyzed for this system and the overall peak hour that was determined from the volumes collected for this project. Within the network, however, each signal was optimized using volumes from its own individual peak hour within the period for which the pattern was designed to operate instead of the overall peak hour.

Time-of-Day	Abbreviation	Pattern No.	Network Peak Hour
Weekday AM Peak	AM	2	7:30 am – 8:30 am
Weekday Midday Peak	MD	1	11:45 am – 12:45 pm
Weekday PM Peak	PM	3	4:00 pm – 5:00 pm
Weekday PM Off-peak	PO	1	6:30 pm – 7:30 pm

Note that pattern 1 runs at all times other than the weekday AM and PM peak periods. Initially, the midday and PM off-peak were modeled separately but it was decided a single pattern could accommodate the traffic characteristics and volumes. So, these two time periods run the same timing plans but are modeled and analyzed separately in this report.

Cycle lengths were developed in an effort to balance optimal progression along Broadway (CR 551) and to limit the delay experienced by pedestrians and side street traffic. Even though some signals were operating in free operation under existing conditions, cycle lengths were selected in an effort to make the adjustment to coordinated timings as unnoticeable as possible to typical drivers on the network. At the intersection of Broadway (CR 551) & Mercer Street, westbound side street volumes were heavier than the southbound volumes, so that was accounted for in developing the progression design.

The existing cycle lengths for the coordinated signals was 75 seconds for all time periods but the existing cycle lengths were observed to be too short for the network at the peak times. So it was determined an increased cycle length would be appropriate for the AM and PM periods but the 75 second cycle could be maintained for the off-peak time period.

4.6 Phase Sequences

Phase sequence diagrams illustrate the phasing at each intersection as well as the sequences that are used with existing and implemented timing patterns. Sequence diagrams are shown in Figure 9 and Figure 10 on pages 26 – 27. For this project, there were no changes in phase sequence from existing to implemented conditions.

4.7 Pre-Implementation Memorandum

Once all timings were developed, the proposed timings were summarized in a series of figures and sent to Gloucester City and Camden County representatives for review. Initial timing directives were created reflecting the proposed timings and simple timing sheets were also developed to match the programming style and terminology in each controller. The provided Pre-Implementation Memorandum is included in the Report folder on the project website. An implementation plan was also proposed to Gloucester City and the consultant team scheduled the implementation.

5.0 SIGNAL TIMING IMPLEMENTATION

5.1 Controller Programming

After the basic timing parameters were updated, optimized signal timings were developed, and an updated day plan schedule was created, this information was coded into database files and tested with coordination diagnostic tools and test controllers where possible. For this system, the Econolite Aries Zone Manager software was utilized where possible for the ASC/2 and ASC/3 controllers on the network. For the LMD controllers, all programming was done by hand. Once each database was tested successfully, each database was downloaded to the local controllers on Wednesday, June 7, 2023. Following the initial downloads, the signals were observed for proper operation and each controller was observed to address any issues that could have occurred during the data transfer.

5.2 Fine-Tuning of Signal Timings

Each new timing plan was observed at each intersection at some point during its respective peak hour to ensure each phase split was appropriate for the traffic conditions present. At some intersections, fine-tuning may consist of simply increasing or decreasing a split for one or more phases. If a movement or intersection is over capacity, split adjustments may be required to manage queue spillback and blockage.

In addition to fine-tuning splits, offset adjustments often have a larger effect on the performance of the network. Offset adjustments at coordinated intersections were determined by conducting travel time runs along the corridor. Travel time runs were conducted using Tru-Traffic (v 10.0). Tru-Traffic, in conjunction with a direct connect GPS unit, tracks the location of the test vehicle within the traffic signal system. Because the software uses the actual traffic signal timing settings and an actual vehicle in the traffic stream, this fine-tuning tool can be powerful. This also provides the user dynamic information about the performance of the traffic signal system such as travel time and delay. Results of the travel time runs under existing signal timings (the “before” runs) and implemented signal timings (the “after” runs) are discussed in Section 6.4 of this report.

The fine-tuning process for this project took place over the course of a week and all signals were observed for proper and optimal operation during each time period, including the off-peak pattern on both Saturdays and Sundays. All changes to the proposed timings presented in the Pre-Implementation Memorandum were documented and updated in each model, timing sheet and timing directive. Once fine-tuning was completed and timings were finalized, timing directives were thoroughly reviewed for accuracy to match the controller programming and were placed in each local cabinet for reference during any maintenance visit that may occur in the future. The changes made during fine-tuning for this project were minor and included offset and phase allocation adjustments to balance optimal progression and side street operations.

6.0 TRAFFIC OPERATIONS ANALYSIS

Operations analysis was conducted, using the traffic models, on each of the periods with existing signal timings. This analysis established a benchmark by which traffic operations with implemented signal timings are compared. In addition to the models, travel time runs were conducted in the field to specifically measure the change in travel time and delay on the primary corridor.

6.1 Intersection Performance Measures

Synchro (v11) was used to determine the delay (in seconds per vehicle) for each lane group as well as the delay and level of service (LOS) for the intersection. SimTraffic was used to determine the delay for each movement and the intersection by averaging five, one-hour simulations. The intersection capacity utilization (ICU) was also determined for each intersection. The delay, LOS, and ICU for each intersection can be found in Figure 11 through Figure 19 on pages 28 – 36.

The figures illustrate traffic operations at the same intersection for the various periods and scenarios analyzed. The top row illustrates each period with existing hourly volumes. The second row illustrates each period with existing signal timings. The third row illustrates each period with implemented signal timings. The bottom row, if present, summarizes traffic operations for each period if recommended capacity improvements are made at the intersection. These recommended improvements are described in Section 8.2 of this report. This arrangement allows easy comparison of operations across all periods and scenarios.

In general, intersections may experience an increase in overall intersection delay when 1) the cycle length is significantly adjusted from its optimal cycle length to provide coordination, 2) green times are allocated with the objective of providing maximum progression on the major street or 3) green times are allocated to prevent queue spillback and blockage. Table 1, below, summarizes the number of intersections that experienced an increase or decrease in overall intersection delay during each period.

Table 1 – Summary of Changes in Intersection Delay

Number of intersections where:	AM	Midday	PM	PM Off-peak
delay decreased	7	9	8	8
delay increased ≤ 5 sec/veh	2	0	1	1
delay increased > 5 sec/veh	0	0	0	0

While delay largely decreased across all periods, there were several intersections where delay increased slightly. However, no intersections experienced a delay increase greater than 5 seconds/vehicle for any time period. The locations where delay increased slightly generally is caused by several factors, including increased clearance intervals, and converting a signal from free operation to coordinated operation. Free operation may result in reduced delay at single intersection but when coordinated across a network, delay is decreased for the overall system.

6.2 Network Performance Measures

While the figures in Section 6.1 summarize performance of each individual intersection by delay, LOS, and ICU, the tables in this section combine and summarize four performance measures for all intersections in the network: total delay, total stops, total travel time, and total fuel consumption. The tables also summarize the percent reduction of each measure, which illustrates the overall improvement to the network with the implemented signal timings. The performance measures were calculated (not field-measured) by two separate models, Synchro and SimTraffic. The models summarize data for all vehicles in the network. Network performance measures developed by Synchro and SimTraffic can be found below.

Table 2 – Broadway (CR 551) Synchro Network Performance Measures

	AM Peak			Midday Peak		
	Existing	Implemented	Difference	Existing	Implemented	Difference
Total Delay (hr)	36	31	-13.9%	26	20	-23.1%
Total Stops	3,708	3,093	-16.6%	3,280	2,706	-17.5%
Total Travel Time (hr)	65	60	-7.7%	52	47	-9.6%
Fuel Consumed (gal)	73	67	-8.2%	61	55	-9.8%
	PM Peak			PM Off-peak		
	Existing	Implemented	Difference	Existing	Implemented	Difference
Total Delay (hr)	101	55	-45.5%	21	16	-23.8%
Total Stops	5,598	4,300	-23.2%	2,647	2,111	-20.2%
Total Travel Time (hr)	142	96	-32.4%	43	38	-11.6%
Fuel Consumed (gal)	141	102	-27.7%	50	44	-12.0%

Table 3 – Broadway (CR 551) SimTraffic Network Performance Measures

	AM Peak			Midday Peak		
	Existing	Implemented	Difference	Existing	Implemented	Difference
Total Delay (hr)	36	28	-23.8%	23	18	-21.1%
Total Stops	3,107	2,690	-13.4%	2,729	2,236	-18.1%
Total Travel Time (hr)	78	68	-13.3%	58	53	-8.3%
Fuel Consumed (gal)	42	40	-6.6%	35	33	-4.3%
	PM Peak			PM Off-peak		
	Existing	Implemented	Difference	Existing	Implemented	Difference
Total Delay (hr)	64	42	-34.4%	16	13	-21.5%
Total Stops	5,317	3,632	-31.7%	2,080	1,704	-18.1%
Total Travel Time (hr)	122	98	-19.7%	45	42	-7.7%
Fuel Consumed (gal)	61	55	-9.8%	28	27	-4.0%

The overall network performance measures improved during all time periods in both Synchro and SimTraffic. Over the expected five-year life of the project and based upon calculated values, the implemented signal timing is estimated to reduce delay by 84,100 hours (33.7%), stops by 4,109,300 (19.8%), and fuel consumption by 77,600 gallons (17.5%). Based on the fuel savings above, the implemented signal timing is estimated to reduce carbon dioxide emissions by 700 metric tons over the life of the project. That estimate is calculated utilizing an equation developed by the US Environmental Protection Agency and factors in a number of the measures from Synchro.

6.3 Time-Space Diagrams

Time-space diagrams can be used as a tool for fine-tuning splits and offsets and maximizing corridor bandwidth and progression. Time-space diagrams for each of the implemented patterns for each roadway are included on the project website. These diagrams show the designed progression for each roadway and the relationship between intersections across the network.

6.4 Travel Time Runs

As stated in Section 2.5, travel time runs were conducted as a fine-tuning tool. In addition to fine-tuning, travel time runs also provide the analyst field-measured metrics such as delay and travel time reductions. While only travel time and delay are summarized here, information on other measures such as the number of stops, stopped delay, and average speed can be found on the project website.

Travel time runs for both directions on Broadway (CR 551) were conducted before and after the new signal timings were implemented. The average of the “existing” runs was compared to the average of the “implemented” runs to determine travel time savings on the corridor. These performance data are field-measured and apply only to vehicles on the main corridor. Figure 7 on page 19 illustrates the average cumulative travel time on the corridor for each direction with existing and implemented signal timings. The tables at the top of these figures summarize the average travel time and delays with existing and implemented signal timings and the percent change in those measurements.

Along Broadway (CR 551), travel time runs were completed between Burlington Street/Warren Street and Koehler Street. In the northbound direction, weekday travel times decreased by up to 120 seconds (40.0%) and weekend travel times decreased by up to 123 seconds (41.7%). In the southbound direction, weekday travel times decreased by up to 108 seconds (35.3%) and weekend travel times decreased by up to 73 seconds (27.2%).

During the travel time runs under both existing and implemented conditions, dash cam video was collected. Those videos were then processed into several comparison videos detailing the improvements across the network. Those videos are available on the project website and were developed for both the northbound and southbound directions for both the AM and PM peak periods on Broadway (CR 551).

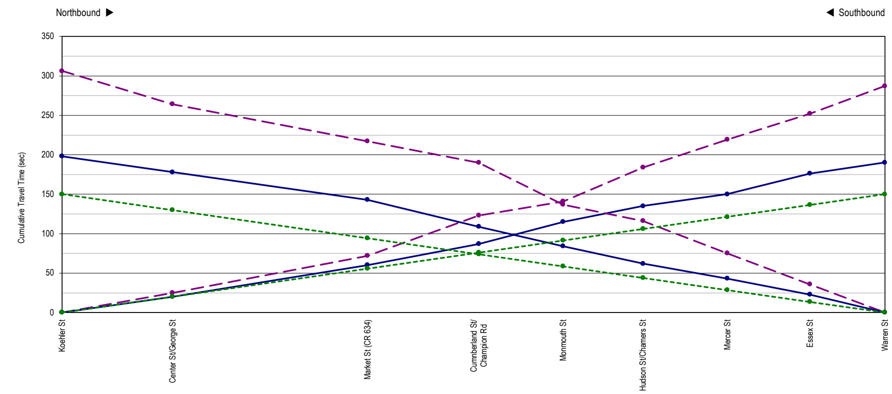
Average Total Travel Time & Delay

Broadway (CR 551): 1.1 miles

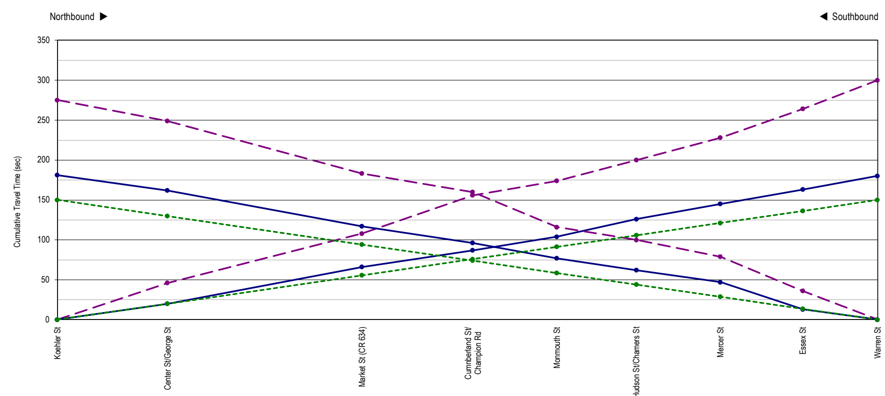
		AM Peak		Midday Peak		PM Peak		PM Off-peak		Weekend Midday Peak	
		Travel Time (s)	Delay (s)	Travel Time (s)	Delay (s)	Travel Time (s)	Delay (s)	Travel Time (s)	Delay (s)	Travel Time (s)	Delay (s)
Northbound	Existing	300	150	295	145	287	137	239	89	295	145
	Implemented	180	30	236	86	190	40	173	23	172	22
	Difference	-120		-59		-97		-66		-123	
	% Difference	-40.0%	-80.0%	-20.0%	-40.7%	-33.8%	-70.8%	-27.6%	-74.2%	-41.7%	-84.8%
Southbound	Existing	275	125	265	115	306	156	259	109	268	118
	Implemented	181	31	228	78	198	48	182	32	195	45
	Difference	-94		-37		-108		-77		-73	
	% Difference	-34.2%	-75.2%	-14.0%	-32.2%	-35.3%	-69.2%	-29.7%	-70.6%	-27.2%	-61.9%

Northbound: Koehler St to Warren St
Southbound: Warren St to Koehler St

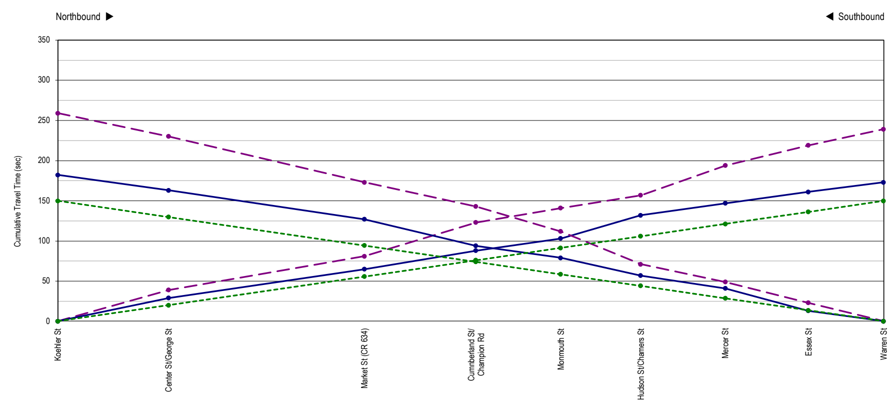
PM Peak



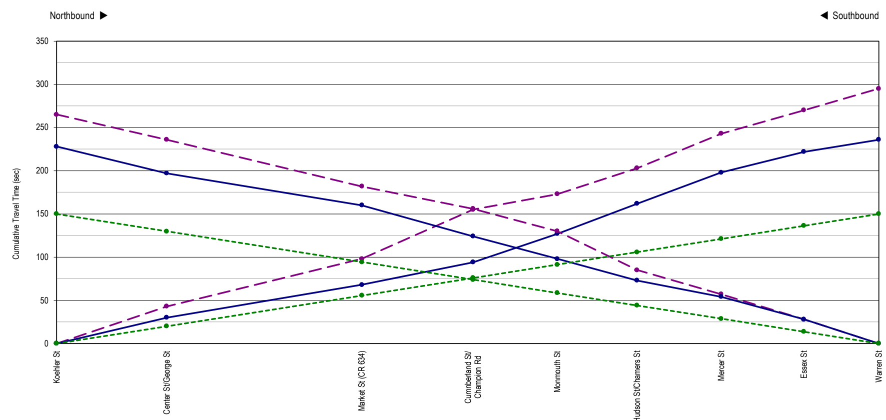
AM Peak



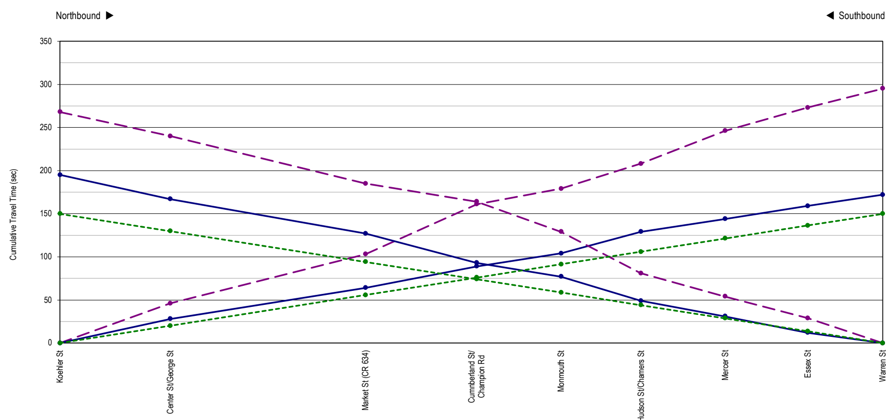
PM Off-peak



Midday Peak



Weekend Midday Peak



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CAMDEN COUNTY NEW JERSEY INC. 1844

iteris®

Existing
Implemented
Free Flow

Figure 7

Average Travel Time & Delay

Broadway (CR 551)

7.0 TRAFFIC SIGNAL RETIMING BENEFIT-COST ANALYSIS

The purpose of this analysis is to establish a project's merit by economically quantifying the benefits and costs associated with the project over its lifetime. According to the ITE, "signal retiming is a beneficial method for maintaining efficient traffic signal operations" and "is the most cost-effective technique to reduce congestion, improve air quality, and potentially reduce accidents." The following discusses the methodology used to determine the benefits and costs of implementing new signal timings at the intersections within the scope of this project.

There are two types of benefits as they relate to transportation improvements. User benefits, or direct benefits, are enjoyed directly by travelers and are determined by a reduction in three distinct travel costs: travel time costs, operating costs, and crash costs. The second type of benefit is non-user benefits, or indirect benefits. These benefits include environmental impacts, air quality, and reduced motorist frustration.

While improved signal timing reduces certain types of crashes, it is difficult to determine the actual reduction without collecting several years of data. Therefore, this analysis assumes the number of crashes will remain constant throughout the life of the project. However, it should be noted that the implemented signal timing and updated clearance intervals may reduce the frequency of some types of crashes at all intersections. Studies reported by the Federal Highway Administration have shown that total crashes are reduced by an average of 15% through retiming; and right-angle crashes reduced by an average of 25% to 32%.

7.1 Travel Time & Operations Benefit-Cost Analysis

Travel time benefits were calculated by modeling delay with existing and implemented signal timings during each hour modeled within Synchro. Each pattern modeled analyzes only the single peak hour for each time period, so benefits were also estimated for non-peak hours during which implemented timings are in coordinated operation. The total delay was multiplied by a value-of-time and auto occupancy to determine the total weekly benefit as a result of reduction in travel time as shown in Table 4 below. The value of time is determined from the Consumer Price Index while the heavy vehicle percentage of three percent on this system was estimated based on the turning movement count data collected in this project, which includes volume counts by classification.

Table 4 – Weekly Benefit for Change in Travel Time Costs – Broadway (CR 551)

Delay (h)	AM	MD	PM	PO
Existing Timings	36	26	101	21
Implemented Timings	31	20	55	16
Change	-5	-6	-46	-5
Estimated Change during other hours				-46
Total Daily Change				-108
Total Weekly Change in Delay				-540
			Auto	Truck
		Vehicle Type	92%	8%
		Value-of-Time ($/hr) [1 2]	$11.12	$114.99
		Auto Occupancy [1]	1.25	1.00
		Total	$6,905	$4,967
Weekly Benefit for Change in Travel Time Costs				**$11,873**

[1] *Taken from* Urban Mobility Report, *Texas Transportation Institute, 2012 and adjusted based on Consumer Price Index*

[2] *Adjusted for trip type per AASHTO* User Benefit Analysis for Highways, *2003*

Benefits for the reduction in operating costs were calculated by modeling fuel consumption within Synchro with existing and implemented signal timings during each peak hour and estimating fuel consumption during non-peak hours. The total change in fuel consumption was multiplied by the twelve-month average fuel cost from the US Energy Information Administration (EIA) for the Central Atlantic Region where this corridor is located. The weekly benefit for change in operating costs is shown in Table 5 on page 21.

Table 5 – Weekly Benefit for Change in Operating Costs – Broadway (CR 551)

Fuel Consumption (gal)	AM	MD	PM	PO
Existing Timings	73	61	141	50
Implemented Timings	67	55	102	44
Change	-6	-6	-39	-6
Estimated Change during other hours				-43
Total Daily Change				-100
Total Weekly Change				-500
Fuel Cost [3]				$3.71
Weekly Benefit for Change in Operating Costs				**$1,856**

3 52-week average fuel cost, US Energy Information Administration Gasoline Prices for the Central Atlantic Region, June 2023 - www.eia.gov

Based on the previous tables, the total weekly benefit is $13,729.

In order to calculate the total lifetime benefit present value, it was assumed the life of this project will be five years even though the benefit should long outlive that period. As with most of estimates made in the benefit section, the analysis used conservative values, so actual benefits are likely much higher. A discount rate of 3% was used for this estimate. It was also assumed that 100% of the total daily benefit will be realized in Year 1. However, as traffic volumes change, the benefits will decrease. Therefore, benefits in subsequent years are reduced by 20% each year. Table 6 summarizes the present values of annual benefits.

Table 6 – Present Value of Annual Benefits

Year	Annual Benefit Present Value
Year 1	$703,105
Year 2	$546,101
Year 3	$397,646
Year 4	$257,376
Year 5	$124,940

The present value of total lifetime benefits based on the table above is approximately $2,029,200.

Costs

The total cost to conduct all the tasks for the intersections within the scope of this project was $82,872.

Benefit-Cost Ratio

Comparing the anticipated benefits from savings in travel time and operating costs to the overall project costs, the anticipated benefit-cost ratio for this project is 24:1.

8.0 RECOMMENDATIONS

8.1 Recommendations for Safety Improvements

Based on the field observations in Section 2.0, the following improvements are recommended to mitigate potentially hazardous conditions.

General Recommendations

- A thorough list of pedestrian detection issues relating to pedestrian displays and crosswalks is included within the Appendix in Figure 8 on page 25. That list is accurate as of June 2023, so could change in the meantime but consider utilizing that list to update and address all pedestrian display issues to improve pedestrian safety and consistency.
- As controllers or cabinet components are upgraded in the future, ensure the timings developed in this project are utilized in the new controllers programming. All critical programming entries are in the timing sheets and directives placed in each cabinet. When controllers are replaced, ensure the controller clocks are set when operational so the background coordinated timings can run as designed through this project.

Broadway (CR 551) & Monmouth Street

- Consider replacing the controller at this intersection since the display had intermittently gone black and was unresponsive. The controller worked through the completion of this project but some of the programming had to be done via Aries Zone Manager and not directly through the controller since the screen was not functional.

Broadway (CR 551) & Market Street (CR 634)

- Consider reviewing and potentially replacing the cabinet at this location since over the entirety of this project, the top portion of the cabinet was very loose. It was tightened at some point in the project between the field notes and the completion of the project, but the top portion was still quite loose on final review, so could have issues with high wind conditions and potentially break off over time.

Broadway (CR 551) & Center Street/George Street

- Consider reviewing and potentially removing the 'STOP' painting in the pavement behind the stop bar for the eastbound (phase 4) approach. Since this approach is signalized, the direction is ignored by drivers and is inconsistent with other intersections throughout this area.

8.2 Recommendations for Capacity and Operational Improvements

Beyond optimizing traffic signal timing, other improvements such as additional capacity can further improve the performance of an intersection and roadway network. Additional consideration should be given to improvements required by future traffic growth and costs of right-of-way, design, construction, etc. However, these considerations are not included in the scope of this project.

General Recommendations

- Consider installing GPS units to all cabinets to keep all controller clocks on a consistent time source. Where there are no GPS units installed and there is no central communication system, as is the case with all cabinets on the network, controller clocks will drift over time. This will gradually reduce the effectiveness of the signal timings and increase the potential for running timings that are not intended from the controller programming. The installation of GPS units would keep all controllers on the same time and will maintain the timings as programmed through this project and as shown on the updated timing directives. If this is not feasible, consider developing a plan to manually set controller clocks regularly every six to eight weeks, or as often as possible. This could also be added to any regular preventative maintenance program already in place for these signals.

- Consider reviewing and potentially adding vehicle detection at strategic locations along the network. At the completion of this project, there was no vehicle detection at any of the signals within this network. Certain locations could be improved significantly with the addition of detection. Note that pedestrian pushbuttons would also be required to fully remove recalls from side street movements since all pedestrian movements service each cycle under existing conditions. The intersections where adding vehicle and pedestrian detection would have the greatest impact are as follows:
    1. Broadway (CR 551) & Market Street (CR 634)
        - This is the critical intersection on this network, so adding detection could allow for the green time on each movement to be more optimally distributed.
    2. Broadway (CR 551) & Hudson Street/Chambers Avenue
        - This signal has two side street phases, meaning there are two completely separate movements that must service each cycle sequentially. During peak periods, this creates queuing along Broadway (CR 551), so adding side street detection could allow the controller to only service those movements when demand is present, which would reduce main street delays.
    3. Broadway (CR 551) & Burlington Street/Warren Street
        - Similar to Hudson Street/Chambers Avenue, there are two sequential side street phases at this intersection. So main street delays are long while waiting for those movements to service and that time could be better distributed if there were detection added.
    4. Broadway (CR 551) & Essex Street
        - This intersection is where Interstate 76/Interstate 676 can enter this system. Adding detection and adjusting programming could allow for servicing diversion traffic more efficiently as spikes in traffic are more common at this location.
    5. Broadway (CR 551) & George Street/Center Street
        - This intersection also has two side street sequential phases, so potentially adding detection would reduce the main street delay and allow for better progression for the heavier movements along Broadway (CR 551).
    6. All other intersection would benefit as well with the implementation of detection, but the other intersections not listed are minor in comparison and only have one side street phase, so main street delays are relatively minimal.

- As this system continues to develop in the future, consider the impact any changes may have to the signal timings for activities such as replacing controllers, upgrading equipment, new developments, or any roadway adjustments.

9.0 APPENDIX

Included in the Appendix within this report are as follows:

- Field Notes Summary with detailed list of detection and operational issues found during project (Figure 8)
- Phase Sequence Diagrams (Figure 9 – Figure 10)
- Traffic Operations Analysis figures (Figure 11 – Figure 19)

Documents included on the project website:

- 7-day, 24-hour directional raw volume counts
- Turning movement counts
- Clearance calculations
- Existing and implemented timing sheets
- Existing and implementing timing directives
- Intersection cabinet, approach, and aerial photographs
- Field notes
- Synchro models with existing and implemented signal timings and report files
- Tru-Traffic files and travel time reports displaying time-space diagrams with implemented signal timings
- Travel time run comparison videos
- Final report

Full NJ Signal Retiming Project URL is as follows:
https://iterisinc1.sharepoint.com/sites/CS-Ext-NJSignalTiming

Individual Project page under Project Page section:
Broadway (CR 551) - Camden County

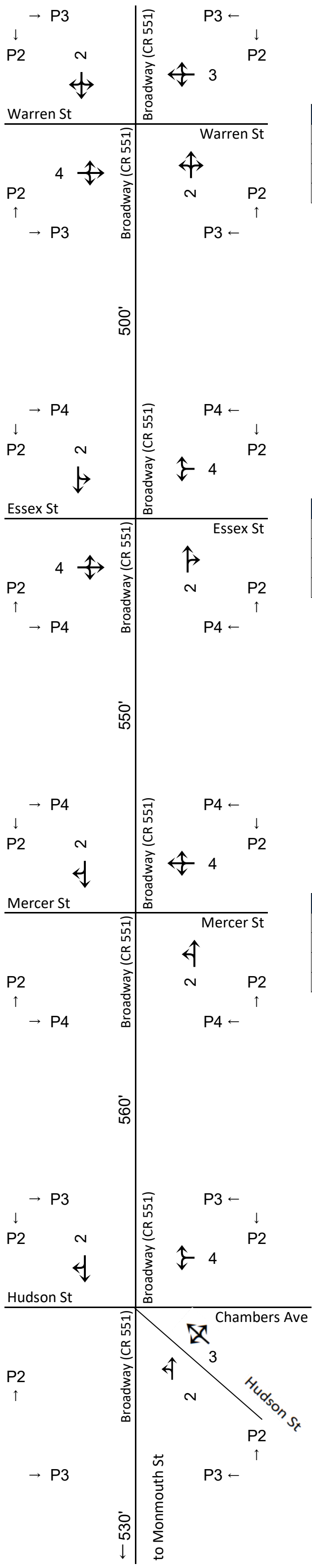
Please note that permissions must be manually added to access SharePoint website, so please direct any requests for access to Brian Jatzke at bjatzke@iteris.com.

ID	Intersection	Date of Last Observation	Controller Type	Notes and observations from Field Notes *Directionality Notes: CR 551 assumed North-South throughout network*
1	Broadway (CR 551) & Burlington St/Warren St	06/27/2023	LMD 9200	No vehicle or pedestrian detection Pedestrian signal heads for pedestrian phase 2 (northbound+southbound) either dim or out (both facing north direction). Also pedestrian head for phase 4 (eastbound) on southwest corner either very dim or fully out.
2	Broadway (CR 551) & Essex St	06/27/2023	Econolite ASC/3	No vehicle or pedestrian detection. There is loop amplifier for the westbound movement but it is not operational. Eastbound pedestrian (phase 4) signal head on southwest corner very dim for HAND display. Looked to be completely out during implementation.
3	Broadway (CR 551) & Mercer St	06/27/2023	LMD 9200	No vehicle or pedestrian detection. Eastbound pedestrian head on southeast corner very dim or completely out. Pedestrian signal head on northeast corner HAND display is out.
4	Broadway (CR 551) & Hudson St/Chambers St	06/27/2023	LMD 9200	No vehicle or pedestrian detection. Westbound (phase 4) pedestrian head on northeast corner both tilted away from crosswalk. Both westbound pedestrian heads on northeast and northwest corners both hand and walk displays out. Southbound (phase 2) pedestrian display on southwest corner has Hand display out.
5	Broadway (CR 551) & Monmouth St	06/27/2023	Econolite ASC/2	No vehicle or pedestrian detection. Pedestrian head for westbound movement on northwest corner hand display out. Controller screen completely unresponsive and blacked out. Screen was functional at times earlier in project but could not get to work or come off a black screen during implementation. Had to set clocks via Aries program.
6	Broadway (CR 551) & Champion Rd/Cumberland St	06/27/2023	Econolite ASC/2	No vehicle or pedestrian detection. Pedestrian display for eastbound (phase 4) movement hand display is out. Same issue for the pedestrian phase 4 display on the northwest corner.
7	Broadway (CR 551) & Market St (CR 634)	06/27/2023	Econolite ASC/3	No vehicle or pedestrian detection. At time of observation, cabinet very loose but better than what was observed during field notes. Pedestrian display for eastbound (phase 4) has hand display out on both corners. Southbound signal head for phase 6 on northwest corner is tilted away from crosswalk, so just needs to be turned to the proper direction.
8	Broadway (CR 551) & George St/Center St	06/27/2023	LMD 9200	No vehicle or pedestrian detection. Pedestrian phase 2 (northbound+southbound) display on northeast corner has both WALK and HAND displays out and tilted away from crosswalk. Display for pedestrian phase 2 on southeast corner WALK display not illuminating. Display for pedestrian phase 2 on southwest corner has HAND display out. Pedestrian phase 4 (eastbound) display on northwest corner blocked by southbound pedestrian display. There is 'STOP' painted in roadway for a signalized movement for the eastbound approach.
9	Broadway (CR 551) & Koehler St	06/27/2023	LMD 9200	No vehicle or pedestrian detection. Pedestrian display for southbound (phase 2) pedestrian movement on southeast corner very dim, cannot see during daytime. Red ball out for northbound movement outside 3-section signal head from mast arm based on the southwest corner.

Figure 8

Field Notes Summary (Post Implementation)

Broadway (CR 551)

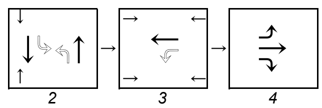


Signal ID: 1

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1

SEQUENCE 1



Signal ID: 2

Sequences

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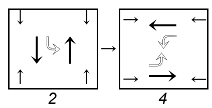
AM	1	1
MD	1	1
PM	1	1
PO	1	1

SEQUENCE 1

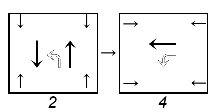


Signal ID: 3

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1

SEQUENCE 1

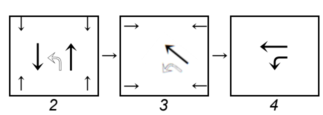


Signal ID: 4

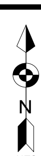
Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1

SEQUENCE 1



Note: 5-legged intersection, Chambers Ave considered Southwestbound movement while Hudson St is considered eastbound-westbound



Permissive Movement

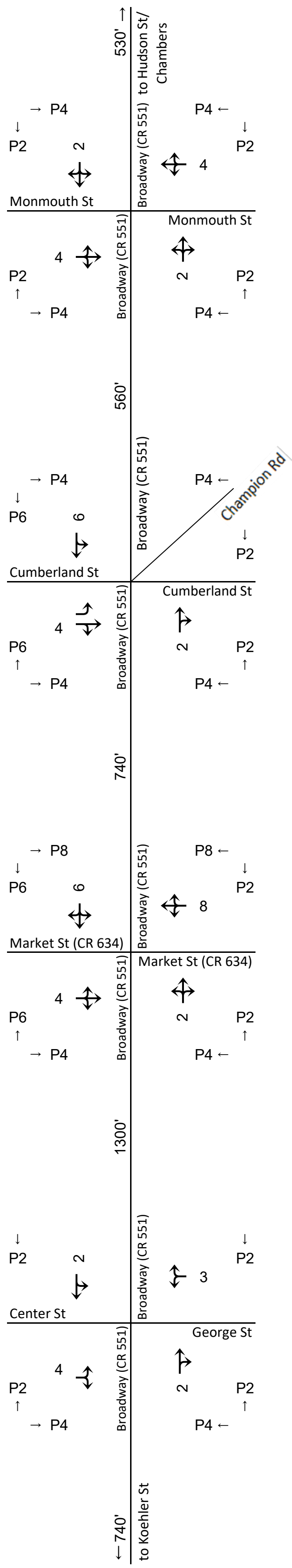
Protected + Permissive Movement

Protected-Only Movement

Figure 9

Phase Sequence Diagrams

Broadway (CR 551) - Burlington St/Warren St to Hudson St/Chambers Ave

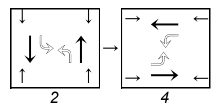


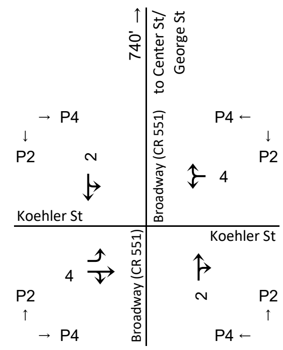
Signal ID: 5

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1

SEQUENCE 1



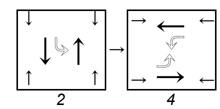


Signal ID: 9

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1

SEQUENCE 1

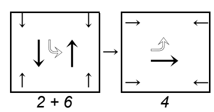


Signal ID: 6

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1

SEQUENCE 1

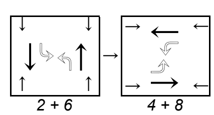


Signal ID: 7

Sequences

Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1

SEQUENCE 1

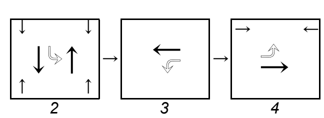


Signal ID: 8

Sequences

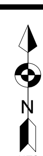
Per	Ex	Imp
AM	1	1
MD	1	1
PM	1	1
PO	1	1

SEQUENCE 1



DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

iteris



Permissive Movement

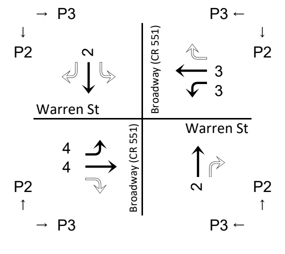
Protected + Permissive Movement

Protected-Only Movement

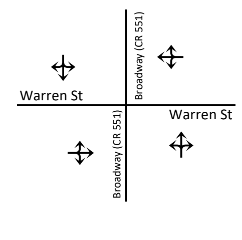
Figure 10

Phase Sequence Diagrams

Broadway (CR 551) - Monmouth St to Koehler St

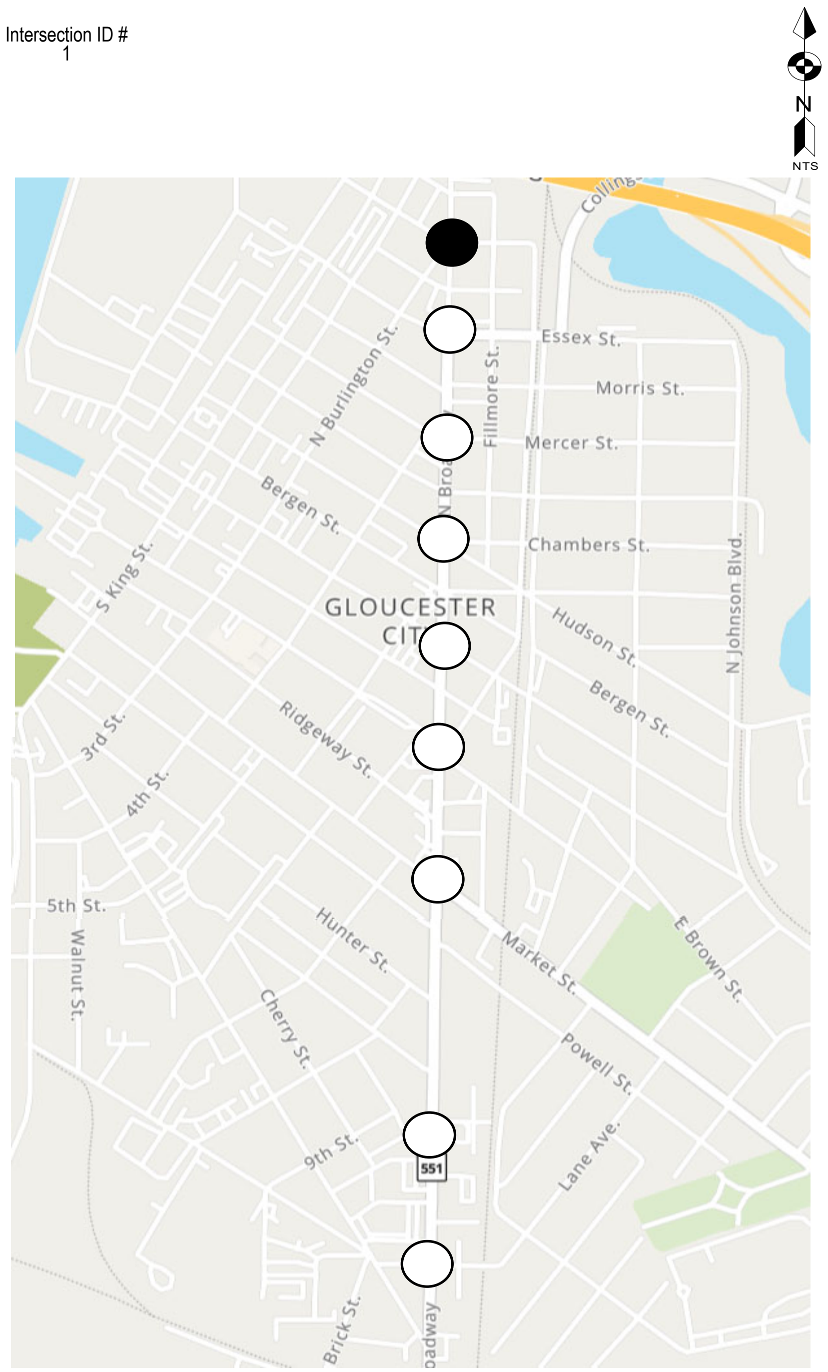


Phasing Diagram



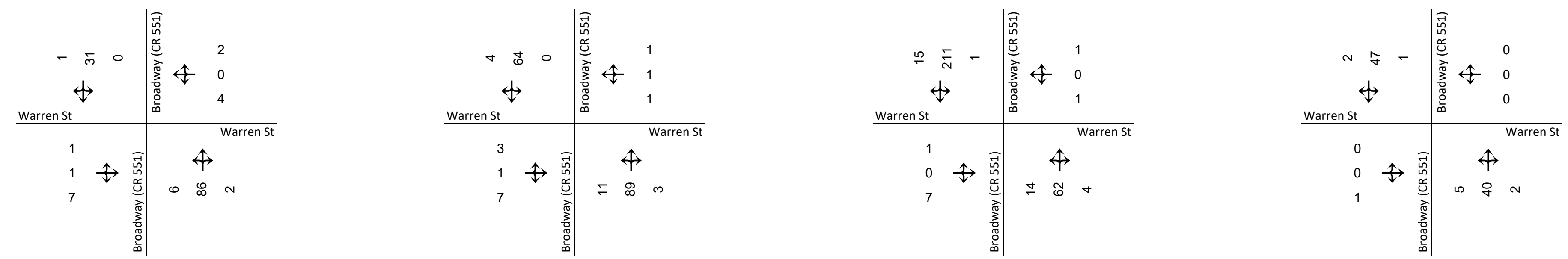
Intersection Geometry

Intersection ID #
1

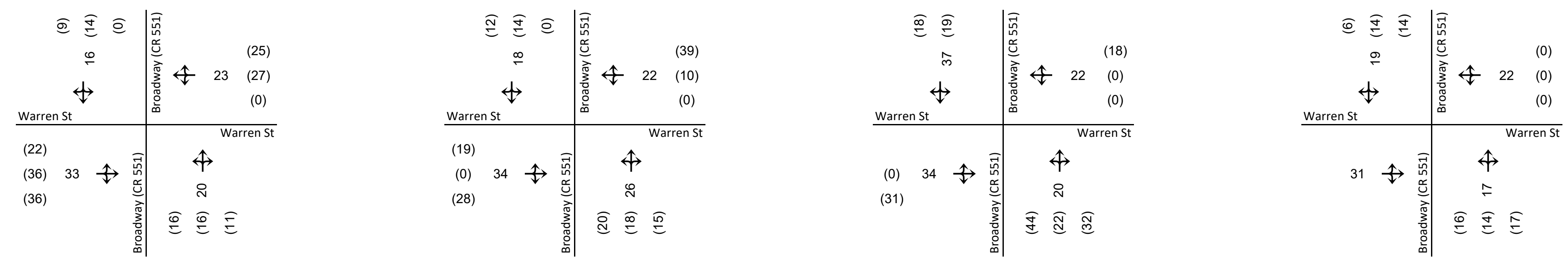


AM Peak	Midday Peak	PM Peak	PM Off-peak

Hourly Volumes



Existing Operations



AM Peak – Summary

Timing Pattern	1	Syn Delay	20	B
Actuated Cycle	75	Sim Delay	(17)	
Max v/C	0.37	ICU	37%	A

Midday Peak – Summary

Timing Pattern	1	Syn Delay	24	C
Actuated Cycle	75	Sim Delay	(17)	
Max v/C	0.60	ICU	38%	A

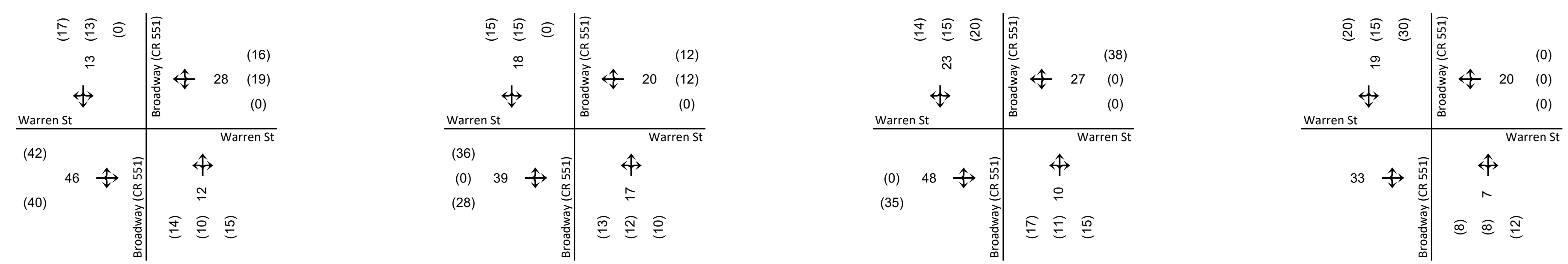
PM Peak – Summary

Timing Pattern	1	Syn Delay	32	C
Actuated Cycle	75	Sim Delay	(21)	
Max v/C	0.81	ICU	44%	A

PM Off-peak – Summary

Timing Pattern	1	Syn Delay	18	B
Actuated Cycle	75	Sim Delay	(15)	
Max v/C	0.33	ICU	30%	A

Implemented Operations



AM Peak – Summary

Timing Pattern	1	Syn Delay	16	B
Actuated Cycle	90	Sim Delay	(13)	
Max v/C	0.30	ICU	35%	A

Midday Peak – Summary

Timing Pattern	2	Syn Delay	19	B
Actuated Cycle	75	Sim Delay	(14)	
Max v/C	0.60	ICU	36%	A

PM Peak – Summary

Timing Pattern	3	Syn Delay	21	C
Actuated Cycle	90	Sim Delay	(15)	
Max v/C	0.64	ICU	42%	A

PM Off-peak – Summary

Timing Pattern	4	Syn Delay	15	B
Actuated Cycle	75	Sim Delay	(12)	
Max v/C	0.33	ICU	32%	A

Operations with Improvements

No operational improvements recommended at this time.

DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

CAMDEN COUNTY NEW JERSEY INC. 1844

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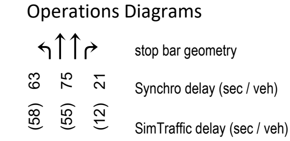
HCM Levels of Service

LOS	Delay/Veh (s)
A	≤10
B	>10 and ≤20
C	>20 and ≤35
D	>35 and ≤55
E	>55 and ≤80
F	>80

ICU Levels of Service

LOS	Utilization (%)
A	≤55%
B	>55% and ≤64%
C	>64% and ≤73%
D	>73% and ≤82%
E	>82% and ≤91%
F	>91% and ≤100%
G	>100% and ≤109%
H	>109%

Operations Diagrams



Hourly Volume Diagrams

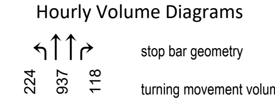
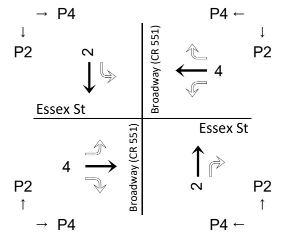


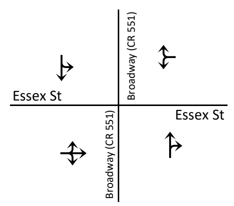
Figure 11

Traffic Operations Analysis

Broadway (CR 551) & Burlington St/Warren St

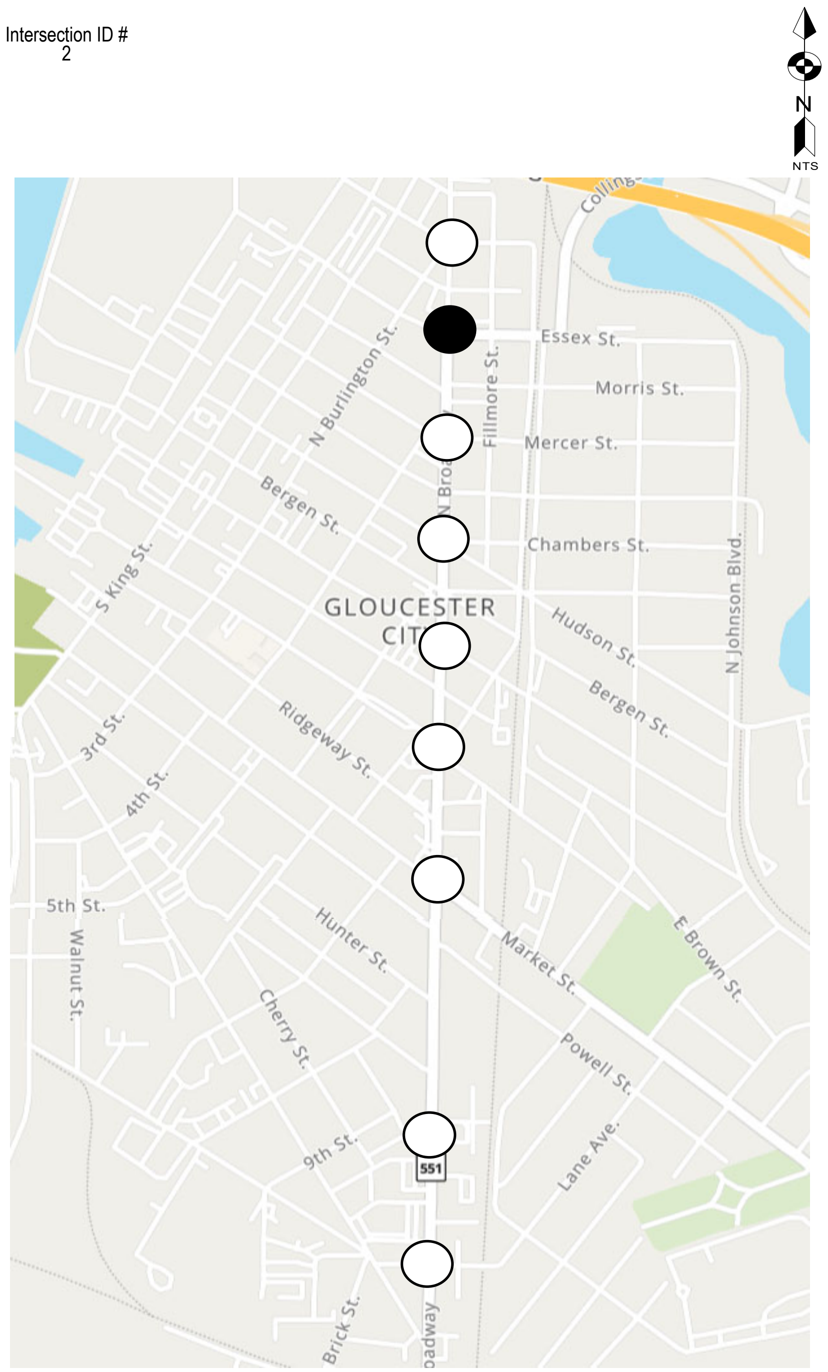


Phasing Diagram



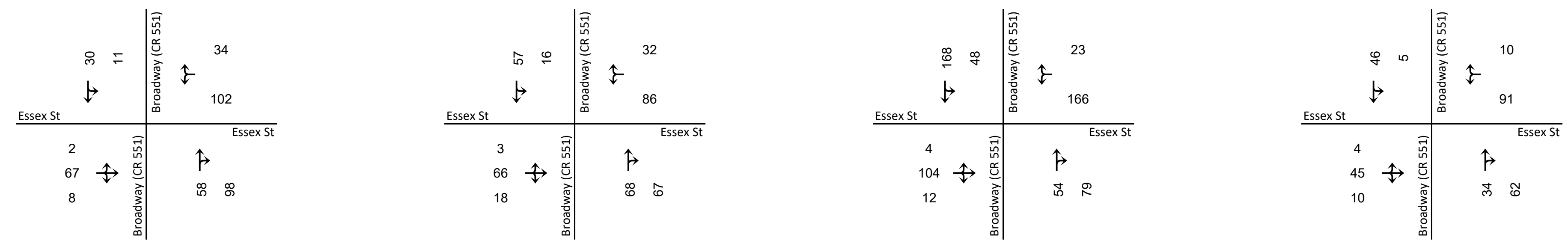
Intersection Geometry

Intersection ID #
2

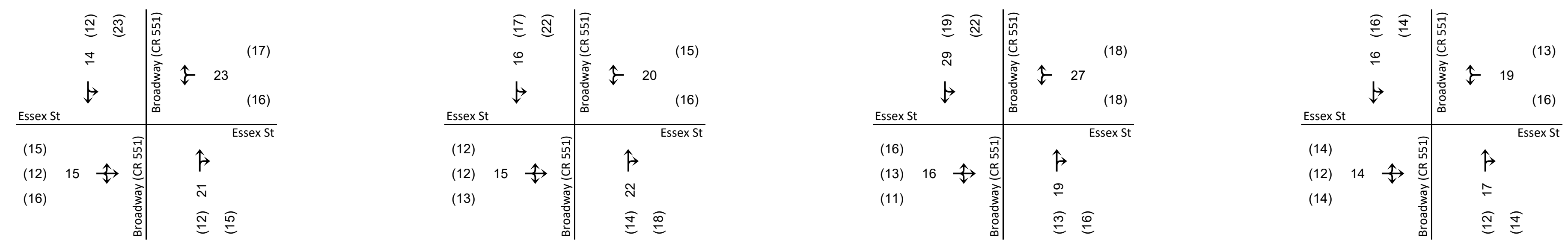


AM Peak	Midday Peak	PM Peak	PM Off-peak

Hourly Volumes

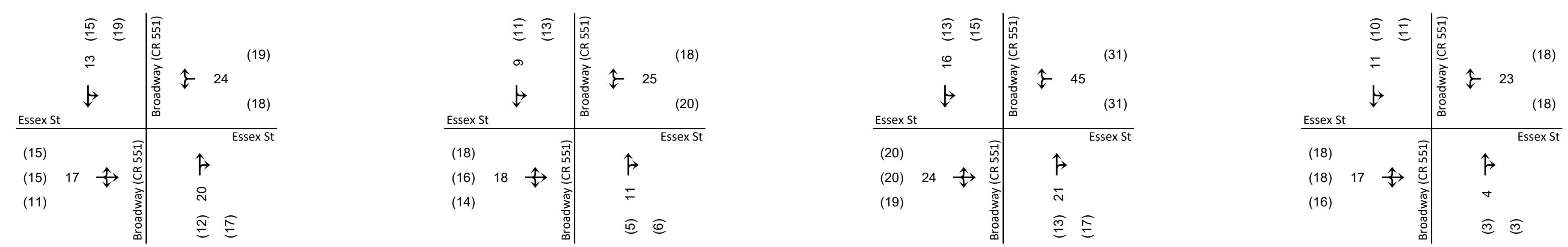


Existing Operations



Summary	AM Peak				Midday Peak				PM Peak				PM Off-peak			
Timing Pattern	FREE	Syn Delay	20	B	FREE	Syn Delay	19	B	FREE	Syn Delay	24	C	FREE	Syn Delay	17	B
Actuated Cycle	72	Sim Delay	(14)		72	Sim Delay	(15)		72	Sim Delay	(17)		72	Sim Delay	(14)	
Max v/C	0.56	ICU	44%	A	0.56	ICU	51%	A	0.73	ICU	77%	D	0.42	ICU	35%	A

Implemented Operations



Summary	AM Peak				Midday Peak				PM Peak				PM Off-peak			
Timing Pattern	1	Syn Delay	20	C	2	Syn Delay	15	B	3	Syn Delay	26	C	4	Syn Delay	13	B
Actuated Cycle	90	Sim Delay	(16)		75	Sim Delay	(12)		90	Sim Delay	(19)		75	Sim Delay	(11)	
Max v/C	0.54	ICU	46%	A	0.53	ICU	53%	A	0.78	ICU	81%	D	0.47	ICU	39%	A

Operations with Improvements

No operational improvements recommended at this time.

DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

CAMDEN COUNTY NEW JERSEY INC. 1844

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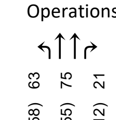
HCM Levels of Service

LOS	Delay/Veh (s)
A	≤10
B	>10 and ≤20
C	>20 and ≤35
D	>35 and ≤55
E	>55 and ≤80
F	>80

ICU Levels of Service

LOS	Utilization (%)
A	≤55%
B	>55% and ≤64%
C	>64% and ≤73%
D	>73% and ≤82%
E	>82% and ≤91%
F	>91% and ≤100%
G	>100% and ≤109%
H	>109%

Operations Diagrams

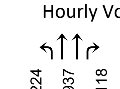


stop bar geometry

Synchro delay (sec / veh)

SimTraffic delay (sec / veh)

Hourly Volume Diagrams



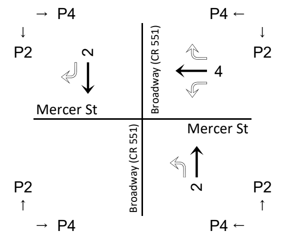
stop bar geometry

turning movement volume

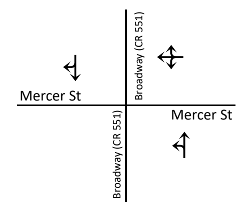
Figure 12

Traffic Operations Analysis

Broadway (CR 551) & Essex St

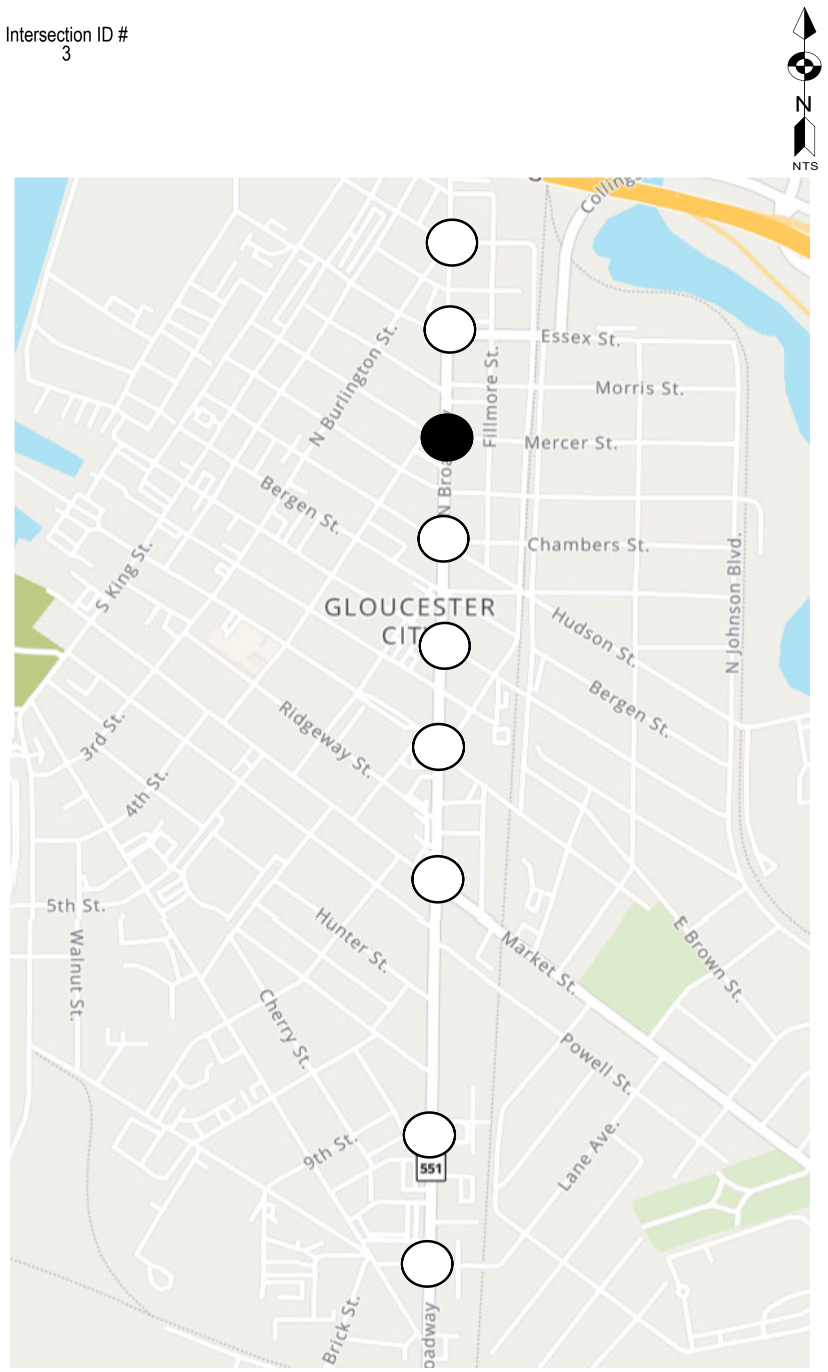


Phasing Diagram



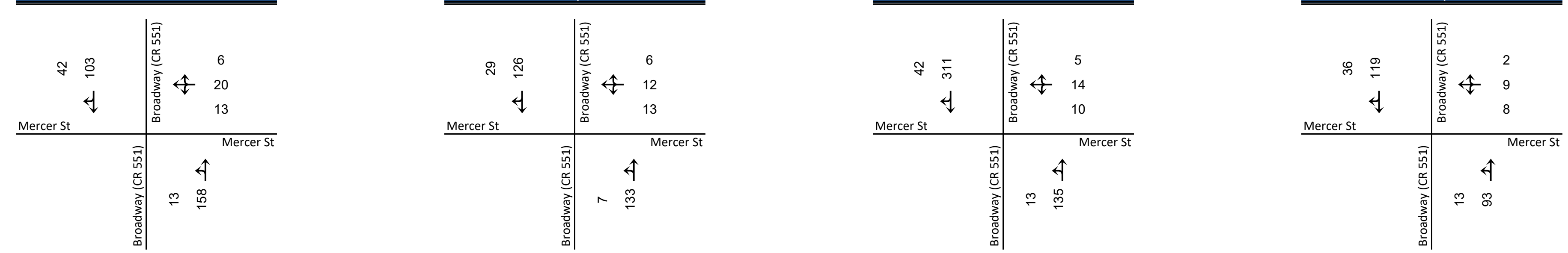
Intersection Geometry

Intersection ID #
3

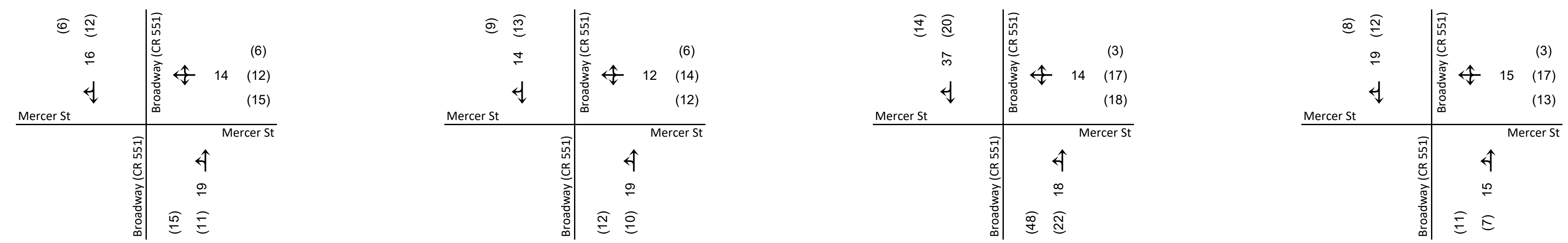


AM Peak	Midday Peak	PM Peak	PM Off-peak

Hourly Volumes

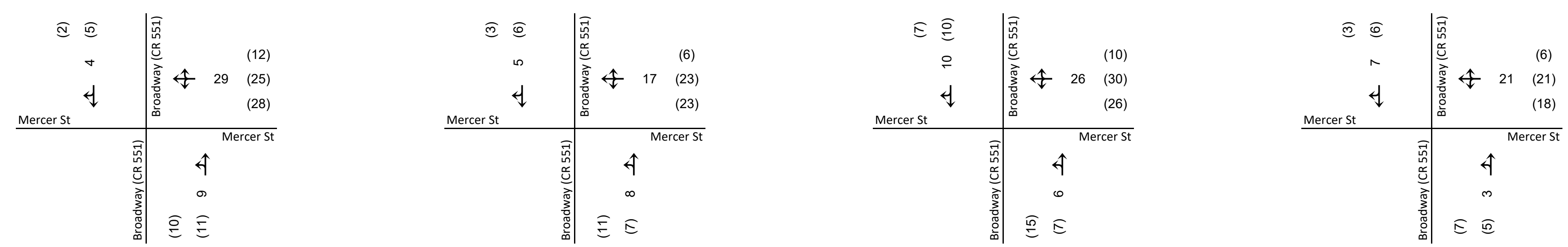


Existing Operations



Summary	AM Peak			Midday Peak			PM Peak			PM Off-peak		
Timing Pattern	1	Syn Delay	17 B	1	Syn Delay	16 B	1	Syn Delay	29 C	1	Syn Delay	17 B
Actuated Cycle	75	Sim Delay	(11)	75	Sim Delay	(11)	75	Sim Delay	(20)	75	Sim Delay	(10)
Max v/C	0.52	ICU	50% A	0.53	ICU	41% A	0.88	ICU	54% A	0.60	ICU	44% A

Implemented Operations



Summary	AM Peak			Midday Peak			PM Peak			PM Off-peak		
Timing Pattern	1	Syn Delay	10 A	2	Syn Delay	8 A	3	Syn Delay	10 A	4	Syn Delay	7 A
Actuated Cycle	90	Sim Delay	(9)	75	Sim Delay	(8)	90	Sim Delay	(10)	75	Sim Delay	(6)
Max v/C	0.37	ICU	49% A	0.42	ICU	40% A	0.63	ICU	53% A	0.48	ICU	43% A

Operations with Improvements

No operational improvements recommended at this time.

HCM Levels of Service

LOS	Delay/Veh (s)
A	≤10
B	>10 and ≤20
C	>20 and ≤35
D	>35 and ≤55
E	>55 and ≤80
F	>80

ICU Levels of Service

LOS	Utilization (%)
A	≤55%
B	>55% and ≤64%
C	>64% and ≤73%
D	>73% and ≤82%
E	>82% and ≤91%
F	>91% and ≤100%
G	>100% and ≤109%
H	>109%

Operations Diagrams

↰↑↑↱	stop bar geometry
63 75 21	Synchro delay (sec / veh)
(58) (55) (12)	SimTraffic delay (sec / veh)

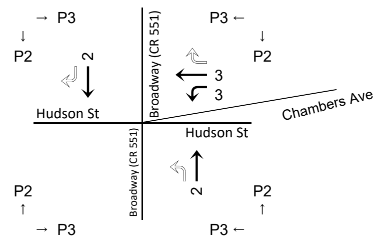
Hourly Volume Diagrams

↰↑↑↱	stop bar geometry
224 937 118	turning movement volume

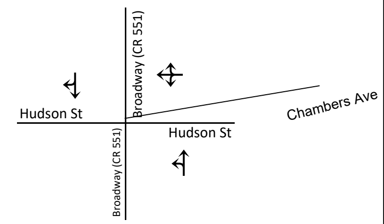
Figure 13

Traffic Operations Analysis

Broadway (CR 551) & Mercer St

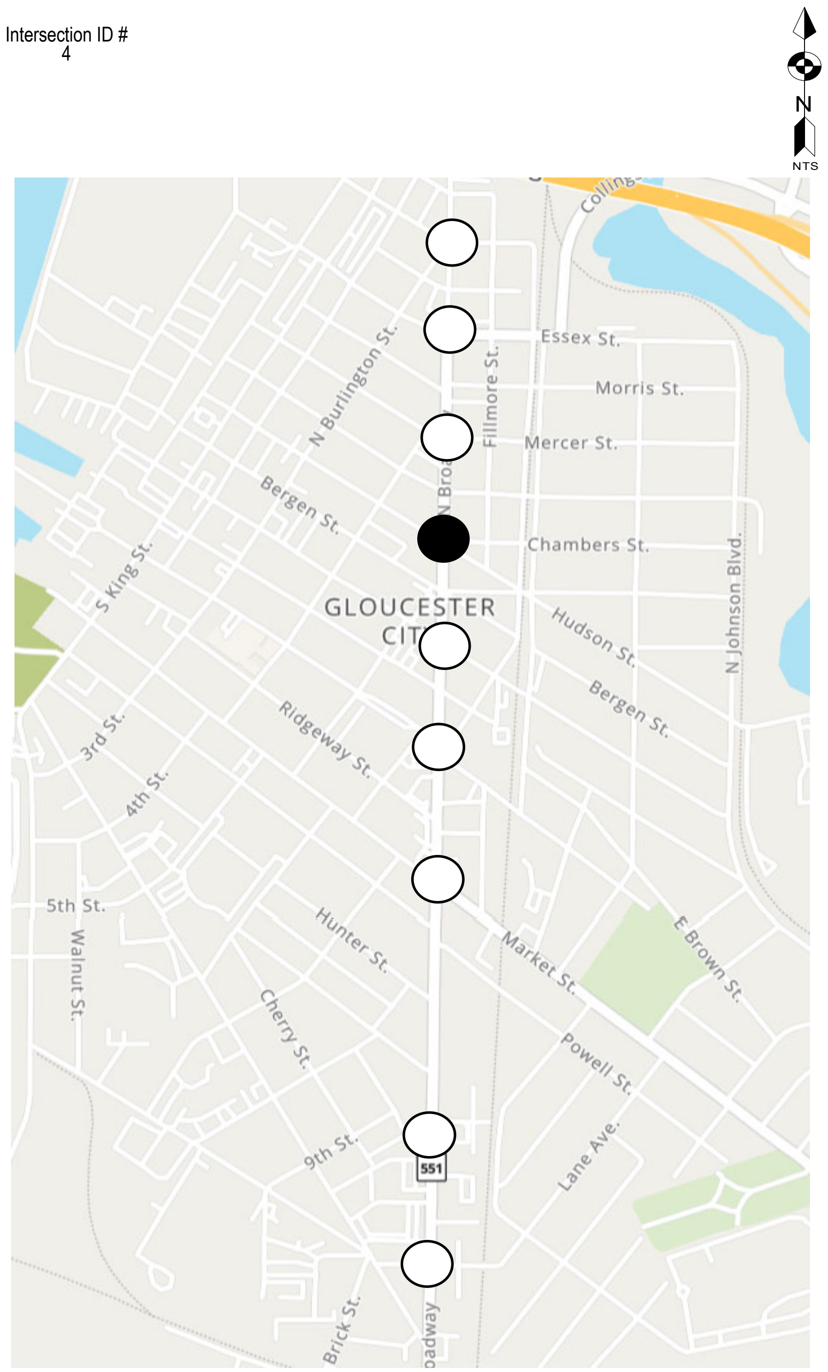


Phasing Diagram



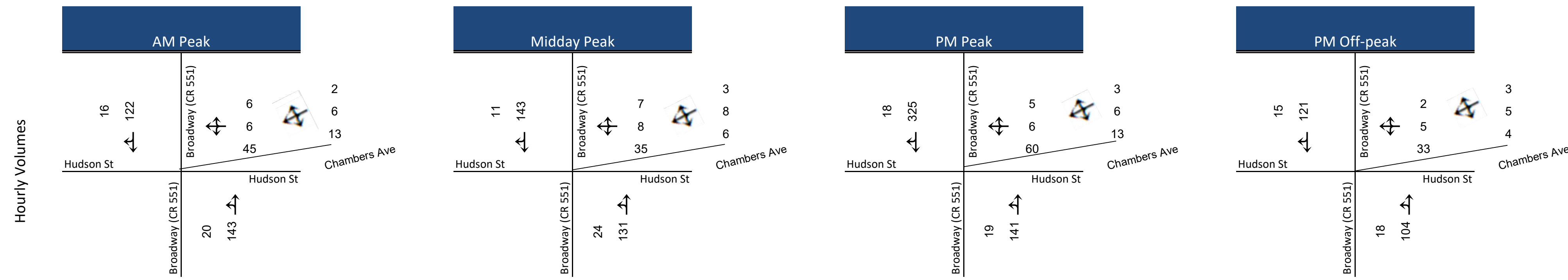
Intersection Geometry

Intersection ID #
4

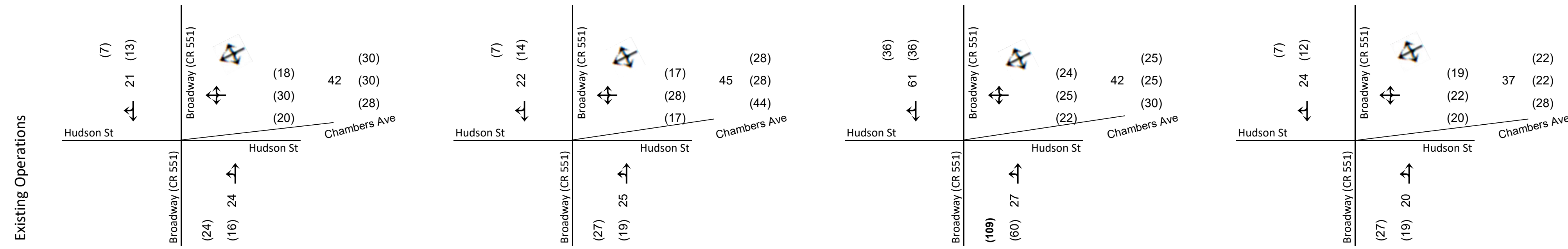


AM Peak | Midday Peak | PM Peak | PM Off-peak

Hourly Volumes

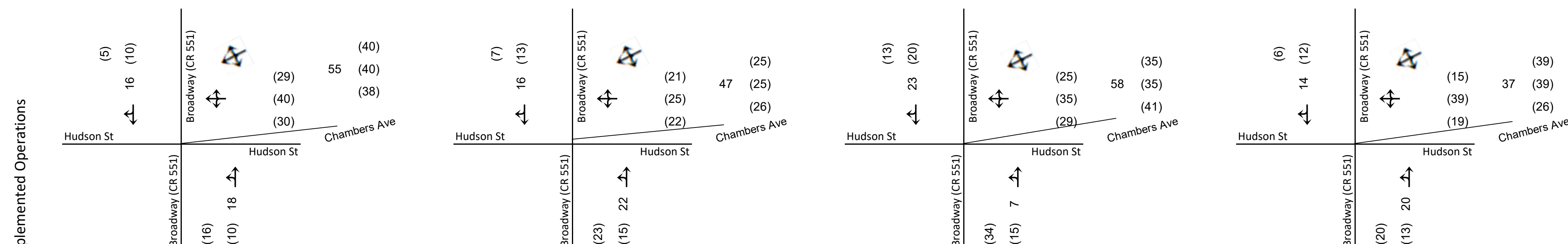


Existing Operations



Summary	AM Peak				Midday Peak				PM Peak				PM Off-peak			
Timing Pattern	FREE	Syn Delay	25	C	FREE	Syn Delay	25	C	FREE	Syn Delay	45	D	FREE	Syn Delay	23	C
Actuated Cycle	75	Sim Delay	(17)		75	Sim Delay	(18)		75	Sim Delay	(43)		75	Sim Delay	(17)	
Max v/C	0.58	ICU	65%	C	0.60	ICU	66%	C	0.98	ICU	68%	C	0.60	ICU	61%	B

Implemented Operations



Summary	AM Peak				Midday Peak				PM Peak				PM Off-peak			
Timing Pattern	1	Syn Delay	24	C	2	Syn Delay	22	C	3	Syn Delay	22	C	4	Syn Delay	19	B
Actuated Cycle	90.4	Sim Delay	(15)		75	Sim Delay	(16)		90	Sim Delay	(20)		75	Sim Delay	(15)	
Max v/C	0.53	ICU	62%	B	0.60	ICU	63%	B	0.78	ICU	64%	C	0.60	ICU	58%	B

Operations with Improvements

No operational improvements recommended at this time.

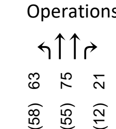
HCM Levels of Service

LOS	Delay/Veh (s)
A	≤10
B	>10 and ≤20
C	>20 and ≤35
D	>35 and ≤55
E	>55 and ≤80
F	>80

ICU Levels of Service

LOS	Utilization (%)
A	≤55%
B	>55% and ≤64%
C	>64% and ≤73%
D	>73% and ≤82%
E	>82% and ≤91%
F	>91% and ≤100%
G	>100% and ≤109%
H	>109%

Operations Diagrams

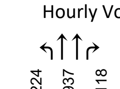


stop bar geometry

Synchro delay (sec / veh)

SimTraffic delay (sec / veh)

Hourly Volume Diagrams



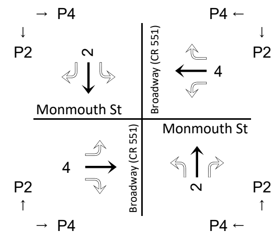
stop bar geometry

turning movement volume

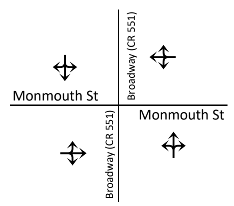
Figure 14

Traffic Operations Analysis

Broadway (CR 551) & Hudson St/Chambers Ave

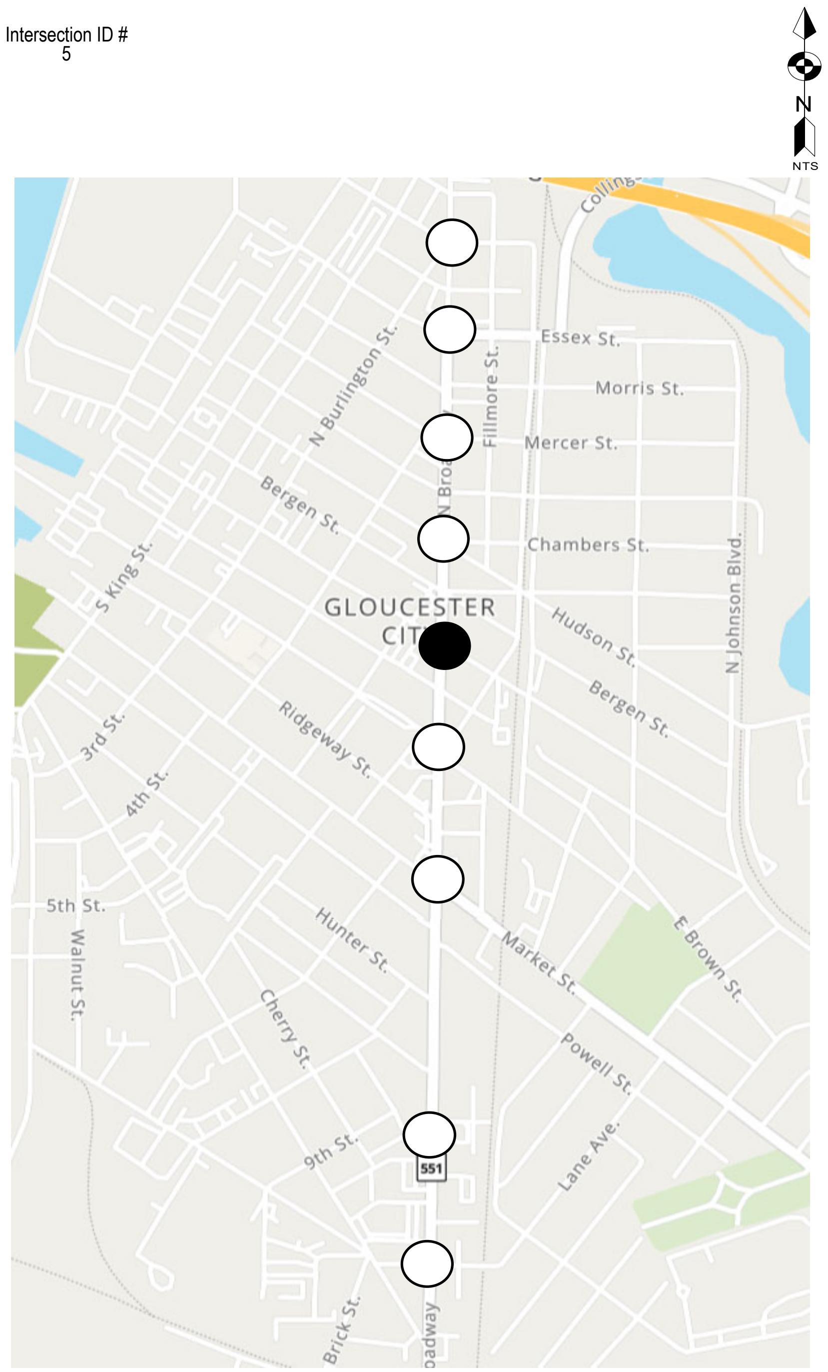


Phasing Diagram



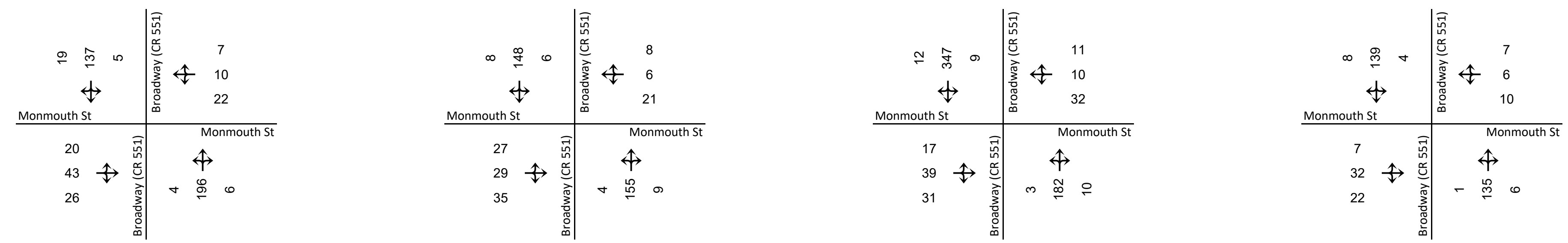
Intersection Geometry

Intersection ID #
5

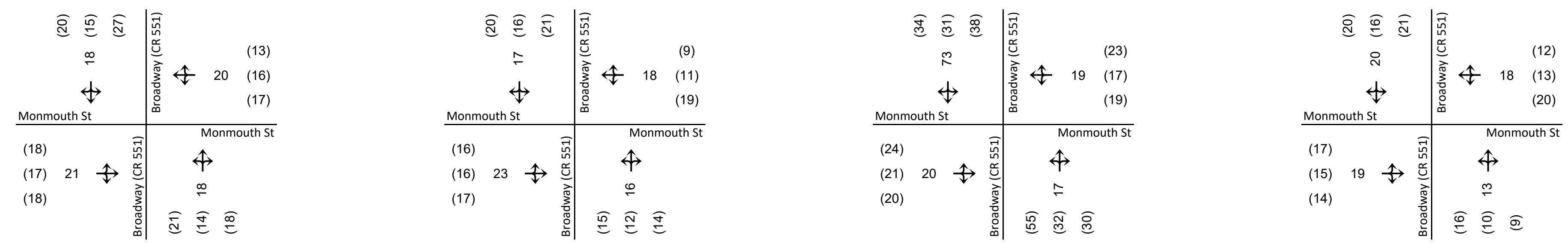


AM Peak | Midday Peak | PM Peak | PM Off-peak

Hourly Volumes



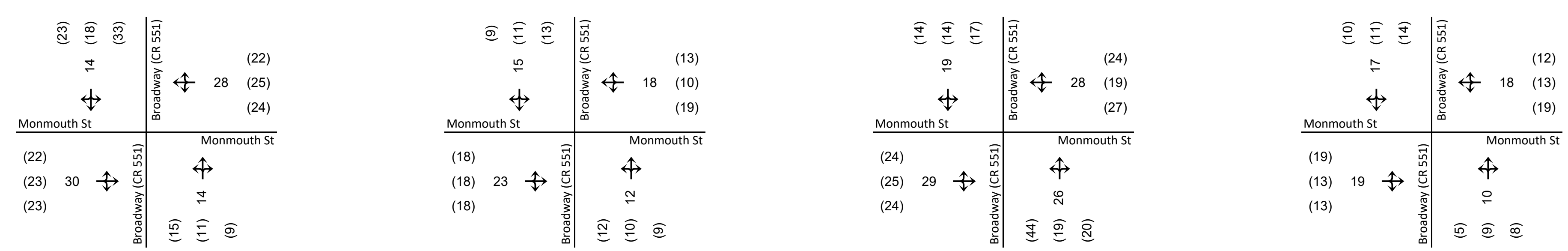
Existing Operations



Summary

Period	Timing Pattern	Actuated Cycle	Max v/C	Syn Delay	Sim Delay	ICU
AM Peak	1	75	0.60	19 B	(15)	47% A
Midday Peak	1	75	0.49	18 B	(15)	44% A
PM Peak	1	75	1.04	47 D	(30)	68% C
PM Off-peak	1	75	0.58	17 B	(14)	43% A

Implemented Operations



Summary

Period	Timing Pattern	Actuated Cycle	Max v/C	Syn Delay	Sim Delay	ICU
AM Peak	1	90	0.51	18 B	(16)	43% A
Midday Peak	2	75	0.49	16 B	(12)	40% A
PM Peak	3	90	0.87	23 C	(17)	66% C
PM Off-peak	4	75	0.58	15 B	(11)	39% A

Operations with Improvements

No operational improvements recommended at this time.

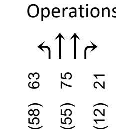
HCM Levels of Service

LOS	Delay/Veh (s)
A	≤10
B	>10 and ≤20
C	>20 and ≤35
D	>35 and ≤55
E	>55 and ≤80
F	>80

ICU Levels of Service

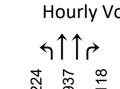
LOS	Utilization (%)
A	≤55%
B	>55% and ≤64%
C	>64% and ≤73%
D	>73% and ≤82%
E	>82% and ≤91%
F	>91% and ≤100%
G	>100% and ≤109%
H	>109%

Operations Diagrams



stop bar geometry
Synchro delay (sec / veh)
SimTraffic delay (sec / veh)

Hourly Volume Diagrams



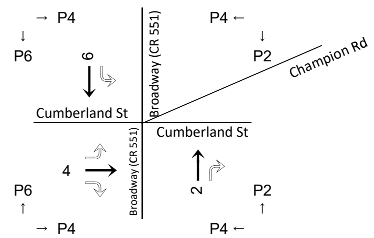
stop bar geometry
turning movement volume

Figure 15

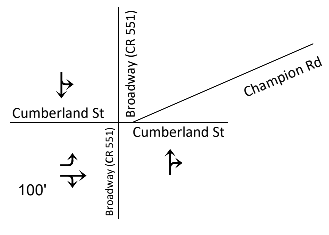
Traffic Operations Analysis

Broadway (CR 551) & Monmouth St

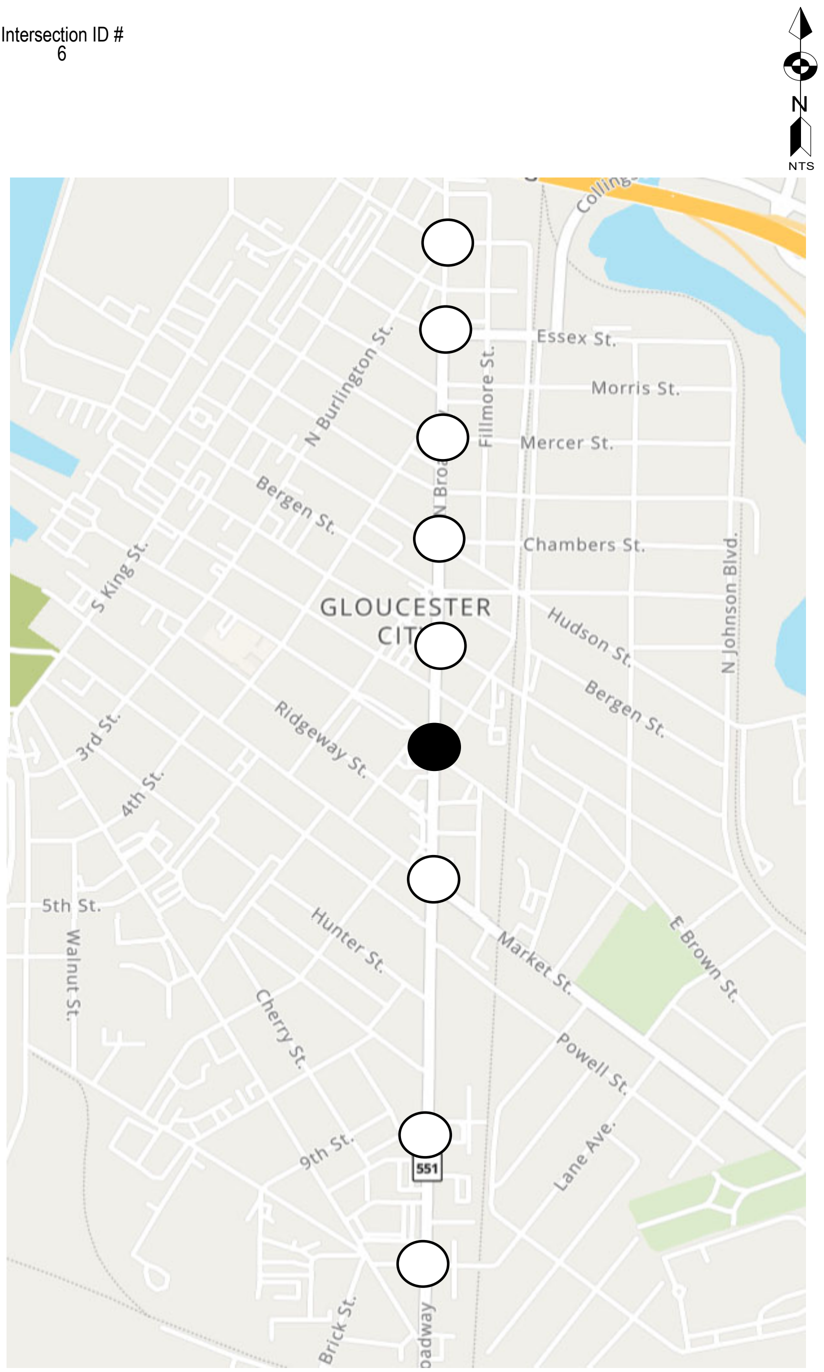
Intersection ID #
6



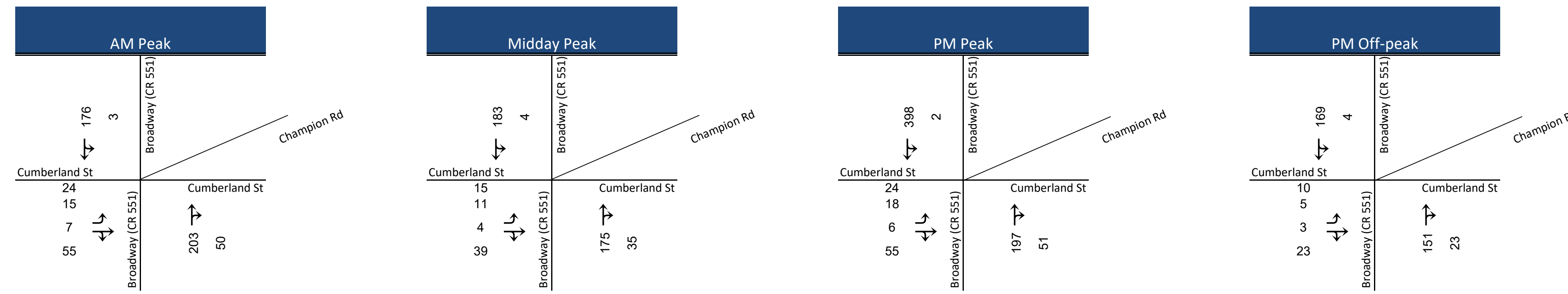
Phasing Diagram



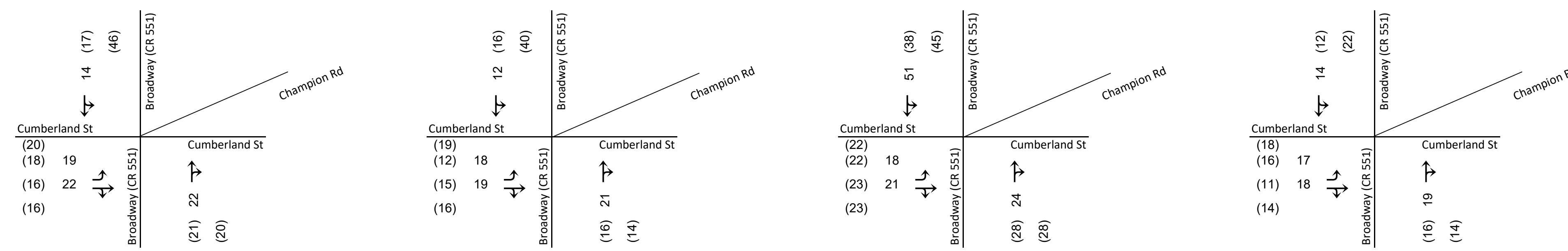
Intersection Geometry



Hourly Volumes



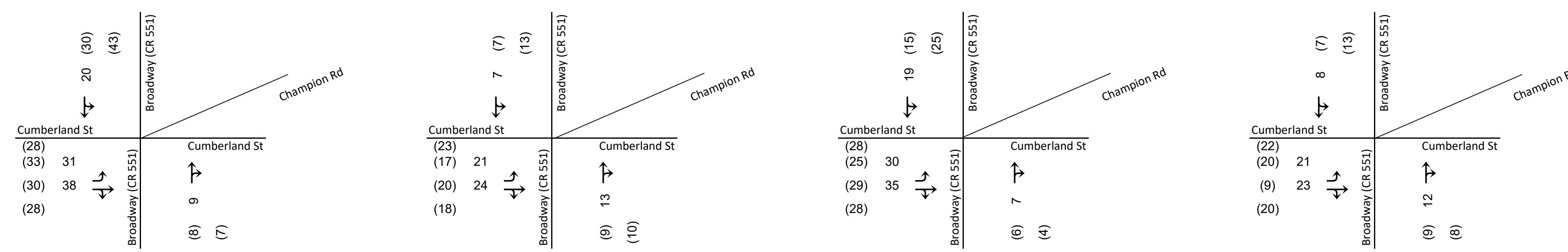
Existing Operations



Summary

	AM Peak	Midday Peak	PM Peak	PM Off-peak
Timing Pattern	1	1	1	1
Actuated Cycle	75	75	75	75
Max v/C	0.69	0.66	1.03	0.64
Syn Delay	19 B	17 B	38 D	16 B
Sim Delay	(19)	(16)	(34)	(14)
ICU	50% A	50% A	69% C	49% A

Implemented Operations



Summary

	AM Peak	Midday Peak	PM Peak	PM Off-peak
Timing Pattern	1	2	3	4
Actuated Cycle	90	75	90	75
Max v/C	0.53	0.58	0.79	0.56
Syn Delay	19 B	12 B	17 B	11 B
Sim Delay	(19)	(9)	(13)	(9)
ICU	46% A	46% A	65% C	45% A

Operations with Improvements

No operational improvements recommended at this time.

DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

CAMDEN COUNTY NEW JERSEY INC. 1844

iteris®

HCM Levels of Service

LOS	Delay/Veh (s)
A	≤10
B	>10 and ≤20
C	>20 and ≤35
D	>35 and ≤55
E	>55 and ≤80
F	>80

ICU Levels of Service

LOS	Utilization (%)
A	≤55%
B	>55% and ≤64%
C	>64% and ≤73%
D	>73% and ≤82%
E	>82% and ≤91%
F	>91% and ≤100%
G	>100% and ≤109%
H	>109%

Operations Diagrams

stop bar geometry

63 75 21 Synchro delay (sec / veh)

(58) (55) (12) SimTraffic delay (sec / veh)

Hourly Volume Diagrams

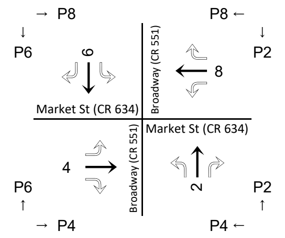
stop bar geometry

224 937 118 turning movement volume

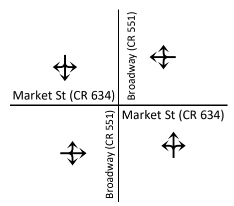
Figure 16

Traffic Operations Analysis

Broadway (CR 551) & Cumberland St/Champion Rd

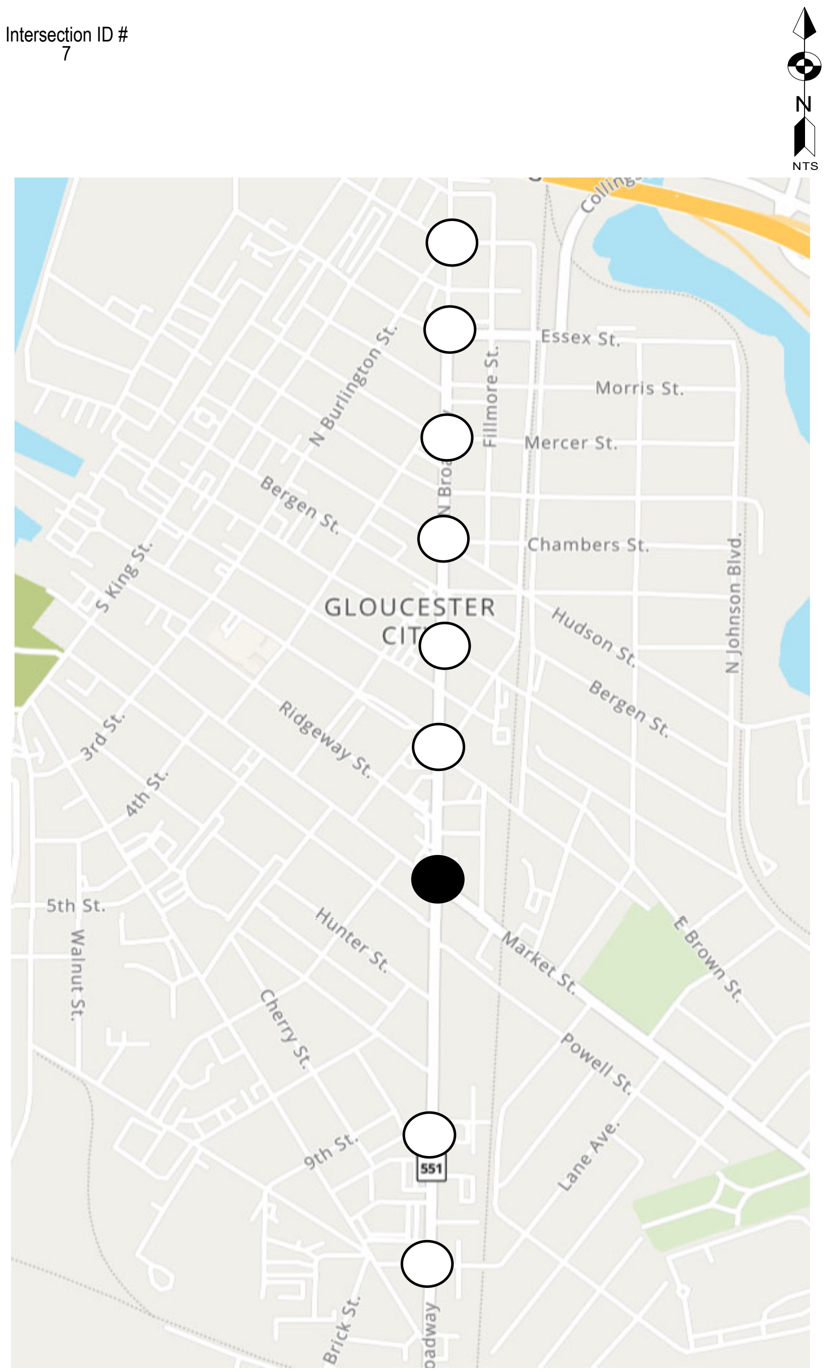


Phasing Diagram



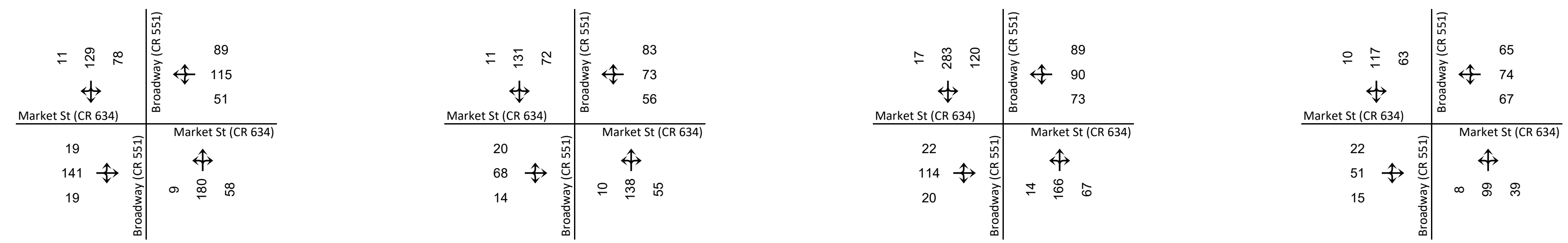
Intersection Geometry

Intersection ID #
7

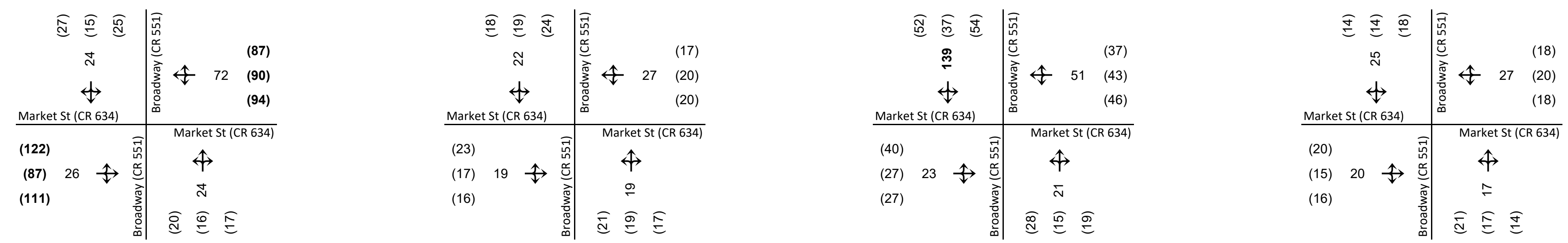


AM Peak | Midday Peak | PM Peak | PM Off-peak

Hourly Volumes



Existing Operations



Summary — AM Peak

Timing Pattern	1	Syn Delay	39	D
Actuated Cycle	75	Sim Delay	(51)	
Max v/C	1.00	ICU	90%	E

Summary — Midday Peak

Timing Pattern	1	Syn Delay	22	C
Actuated Cycle	75	Sim Delay	(19)	
Max v/C	0.66	ICU	78%	D

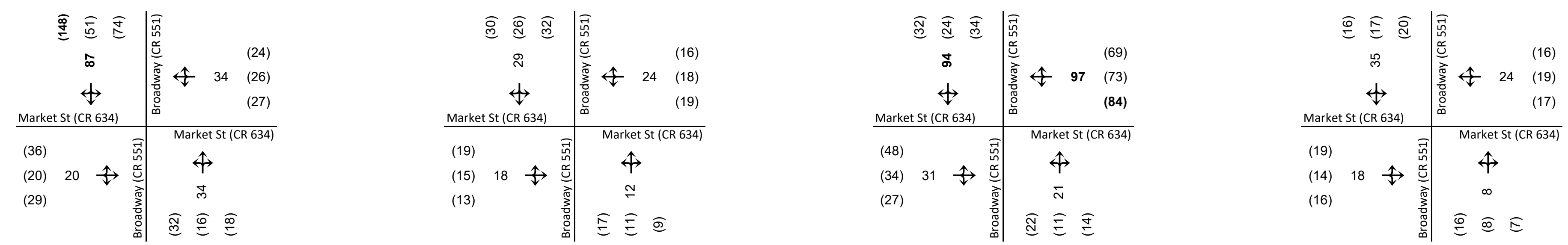
Summary — PM Peak

Timing Pattern	1	Syn Delay	75	E
Actuated Cycle	75	Sim Delay	(34)	
Max v/C	1.25	ICU	**108%**	G

Summary — PM Off-peak

Timing Pattern	1	Syn Delay	23	C
Actuated Cycle	75	Sim Delay	(17)	
Max v/C	0.75	ICU	70%	C

Implemented Operations



Summary — AM Peak

Timing Pattern	1	Syn Delay	44	D
Actuated Cycle	90	Sim Delay	(32)	
Max v/C	1.05	ICU	**93%**	F

Summary — Midday Peak

Timing Pattern	2	Syn Delay	21	C
Actuated Cycle	75	Sim Delay	(19)	
Max v/C	0.75	ICU	80%	D

Summary — PM Peak

Timing Pattern	3	Syn Delay	69	E
Actuated Cycle	90	Sim Delay	(34)	
Max v/C	1.13	ICU	**110%**	H

Summary — PM Off-peak

Timing Pattern	4	Syn Delay	23	C
Actuated Cycle	75	Sim Delay	(15)	
Max v/C	0.85	ICU	72%	C

Operations with Improvements

No operational improvements recommended at this time.

DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

CAMDEN COUNTY NEW JERSEY INC. 1844

iteris®

HCM Levels of Service

LOS	Delay/Veh (s)
A	≤10
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F	>80

ICU Levels of Service

LOS	Utilization (%)
A	≤55%
B	>55% and ≤64%
C	>64% and ≤73%
D	>73% and ≤82%
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F	>91% and ≤100%
G	>100% and ≤109%
H	>109%

Operations Diagrams

63 75 21 — stop bar geometry; Synchro delay (sec / veh)
(58) (55) (12) — SimTraffic delay (sec / veh)

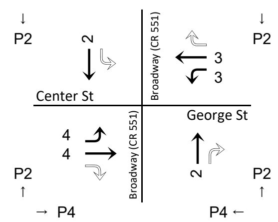
Hourly Volume Diagrams

224 937 118 — stop bar geometry; turning movement volume

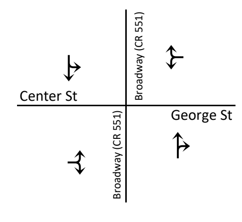
Figure 17

Traffic Operations Analysis

Broadway (CR 551) & Market St (CR 634)

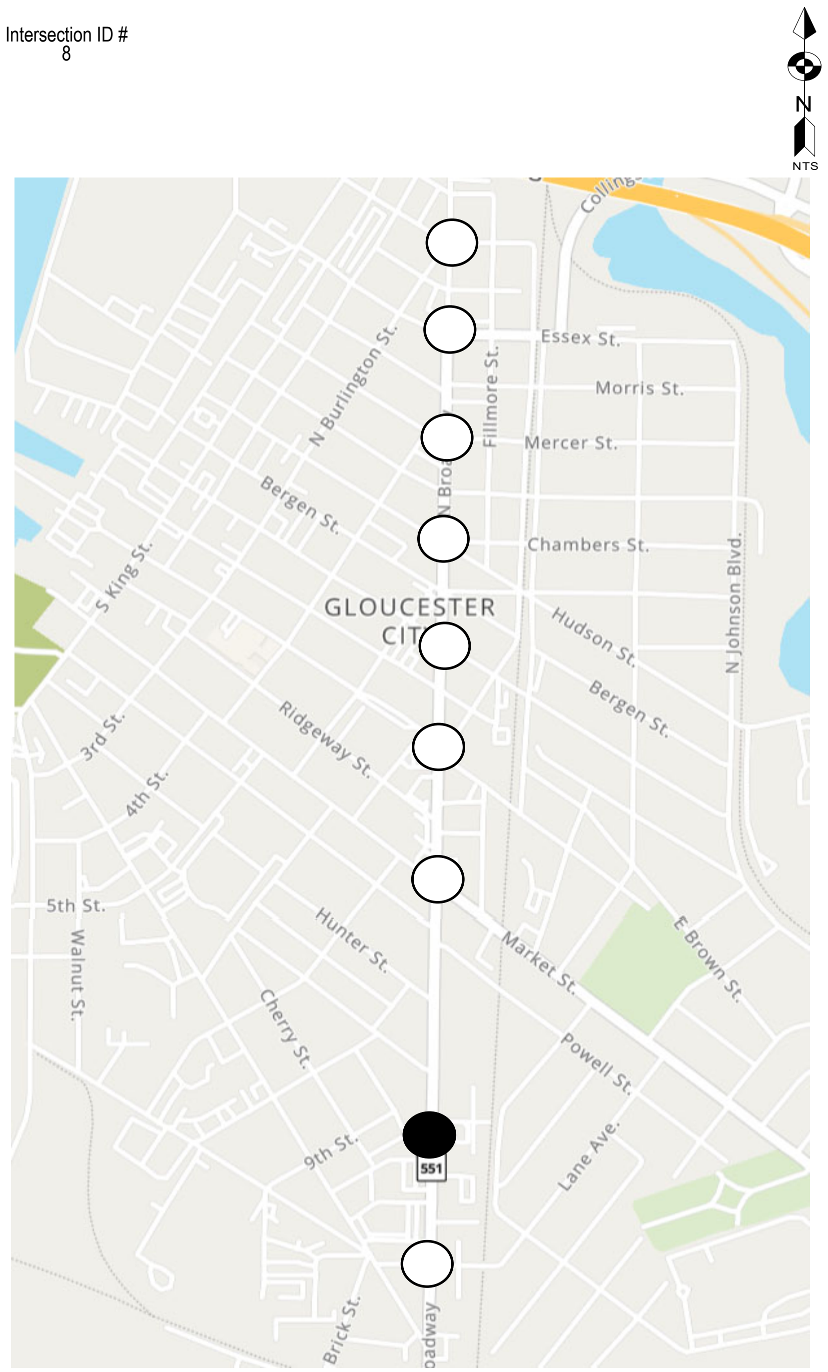


Phasing Diagram



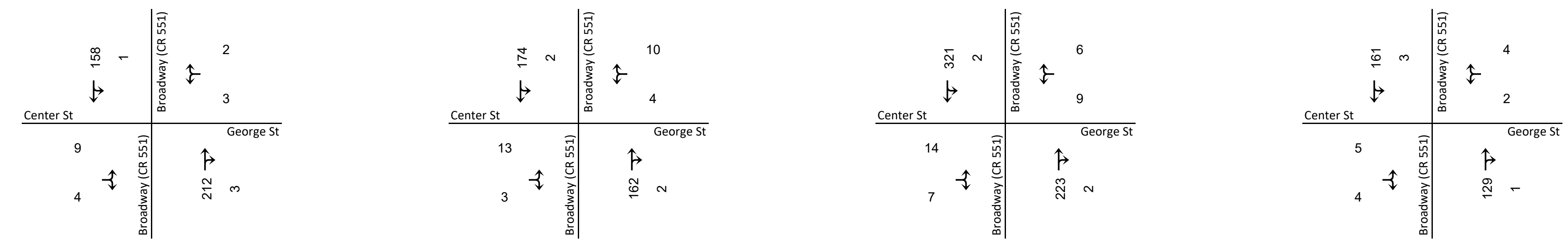
Intersection Geometry

Intersection ID #
8

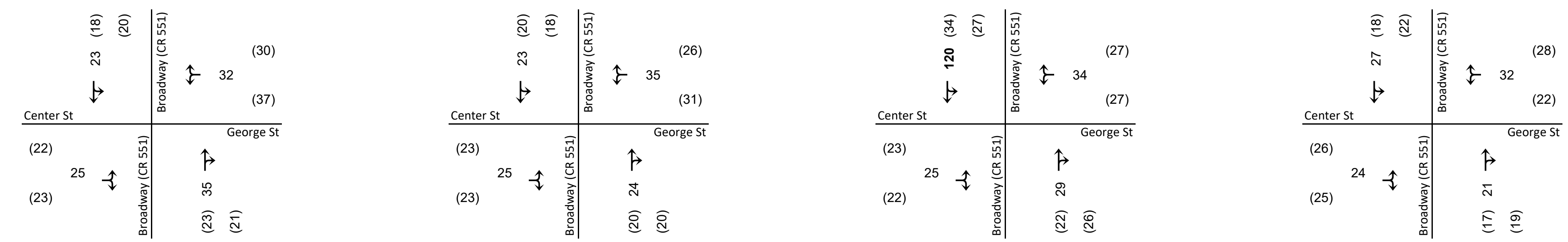


AM Peak	Midday Peak	PM Peak	PM Off-peak

Hourly Volumes



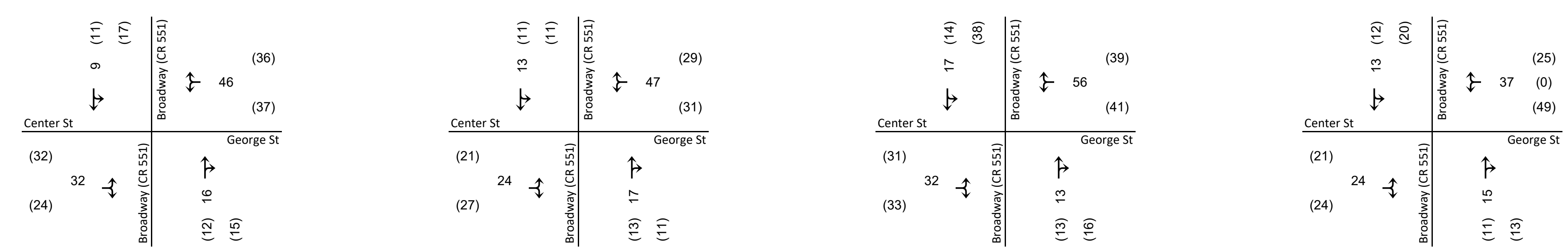
Existing Operations



Summary

Period	Timing Pattern	Syn Delay	Actuated Cycle	Sim Delay	Max v/C	ICU
AM Peak	FREE	30 C	75	(21)	0.80	42% A
Midday Peak	FREE	24 C	75	(21)	0.58	40% A
PM Peak	FREE	**82** F	75	(28)	1.17	54% A
PM Off-peak	FREE	25 C	75	(18)	0.69	40% A

Implemented Operations



Summary

Period	Timing Pattern	Syn Delay	Actuated Cycle	Sim Delay	Max v/C	ICU
AM Peak	1	14 B	90	(12)	0.59	41% A
Midday Peak	2	17 B	75	(13)	0.53	39% A
PM Peak	3	17 B	90	(15)	0.87	54% A
PM Off-peak	4	14 B	75	(12)	0.63	39% A

Operations with Improvements

No operational improvements recommended at this time.

dvrpc DELAWARE VALLEY REGIONAL PLANNING COMMISSION

CAMDEN COUNTY NEW JERSEY INC. 1844

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HCM Levels of Service

LOS	Delay/Veh (s)
A	≤10
B	>10 and ≤20
C	>20 and ≤35
D	>35 and ≤55
E	>55 and ≤80
F	>80

ICU Levels of Service

LOS	Utilization (%)
A	≤55%
B	>55% and ≤64%
C	>64% and ≤73%
D	>73% and ≤82%
E	>82% and ≤91%
F	>91% and ≤100%
G	>100% and ≤109%
H	>109%

Operations Diagrams

stop bar geometry
63 75 21 — Synchro delay (sec / veh)
(58) (55) (12) — SimTraffic delay (sec / veh)

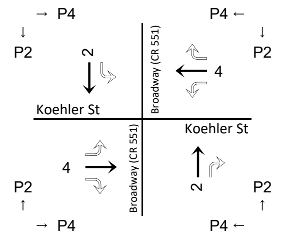
Hourly Volume Diagrams

stop bar geometry
224 937 118 — turning movement volume

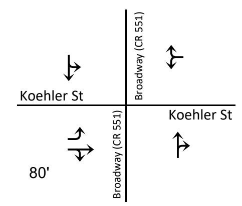
Figure 18

Traffic Operations Analysis

Broadway (CR 551) & Center St/George St

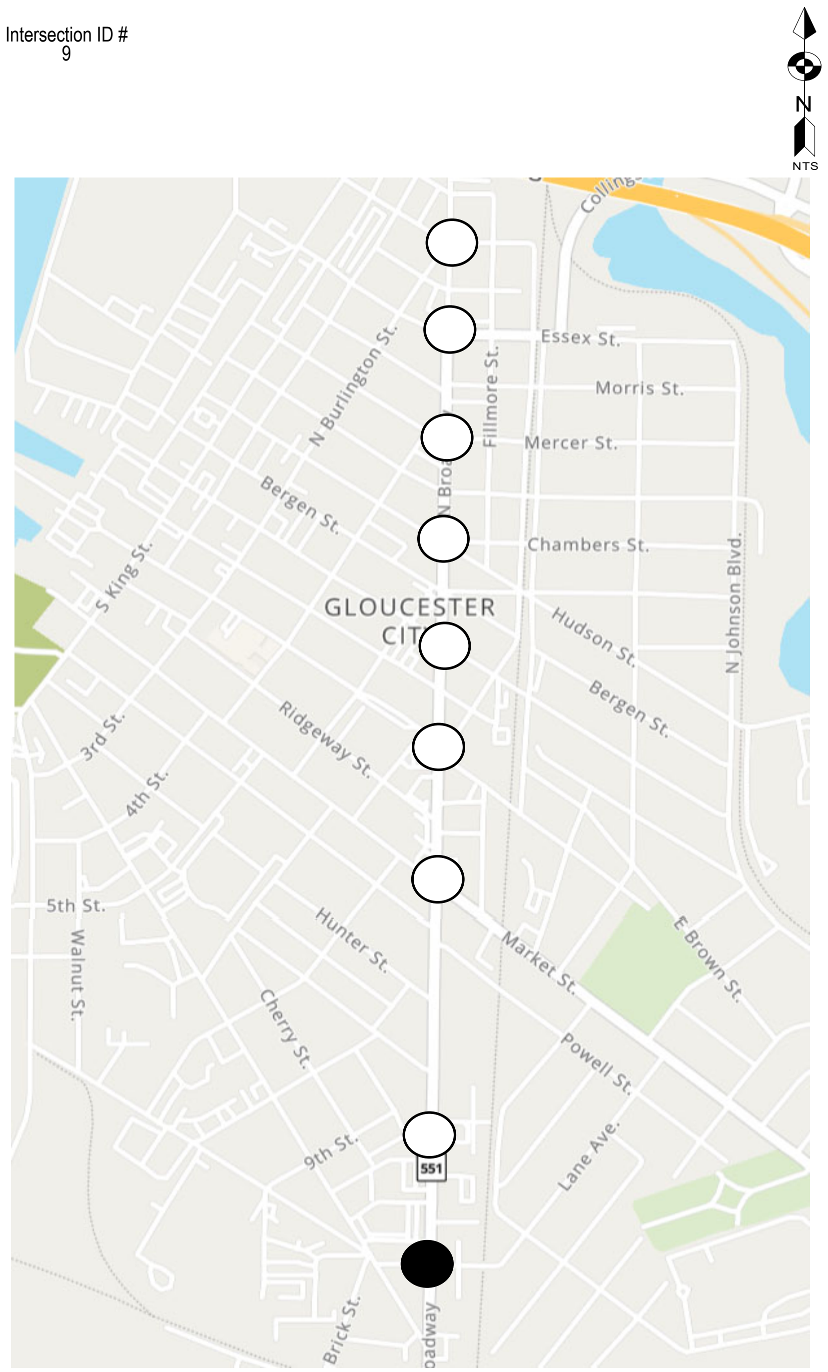


Phasing Diagram



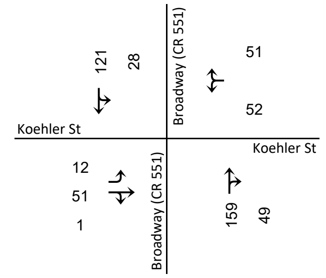
Intersection Geometry

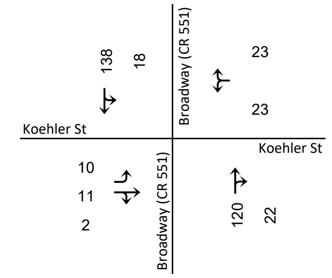
Intersection ID #
9

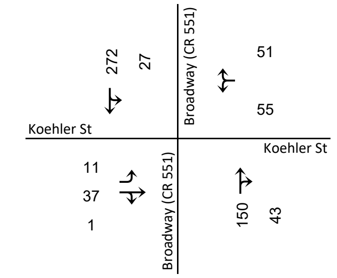


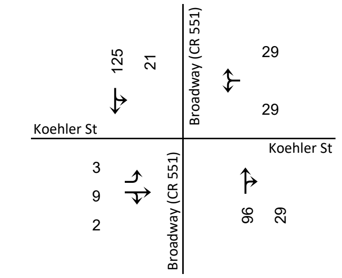
AM Peak	Midday Peak	PM Peak	PM Off-peak

Hourly Volumes

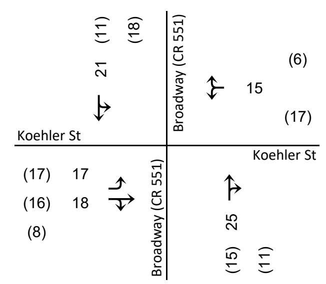




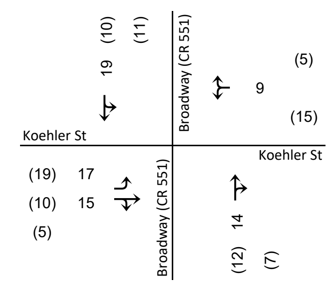




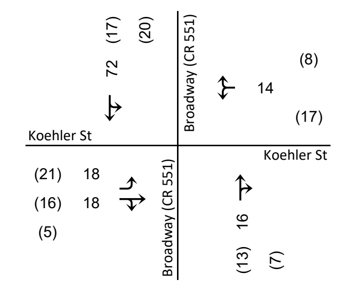
Existing Operations



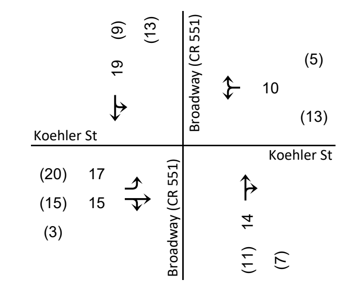
Summary			
Timing Pattern	1	Syn Delay	21 C
Actuated Cycle	75	Sim Delay	(13)
Max v/C	0.74	ICU	65% C



Summary			
Timing Pattern	1	Syn Delay	16 B
Actuated Cycle	75	Sim Delay	(11)
Max v/C	0.58	ICU	55% A

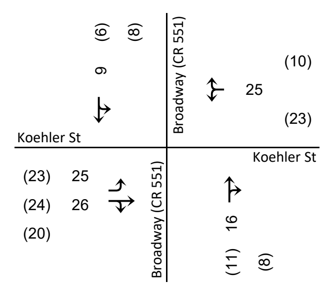


Summary			
Timing Pattern	1	Syn Delay	43 D
Actuated Cycle	75	Sim Delay	(15)
Max v/C	1.04	ICU	79% D

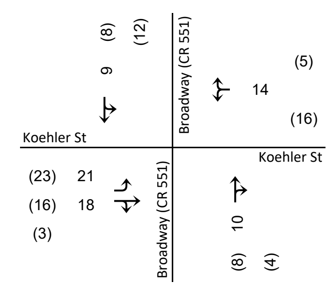


Summary			
Timing Pattern	1	Syn Delay	16 B
Actuated Cycle	75	Sim Delay	(10)
Max v/C	0.57	ICU	53% A

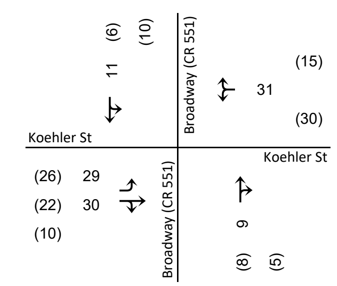
Implemented Operations



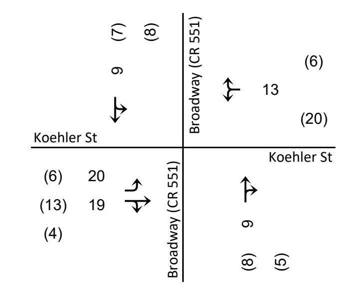
Summary			
Timing Pattern	1	Syn Delay	16 B
Actuated Cycle	90	Sim Delay	(11)
Max v/C	0.62	ICU	63% B



Summary			
Timing Pattern	2	Syn Delay	11 B
Actuated Cycle	75	Sim Delay	(9)
Max v/C	0.50	ICU	53% A



Summary			
Timing Pattern	3	Syn Delay	16 B
Actuated Cycle	90	Sim Delay	(10)
Max v/C	0.80	ICU	77% D



Summary			
Timing Pattern	4	Syn Delay	10 A
Actuated Cycle	75	Sim Delay	(8)
Max v/C	0.49	ICU	52% A

Operations with Improvements

No operational improvements recommended at this time.

DELAWARE VALLEY dvrpc REGIONAL PLANNING COMMISSION

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ICU Levels of Service

LOS	Utilization (%)
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G	>100% and ≤109%
H	>109%

Operations Diagrams

stop bar geometry
63 75 21 Synchro delay (sec / veh)
(58) (55) (12) SimTraffic delay (sec / veh)

Hourly Volume Diagrams

stop bar geometry
224 937 118 turning movement volume

Figure 19

Traffic Operations Analysis

Broadway (CR 551) & Koehler St