FHWA-NJ-2005-008

COMPUTER MODELING AND SIMULATION OF NEW JERSEY SIGNALIZED HIGHWAYS

(VOLUME I - OPTIMIZATION)

FINAL REPORT
June 2005

Submitted by

Steven I-Jy Chien, PhD.
Principal Investigator, Associate Professor
New Jersey Institute of Technology
Interdisciplinary Program in Transportation

George Fallat, P.E.
Deputy Director
New Jersey Institute of Technology
National Center for Transportation and Industrial Productivity

NJDOT Research Project Manager
Karl Brodtman

In cooperation with

New Jersey
Department of Transportation
Division of Research and Technology
and
U.S. Department of Transportation
Federal Highway Administration

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1. Report No. FHWA-NJ-2005-008		3. Recipient's Catalog No.
4. Title and Subtitle Computer Modeling and Simulation of New Jersey Signalized Highways		5. Report Date: June 2005
		6. Performing Organization Code
7. Author(s) Steven Chien & George Fallat		8. Performing Organization Report No.
9. Performing Organization Name and Address New Jersey Department of Transportation PO 600 Trenton, NJ 08625		10. Work Unit No.
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Highway Administration U.S. Department of Transportation Washington, D.C.		13. Type of Report and Period Covered Final Report
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

Development and implementation of intelligent transportation systems along highway corridors includes deployment of various, usually considerably expensive technologies. In the area of traffic control, these technologies were used to optimize an array of signal cycle lengths, phasing, splits, and offsets, while considering dynamic traffic conditions (e.g., fluctuations in traffic volume, speed, and density). In order to facilitate cost efficient traffic signal control on New Jersey highways, this study developed computer models to optimize the array of aforementioned variables, evaluate the benefits of optimized array, and determine the resulting level of service prior to actual implementation in the studied corridors.

The objective of this study was to assess and optimize corridor performance through enhancements of existing signal timing plans for the studied corridors, which has been achieved through performing the following activities:

- Review, investigate, and summarize the state-of-the-art methodologies for signal optimization;
- Identify studied corridors and collect necessary data for developing signal optimization and traffic simulation models;
- Develop computer models to optimize traffic signal cycle lengths, phasing, splits, and offsets for the studied corridors;
- Develop simulation models to simulate and assess the recommended signal timings prior to field implementation on the studied corridors;
- Assist NJDOT in producing timing directives for recommended signal timings; and
- Provide training and technology transfer to NJDOT.

In this study, SYNCHRO (version 5.0) was applied to evaluate the operations of traffic control systems for individual or group of intersections along the corridor. However, due to the dynamic nature of traffic operations, the results of SYNCHRO are not effective in responding to continuously changing real-time traffic conditions. Therefore, SimTraffic was applied to validate the results of SYNCHRO. With SYNCHRO and SimTraffic, before and after scenarios for implementing the optimized signal timings were assessed, while the "savings" in travel times, number of stops, fuel consumption, and vehicle emissions were calculated.

17. Key Words Traffic control, signal timing, highway, signalized arterial, progression, optimization, simulation		18. Distribution Statement	
19. Security Classif (of this report) None	20. Security Classif. (of this page) None	21. No of Pages 149	22. Price

Form DOT F 1700.7 (8-69)

Acknowledgements

We wish to express our sincere thanks to the New Jersey Department of Transportation for their dedication to this project. We especially would like to thank Mike Asson, the project customer and Karl Brodtman, the Project Manager. We would also like to thank the following the following persons from NJDOT who provided excellent technical insight to the project: Scott Oplinger, Dave Martin, Pete Amin, and Wayne Mathis. Finally, we would like to thank several students who assisted us in this project, especially, Jiangtao Luo, Xiabo Liu, Saroj Joshi, and Kitae Kim.

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SUMMARY

The New Jersey Department of Transportation has undertaken an initiative to systematically improve traffic operations along the state's signalized highway corridors. Two corridors in this study, NJ Route 23 and NJ Route 42/322 were selected as studied arterials for undertaking a systematic approach to observe current traffic conditions, obtain current traffic volume data and then assimilate this information as well as existing roadway geometric characteristics into a traffic signal optimization software. The results of these efforts would produce new timing directives that could be readily implemented. Expanding such initiatives to New Jersey's signalized arterials has the potential of reducing congestion and improving air quality.

As a follow up to this study, a cost benefit analysis is being conducted to better evaluate the savings (or losses) experienced through comparing selected measures of effectiveness before and after implementing optimized timing plans. The results of the cost benefit analysis could then provide justification for receiving future funding update traffic signal timing plans for New Jersey's signalized corridors.

The studied section of the Route 23 corridor consists of 19 signalized intersections and is a total length of 12 miles. The study section is physically divided with no provisions for direct left turns from the mainline. Therefore, the timing/phasing plans do not include separate phasing to accommodate direct left turns from the mainline. The Route 42/322 study section is approximately 9-miles long and includes Route 42 from MP 0.0 and ending at MP 6.17 and Route 322 from MP 24.71 to MP 26.87. The study section consists of 17 signalized intersections, many of which, provide signal phasing for direct left turn movements were permitted. .

For the two study corridors, several steps were undertaken to develop the final version of traffic signal timing directives containing optimal timing settings. The first step included an extensive data collection effort for which the following information was obtained:

- Existing roadway geometric features, including number and designation of lanes, lane widths and presence of shoulders;

- Distance between intersections;
- Traffic counts, turning movement, and truck percentages; and
- Existing signal timing plans.

The project team also conducted field observations of traffic flow patterns and identified locations where large traffic generators exist.

The next step consisted of “balancing” traffic volumes between adjacent intersections, so that the total traffic volume exiting on the main street was equal to the total traffic on the main street approach. Where there were potentially large uncounted traffic generators (e.g. unsignalized intersections, driveways from large retail facilities) between two intersections, network flows were not balanced. The adjusted flows as well as geometric data were then used as the input for modeling Synchro networks. Existing splits and offsets were entered into the Synchro models, and then the traffic simulation during morning, noon and evening peak periods can be performed and the results were tabulated.

The Synchro software is capable of optimizing green times for all intersection approaches and overall green time progression on a selected section. The software also enables the user to optimize the intersection phasing sequence to maximize traffic signal progression along the corridor. The user can also specify a set phasing scenario or allow Synchro to generate an optimal phasing plan. With direct left turns permitted along the Route 42/322 corridor, there is opportunity to employ innovative phasing alternatives, such as lagging left turn phases and different phasing options for different times of day. However, it was requested that the current phasing be retained and that it remain consistent throughout the day with only optimized splits and offsets. In addition, Timing modifications also considered the limitation of existing traffic signal equipment.

The following periods were examined for optimizing existing traffic signal timing plans at the two studied corridors:

Route 23

- Weekday morning peak hours (From 5:30 A.M. to 9:00 A.M.)
- Weekday noon peak hours (From 11:00 A.M to 1:00 P.M.)

- Weekday evening peak hours (From 3:00 P.M. to 7:30 P.M.)

Route 42/322

- Weekday morning peak hours (From 6:00 A.M. to 10:00 A.M)
- Weekday noon peak hours (From 10:00 A.M. to 3:00 P.M) and Weekend (From 8:00 A.M. to 6:00 P.M.)
- Weekday evening peak hours (From 3:00 P.M. to 7:00 P.M.)
- Weekday off-peak hours (All other time periods)

Since turning movement data was not available for off-peak hours, it was assumed that the current timing in place for off-peak hours would be retained. In addition, the revised timing plans also had to accommodate potential pedestrian crossing volumes, although few, pedestrians were observed during peak periods.

The results of this study include the optimal timing plans and the development of new timing directives for both studied sections on Route 23 and Route 42/322. The directives are produced in a format such that they can be readily understood by field maintenance personnel and can be easily updated in the future. The revised timing directives were also reviewed and approved by NJDOT's Bureau of Traffic Engineering and Safety Programs to ensure that they comply with NJDOT standards and format.

Initial results of our analysis indicate that significant improvements in Level of Service (LOS) could be achieved by simply retiming the traffic signals. For example, on Route 42/322, average vehicle delays were reduced by over half at one intersection during the morning peak hour, resulting in a LOS improvement from C to B. Arterial travel speeds and improved progression, overall, also improved.

A programmatic approach for optimizing signalized state highway corridors, however, would require a consistent funding source for collecting the up-to-date traffic volume data, entering and manipulating this information into a computer model, developing traffic signal timing directives and then implementing these changes in the field. Therefore, as a follow up to this report, a study will be conducted to quantify the full extent of implementation costs and benefits associated with optimized traffic signal timing plans for each corridor.

INTRODUCTION

Various costly ITS technologies are considered for deployment along ITS freeways, arterials and streets operated by the New Jersey Department of Transportation (NJDOT). In the area of traffic control, these technologies include an optimal array of signal cycle lengths, splits, and offsets while considering dynamic traffic conditions. In taking advantage of these technologies, however, there is a need for traffic engineers to develop computer models for signalized highways, optimize the array of decision variables, evaluate optimized timing plans, and determine the level of service prior to actual implementation and operation at the study site. Traffic engineers must also monitor and update implemented timing plans in response to time variant traffic conditions.

The development of a method for integrating simulation/optimization models to optimize traffic control for New Jersey highways was primarily motivated by the following factors:

1. NJDOT needs a better method to develop, implement and update traffic signal timing plans for roadway networks of connected and non-connected intersections.

2. Existing traffic simulation models require extensive data collection and substantial efforts to develop and are not responsive to dynamic patterns of traffic flow. Furthermore, development of traffic signal timing plans, the means to implement the results of these models, has not been integrated into the output of the models.

3. The application of simulation/optimization models can advance the state of the art in research and development of advanced traffic control systems, and can enhance the state of the practice in their implementation.

Computerized simulation and optimization models (e.g., SimTraffic and Synchro) can be employed to evaluate the performance of traffic control systems. These models allow experimentation with “what-if” scenarios and evaluation of technologies and systems impacts before they are actually deployed. However, due to the dynamic nature of traffic conditions, the output of these models is not effective in responding to changing traffic conditions. Furthermore, considerable resources are required to collect traffic data, develop simulation and optimization models, and then implement the solutions recommended by these models. In addition to providing excellent learning opportunities for students, the New Jersey Institute of Technology Traffic Simulation Laboratory (NJIT-TSL) is an ideal candidate for collecting the necessary data, developing models for non-connected and connected intersections on the selected networks and optimizing signal cycle lengths, timings, and offsets.

The NJIT-TSL was engaged in collecting data, evaluating traffic control systems, developing simulation/optimization models and producing the documentation necessary for field implementation

The NJIT-TSL, consisting of experienced/trained research members and a number of personal computers supported by the Interdisciplinary Program in Transportation at NJIT, has achieved the following objectives:

1. Identify and collect necessary data for developing signal optimization and traffic simulation models;

2. Develop Synchro models to optimize signal cycle lengths, splits, and offsets for selected non-connected or connected signalized intersections;

3. Assist NJDOT traffic engineers in implementing the results on the selected roadway sections, until the signalized roadway(s) and sections have been optimized;

4. Prepare traffic signal directives in accordance with NJDOT's format so that NJDOT field personnel can easily implement the model output results.

LITERATURE REVIEW

The existence of the signal control system greatly affects the traffic movements over space and time and contributes the primary delay and other measures of effectiveness (MOEs) on the traffic stream in a signalized transportation network. NJDOT needs a better method to optimize traffic signal timing plans for roadways with connected and non-connected intersections. Existing traffic simulation models require extensive data collection and substantial efforts to develop, and some of them are not responsive to dynamic patterns of traffic flow. Furthermore, development of traffic signal timing plans, the means to implement the results of these models, has not been integrated into the output of the models. The application of traffic simulation and signal optimization models can advance the state-of-the-art traffic control systems, and can enhance the state-of-the-practice in their implementation. Therefore, it is necessary to research the application of simulation/optimization models and develop an integrated method for optimizing signalized traffic control on New Jersey highways.

The complete literature review of signal optimization and traffic simulation models are discussed and shown in Appendix E.

RESEARCH APPROACH

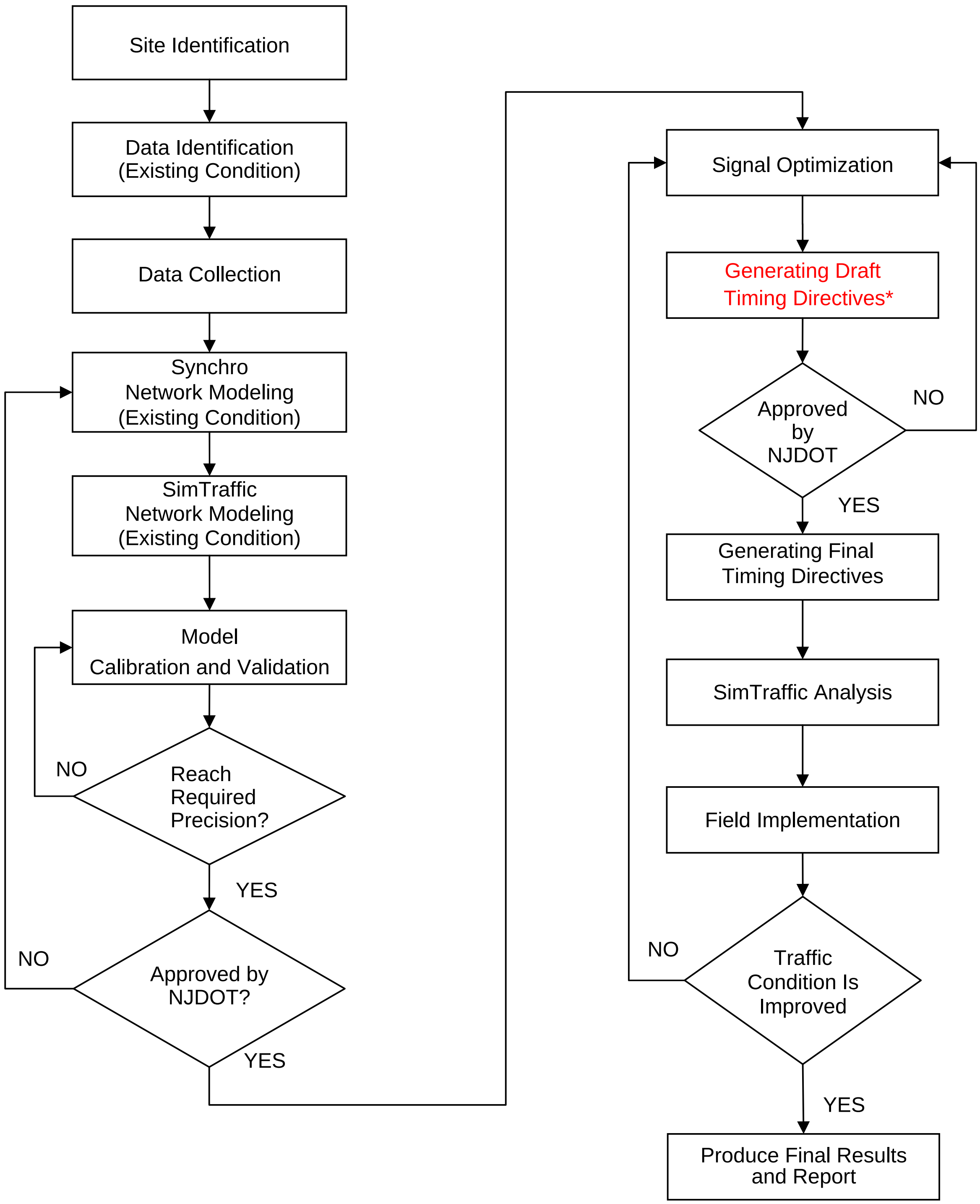
This section of the report discusses the research approach, which includes tasks for developing optimal signal timing plan for Route 23 and Route 42/322 corridors. While each corridor is unique in terms of its traffic volume patterns and roadway characteristics, similar research methodologies were applied to build the simulation networks and optimize traffic signal progression. The tasks included in the research approach are listed below, and itemized tasks are illustrated in Figure 1.

- Task 1. Site Identification and Data Needs.
- Task 2. Data Collection.
- Task 3. Network Modeling with Synchro and SimTraffic.
- Task 4. Optimization of Signal Timing Plan with Synchro and SimTraffic.
- Task 5. Generation of Timing Directives.

Sections of Studied Corridors

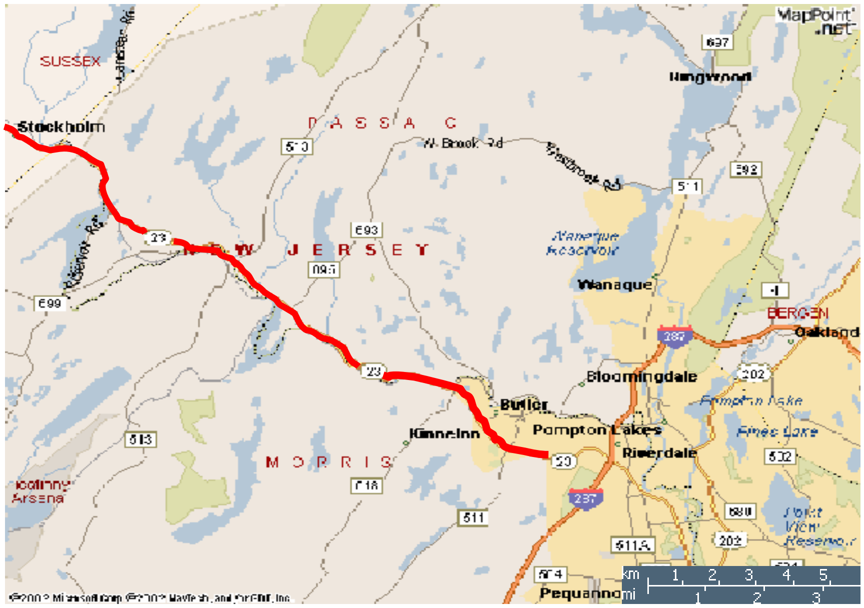
The sections of Route 23 (located in the northern portion of the state) and Route 42/322 (in the southern half of the state) were identified by NJDOT as the two studied corridors in this project. Route 23 runs primarily north-south and is a heavy commuter route for motorists accessing Interstate 80 from residential areas in suburban Morris County. Route 42/322 runs primarily east-west and provides access between Interstate 295 and residential areas in Camden, Gloucester and Atlantic Counties. The Route 42/322 corridor is also a major route to Atlantic City and other summer recreational communities along the Jersey shore. Both Route 23 and Route 42/322 are considered major urban signalized arterials and provide at-grade access to cross streets, adjacent commercial development, and surrounding residential areas. Pedestrian activity was observed to be minimal along both corridors, with vehicle usage consisting largely of single occupant passenger cars.

The studied section of Route 23 is approximately 12-mile long with 19 signalized intersections and extends from milepost (MP) 14.98 to MP 27.30. The geographic location of the study site is mapped and shown in Figure 2.



*: Detailed Procedure is illustrated in Figure 6.

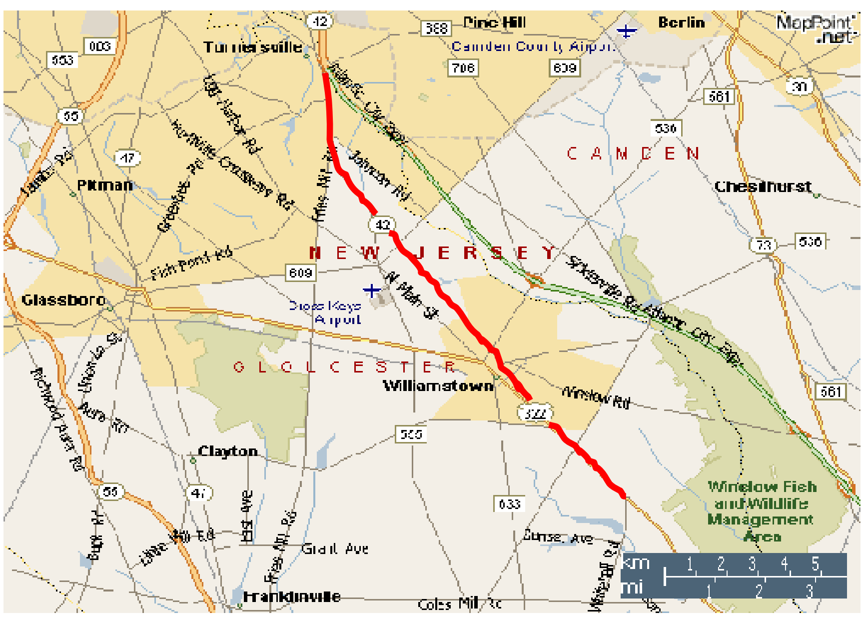
Figure 1. Configuration of Research Approach



(Source: http://www.mapquest.com)

Figure 2. Route 23 Corridor

The Route 42/322 study corridor includes Route 42 from MP 0.0 to MP 6.17and Route 322 from MP 24.71 to MP 26.87. The Route 42/322 section includes 17 signalized intersections and totals approximately 9 miles. The configuration of the studied site is shown in Figure 3.



(Source: http://www.mapquest.com)

Figure 3. Route 42/322 Corridor

Data Identification

Data identification was divided into two sections of studied corridors (Route 23 and Route 42/322) to provide a clear understanding at each site. Each section will be deployed as guided in Figure 1.

Data Collection

An important aspect of this study is to develop optimal signal timing plans using accurate, up-to-date information. NJDOT, under its on-going traffic counting program, provided existing intersection turning movement and volume counts for the studied Route 23 corridor. For both studied corridors, NJDOT provided intersection plans, signal timing directives, and straight line diagrams. Geometric data included the following information:

- Number of lanes
- Lane width and length
- Intersection location and layout
- Spacing between intersections.

NJDOT provided current turning movement data for the studied Route 23 corridor for weekday morning and evening peak periods. Current traffic data for the Route 42/322 corridor was not readily available. Therefore, NJIT solicited proposals and selected a consultant, Louis Berger and Associates, to obtain up-to-date turning movement and traffic volume counts at signalized locations along the Route 42/322 corridor. The consultant also provided 24-hour Automatic Traffic Recorder (ATR) counts at selected locations. This data provided insight as to the general traffic patterns during both peak and non-peak traffic periods. In addition to traffic volume data, the consultant provided sketches, depicting the number and configuration of lanes, for each signalized intersection. Turning movement data for the corridor was obtained for weekday morning, evening and Noon peak periods. The collected data for intersections for Route 42/322 is summarized in Table 2.

Table 1. List of Data Collected for Route 23 (19 Signalized Intersections)

No.	MP	Intersection	Count	Plan	Signal	Timing	Note *	Figure**
	27.32	Lake Stockholm Rd.(SB)					T, 2220	
1	26.9	Vernon Stockholm Rd.(Rt.515)	√	√	√	√	5650	B-1
2	25.83	Canister Rd.	√	√	√	√	6810	B-2
3	24.54	Reservior Rd.	√	√	√	√	2060	B-3
4	24.15	Doremus	√	√	√	√	4700	B-4
5	23.26	Paradise Rd.	√	√	√	√	1265	B-5
	23.02	Allson Ave. (NB)					T, 845	
6	22.86	Oak Ridge Rd.	√	√	√	√	1110	B-6
7	22.65	Clinton Rd.	√	√	√	√	2375	B-7
8	22.2	Larue Rd. (NB)	√	√	√	√		B-8
9	22.2	Larue Rd. (SB)	√	√	√	√	685	B-9
	22.07	Green Rd. (Rt.513) (SB)					T, 1055	
	21.87	Union Valley Rd. (Rt.513) (NB)					T, 740	
10	21.73	Kanhouse (Old Rt. 23)	√	√	√	√	2325	B-10
	21.29	(Connect Old Rt.23) (NB)					T, 4435	
11	20.45	Echo Lake Rd.	√	√	√	√	9345	B-11
	18.68	Unnamed Rd.(NB)					T, 2270	
	18.25	Germantown Rd.(SB)					T, 210	
	18.21	Germantown Rd.(NB)					T, 5225	
	17.22	High Crest Rd. (NB)					T, 3960	
12	16.47	Center Court	√	√	√	√	2320	B-12
13	N/A	Kiel Ave. &Ramp CC	√	√	√	√		B-13
14	16.03	Kinnelon Rd. (Rt.618)	√	√	√	√	1585	B-14
15	N/A	Kakeout Connector & Kinnelon Rd.	√	√	√	√		B-15
	15.73	Hillcrest Ave.(NB)					T, 790	
	15.58	Valley Rd.(NB)					T, 790	
	15.43	Roosevelt Ave.(NB)					T, 580	
16	15.32	Cascade Way	√	√	√	√	1635	B-16
17	15.01	Boonton Ave.	√	√	√	√	530	B-17
	14.91	Bartholdi Ave.					1480	
18	14.63	Morse Ave.	√	√	√	√	1635	B-18
	14.32	Mathews Ave.					T,1160	
	14.1	Drive Way (NB)					T, 530	
19	14	Cotluss Rd.	√	√	√	√		B-19
Total		**Marked**	**19**	**19**	**19**	**19**		

*: Type T intersection, and the distance (ft) between connected two intersections.
For example, Lake Stockholm intersection is a T intersection, and the distance is 2220 (ft) to Vernon Stockholm intersection.

**: Figure of each intersection is provided in Appendix B.

Table 2. List of Data Collected for Route 42/322 (17 Signalized Intersections)

No.	MP	Intersection	Count	Plan	Signal	Timing	Note *	Figure
1	6.17	Shopping Center Dr.	√	√	√	√	1375	B-20
	5.91	Unnamed Rd.1					T, 530	
2	5.81	Greentree Rd.	√	√	√	√	160	B-21
	5.78	Irvin Ave.(NB)					T, 580	
3	5.67	Whitman Dr.	√	√	√	√	1595	B-22
	N/A	Unnamed Rd.2(NB)					T, 360	
4	5.3	Gantown Rd.	√	√	√	√	195	B-23
	N/A	Unnamed Rd.3 (NB)					T, 595	
	5.15	W Garfield Ave.-Garfield Ave.					265	
5	5.1	Johnson Rd.(NB)	√	√	√	√	T, 475	B-24
	5.01	Mckinley Ave.(SB)					T, 475	
6	4.92	Fries Mill Rd.(SB)	√	√	√	√	T, 1375	B-25
	4.66	Unnamed Rd.4 (SB)					T, 1320	
	4.41	Leddon Ln.(NB)					T, 900	
	4.24	Medison Ave.					270	
	N/A	Unnamed Rd.5 (SB)					T, 1420	
7	3.92	Watson Dr.	√	√	√	√	1265	B-26
	3.68	American Blvd.(SB)					T, 550	
	N/A	Unnamed Rd.6 (SB)					T, 350	
8	3.51	Tuckahoe Rd.-Stagecoach Rd.	√	√	√	√	790	B-27
	3.36	Ardmore Ave***					210	
	N/A	Unnamed Rd.7 (SB)					T, 160	
	3.29	Wayne Ave.(SB)					T, 315	
	3.23	Narbeth Ave.(SB)					T, 55	
	3.22	Unnamed Rd.8 (NB)					T, 315	
	3.16	Woodlawn Ave. (SB)					T, 220	
	N/A	Unnamed Rd.9(NB)					T, 95	
	3.1	Evergreen Ave.(SB)					T, 160	
	3.07	Fairmount Dr.(NB)					T, 210	
	3.03	Sycamore Ave. (SB)					T, 265	
	N/A	Twin Hollow Ct. (NB)					T, 50	
	2.97	Strand Ave.(SB)					T, 370	
	2.9	Highland Ave.(SB)					T, 315	
	2.84	Summit Ave.(SB)					T, 370	
	2.77	Laurel Ave.(SB)					T, 790	
9	2.62	Berlin Cross Keys Rd.	√	√	√	√	565	B-28
	N/A	Unnamed Rd.10 (NB)					T, 555	
	N/A	Unnamed Rd.11 (NB)					T, 675	
	2.28	Prosser Ave. (NB)					T, 265	
	2.23	Unnamed Rd.12 (SB)					T, 740	
10	2.09	Kennedy Dr. (SB)	√	√	√	√	T, 475	B-29
	2	Veronica Ln.(NB)					T, 1160	
	1.78	Wildwood Ave.(NB)					T, 330	
		Unnamed Rd.13 (NB)					T, 410	
	1.64	Dewey Ave.(NB)					T, 265	
	1.59	Crystal Dr.(NB)					T, 475	
	1.5	Laurel Ave.(NB)					T, 950	
	1.32	Kelal Ave.(NB)					T, 160	
	1.29	Grandview Ave.(SB)					T, 210	

Table 2. List of Data Collected for Route 42/322 (Continued)

No.	MP	Intersection	Count	Plan	Signal	Timing	Note *	Figure**
	1.25	Harrell Ave (SB)					2T, 160	
	N/A	Flemming Ln.(NB)					T, 370	
	1.15	ENT to APT (Brookdale Blvd.) (NB)					T, 1955	
11	0.78	Lake Ave.	√	√	√	√	880	B-30
	N/A	Unnamed Rd.14 (SB)					T, 440	
	0.53	Maxine Ave.(SB)					T, 420	
	0.45	Marsha Ave. (SB)					T, 160	
	0.42	Pedrick Ave.-Hoffman Ave.(SB, NB)					2T, 530	
	0.32	Lindele Ave. (SB)					T, 160	
	0.29	May Ave.(NB)					T, 160	
	0.26	Saybrook Ave.(SB)					T, 530	
	0.16	Pine St.1(NB)					T, 160	
	0.13	Pine St.2 (SB)					T, 265	
	0.08	Broad St.(NB)					T, 160	
	0.05	Willow Ave.(SB)					T, 265	
12	0	Sicklerville Rd.	√	√	√	√	475	B-31
	N/A	Gordon Ave.(SB, NB)					2T, 315	
	N/A	Unnamed Rd.15 (SB)					T, 740	
13	24.71	Poplar St.- New Brooklyn Rd.	√	√	√	√	740	B-32
	24.85	Washington Ave.(SB, NB)					2T, 790	
	25	Jefferson Ave.(SB, NB)					2T, 950	
	N/A	Hartman Ave.(NB)					T, 160	
	25.18	Walnut St.(SB, NB)					2T, 560	
	N/A	James Rd.					T, 1760	
	N/A	Unnamed Rd.16 (SB, NB)					2T, 265	
	25.67	Mellisa Ln. (NB)					T, 265	
14	25.72	Main St. (Rt.322)	√	√	√	√	2375	B-33
	N/A	Dickens Ct. (SB, NB)					2T, 580	
15	26.28	Corkery Ln.	√	√	√	√	580	B-34
	26.39	Forest Dr.(SB)					T, 1265	
	26.63	Karen Dr.(SB)					T, 580	
	26.74	Concord Dr.(NB)					T, 685	
	N/A	Unnamed Rd.17 (SB)					T, 325	
16	26.87	Malaga Rd.	√	√	√	√	375	B-35
	N/A	Unnamed Rd.18 (NB)					T, 220	
	N/A	Luther Ave. (NB)					T, 750	
	N/A	Luther (SB)					T, 650	
	N/A	Luther Ave. (SB,NB)					2T, 1110	
	N/A	Unnamed Rd.19 (SB)					T, 1000	
	N/A	Unnamed Rd.20 (NB)					T, 325	
	27.69	Battles Rd.(NB)					T, 265	
	27.74	Theresa Ln.(NB)					T, 100	
	N/A	Unnamed Rd.21 (SB)					T, 610	
	N/A	Unnamed Rd.22 (NB)					T, 1525	
	N/A	Unnamed Rd.23 (SB, NB)					2T, 265	
17	28.2	White Hall Rd.-Corkery Ln.	√	√	√	√	220	B-36
		Unnamed Rd.24 (NB)						
Total		**Marked**	**17**	**17**	**17**	**17**		

*: Type T intersection, and the distance (ft) between connected two intersections.
**: Figure of intersection is provided in Appendix B.

***: Included in Synchro files.

These data were subsequently configured, entered into Synchro and ultimately used to develop revised traffic timing directives.

Manual traffic counts were broken into 15-minute groups and included individual turning movement volumes and vehicle classifications. Some limited speed information was also collected. NJDOT provided signal timing data in the form of the existing timing directives in Microsoft Excel format. These directives include information such as cycle lengths, signal phases, splits, and offsets. The collected data for Route 23 are summarized in Table 1. Collected data for Route 42/322 are shown in Table 2.

In addition to traffic volume and roadway geometric data, the project team has conducted several site visits to verify the intersection layouts, roadway geometry, posted speed limits, and traffic operational conditions. Locations at which turning movement data were not collected and are significant trip generators (e.g., shopping centers, driveways, or street intersections), were noted for the determination of "break points". Break points are locations at which the total exiting traffic flow from the downstream location does not equal to the total entering flow from its upstream intersection.

Network Modeling

The collected data were applied for establishing Synchro networks. Based on the data collected, traffic simulation models were developed by importing the developed Synchro networks into SimTraffic for morning, evening and noon peak periods for both study corridors.

While the time and durations of peak periods are consistent for both study corridors, peak traffic volumes at intersections do not occur at the same time interval. Therefore, it was necessary to adjust the volumes and balance the flows. The total volume leaving an intersection was thus equal to the total volume entering its downstream intersection. For any non-signalized intersection, the peak hour volumes should be determined based on land usage, such as residential, retail, or office spaces, etc.

For signalized intersections, the difference between volumes at two adjacent signalized intersections was adjusted based on one of two scenarios.

In the first scenario, at least one non-signalized intersection is between two signalized intersections. Volume differences between the two signalized intersections were then assigned to the unsignalized intersections based on the percentages of turning movements. For example, in Figure 4, Route 23 Southbound (SB) traffic volume (3832 vph) entering Morse intersection was increased from 3832 to 4130 vph to be balanced with the maximum peak volume at the adjacent upstream signalized intersection. The increased volume (298 vph) has been added into traffic volume exiting Morse intersection hence the exiting traffic volume will be increased from 4082 to 4380 for the next downstream signalized intersection.

In the second scenario, there is no access point between two signalized intersections. The volume difference was based on fixing the critical signal intersection whose volume remains unchanged, while the volume at the other intersection can be adjusted.

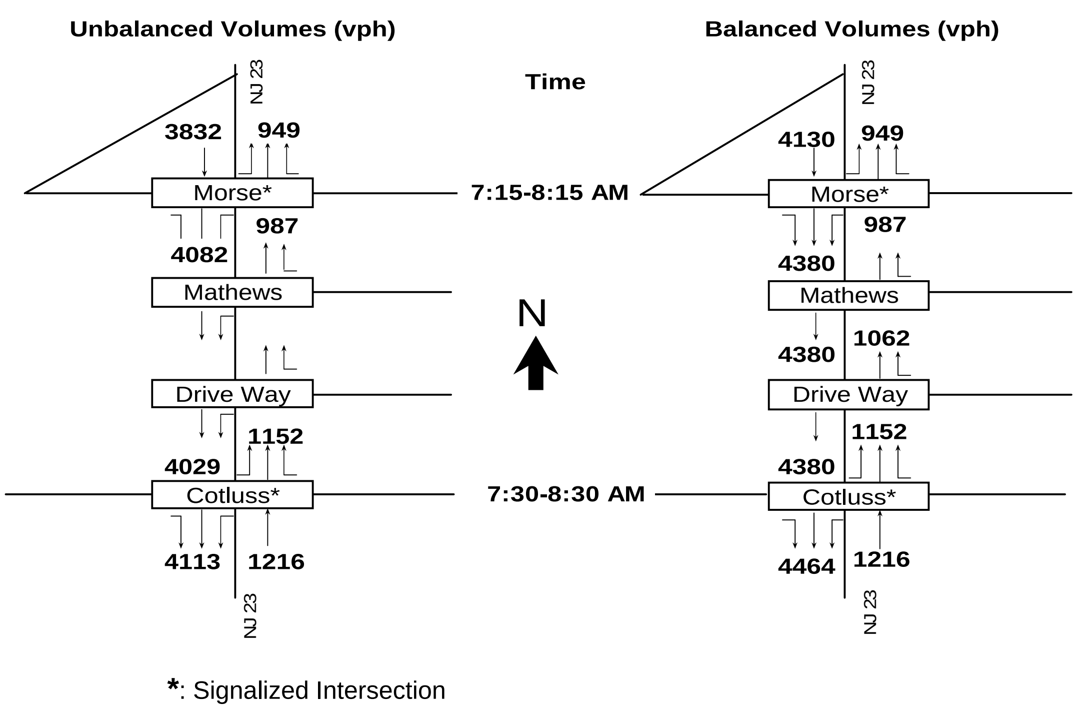
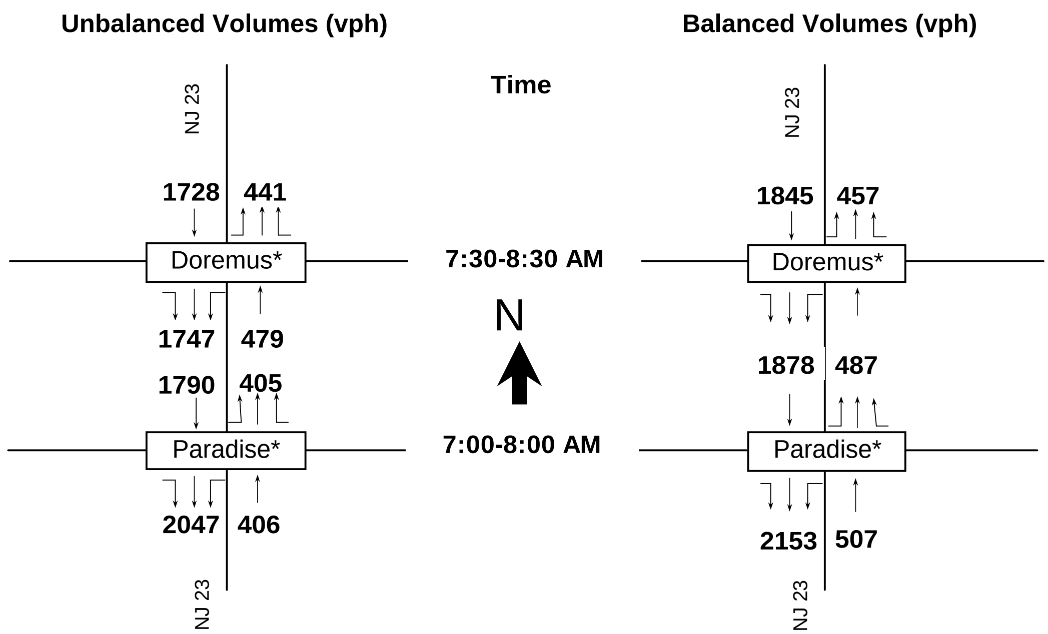


Figure 4. Balanced Volume (Scenario 1)

In Figure 5, Route 23 Northbound (NB) volume (406 vph) at Paradise intersection was increased to 507 vph to be balanced with the identified maximum peak volume in network. Since NB traffic volume (405 vph) exiting Paradise intersection and NB traffic volume (479 vph) entering Doremus intersection were not consistent, the volume in the link between Paradise and Doremus intersection was changed to 487 vph to be balanced with the volume (507 vph) entering Paradise intersection. SB volumes were also balanced in the same manner.

The purpose of the two volume balancing scenarios was intended to consider the worse case (e.g., maximum peak volume) during each peak period at the studied location. When optimizing splits, Synchro attempts to provide enough green time to serve the 90th percentile lane group flow. If there is not enough cycle time to meet this objective, Synchro will attempts to serve the 70th percentile traffic and then the 50th percentile traffic. Any extra time is given to the main street phases.



*****: Signalized Intersection

Figure 5. Balanced Volume (Scenario 2)

The next step of network modeling is inputting data into Synchro. In addition to adjusting volumes and peak hour factors, existing signal timing plan information including cycle lengths, phases, splits, yellow times, all red times, offsets, vehicle extensions, controller type, etc. were entered into Synchro for morning, noon, and evening peak periods. In order to compare the output of developed Synchro models with field conditions, the SimTraffic Models were converted from the Synchro models. Both the Synchro and SimTraffic files were reviewed and approved by NJDOT. Some adjustments were made to better reflect actual field conditions. For example, the model conditions did not reflect actual field conditions at the intersection of Route 23 and Oak Ridge Road. During a PM field visit, it was found that the queues at different jug handles would develop on the right hand shoulder in the two lane section of Route 23. In order to correct for this situation, the model was modified by adding a 3rd lane to the northbound section of the road with NJDOT's approval.

Model Calibration and Validation

Synchro and SimTraffic contain many parameters that describe traffic control operation, traffic flow characteristics, and driver behavior. Although these models provide default values for each variable, great attention should be paid to calibration so that the model accurately represents local conditions. Calibration is an iterative process in which the engineer adjusts the simulation model parameters until the results produced by the simulator match field measurements. The calibrated parameters in Synchro and SimTraffic are listed below:

- Lost Time
- Lane Utilization Factor
- Right (Left) Turn Factor
- Right (Left) Pedestrian Factor
- Heavy Vehicle Factor
- Headway Factor
- Right (Left) Turning Speed

Synchro and SimTraffic generally yielded un-calibrated results that most closely reflected observed field conditions. Particularly, SimTraffic provides queue calculations in terms of feet rather than number of vehicles. This was felt to provide more accurate queue estimates and required less computation time for the user. Nonetheless, Synchro and SimTraffic networks required fine tuning. The adjustment made in Synchro was the lost time factors as 2 seconds, 4 seconds, and 3 seconds for AM, NOON, and PM period, respectively in order to consider difference of driver's behavior in each time period. Right turn speed factor was also adjusted slightly to achieve better results. It was felt that the default right turning speed (15 mph) was too slow for the most congested segments, resulting in many vehicles blocking traffic while waiting to make right turn.

Signal Optimization

The research team used Synchro to optimize signal timing plans for both studied sections on Route 23 and Route 42/322. The following optimization stages were considered to be performed:

1. Optimize offsets (low impact)
2. Optimize offsets and cycle lengths (low-medium impact)
3. Optimize Signal Phase, offsets and cycle lengths (medium-high impact)
4. Suggest possible geometric changes and optimize Signal Phase, offsets and cycle lengths (high impact)

Fourth stage optimization was not considered for this research project.

The different tools of Synchro were used in the following steps to perform the optimization:

- Network Partitioning
- Signal Phase and Cycle Length Optimization
- Offset Optimization

Network partitioning allows a studied street network to be coordinated by different zones and cycle lengths, while timing plans within each zone are allowed to be tailored to fit local conditions. The process of network partitioning begins by dividing the full network into smaller networks or zones. Each intersection is then assigned to a specific zone. Partitioning a network into multiple zones is recommended under the following conditions:

- Large distances geographically separate the studied network into several sub-networks;
- The studied network contains different traffic characteristics within various locations or zones. For example, the signals at CBD may use two phase

signals with short cycle lengths, while the ones in suburban areas may applying eight phase signals with long cycle lengths; and

- It is possible to use shorter cycle lengths in some areas and longer cycle lengths in the more congested areas

Two reasons to use one zone optimization instead of multi-zone optimization:

- Controller hardware is not able to support multiple zones, and
- All intersections are close to each other (e.g., less than 500 ft)

According to the criteria listed above Route 23 was partitioned into three zones:

- Cotluss Road to Center Court Road (2.4 Miles, 8 Intersections)
- Echo Lake Road to Larue Road (1.7 Miles, 4 Intersections)
- Clinton Road to Lake Stockholm Road (4.2 Miles 7 Intersections)

Through the procedures performed in Signal Phase and Cycle Length Optimization, two different cycle lengths for the peak periods of the network were produced. Since the last two zones (from Echo Lake Road to La Rue Road & from Clinton Road to Lake Stockholm Road) were given the same optimal cycle lengths, they were combined to form one zone and leave the entire network divided into two zones as currently found on the roadway. With this assumption the offsets could be set to the same master controllers as in the existing timing directives. Once the optimization of the offsets was completed the new timing directives were created.

The Route 42/322 network was partitioned into five different zones by the roads listed as follows:

- Shopping Center Dr. to Fries Mill Rd (1.3 Miles, 6 Intersections)
- Watson Dr. to Tuckahoe Rd (0.4 Miles, 2 Intersections)
- Cross Keys Rd to Kennedy Dr. (0.53 Miles, 2 Intersections)
- Lake Ave to Poplar St. (1.1 Miles, 3 Intersections)
- Main St. to White Hall Rd. (2.5 Miles, 4 Intersections)

The optimum cycle lengths for individual intersections were around 110 seconds, and ranged from 90 seconds to 120 seconds. It was necessary that all of the intersections would function as a coordinated single network. A cycle length of 110 seconds was selected for all of the intersections, with the offsets determined from a single master controller location. A 90-second cycle length was selected for off-peak periods but still with the offsets measured from a single master controller location.

In developing off peak timing plans for Route 42/322, it was decided to compare the volumes obtained from ATR counts with turning movement volumes for the midday period. The midday period was selected as it represents non-commuter conditions, as would be typical during off peak periods. Average and median values were calculated for non-peak hour periods. It was found that the median value was approximately 30 percent of the noon peak hour values. Therefore, the midday peak hour turning movement volumes were adjusted accordingly to reflect average off peak hour conditions. Splits and offset were then calculated for off peak periods using a 90 second cycle length. These outputs were then incorporated into the revised timing directives for Route 42/322.

Timing Directives

Once the splits and offsets were optimized for the studied corridors, timing directives were prepared in accordance with NJDOT format. Initially, it was believed that the information recommended by Synchro could be directly integrated into an NJDOT format electronic spreadsheet. Due to the complexity of the timing plans, phasing options and other unique elements associated with standard timing directive, converting Synchro output into the timing directives was very labor intensive and not practical to be done. Therefore, the new timing directives for each signalized intersection needs to be developed manually. However, with the revised timing directives now in Excel format, revisions to cycle length, splits and offsets can be easily made. Changes that would result in adding or eliminating signal phases would require entire revamping of the directives.

The recommended timing directives by Synchro were reviewed by NJDOT. The procedure for developing the timing directives is summarized in Figure 6. The final directives for both study corridors Rt 23 and Rt 42/322 are provided in Appendix C and D.

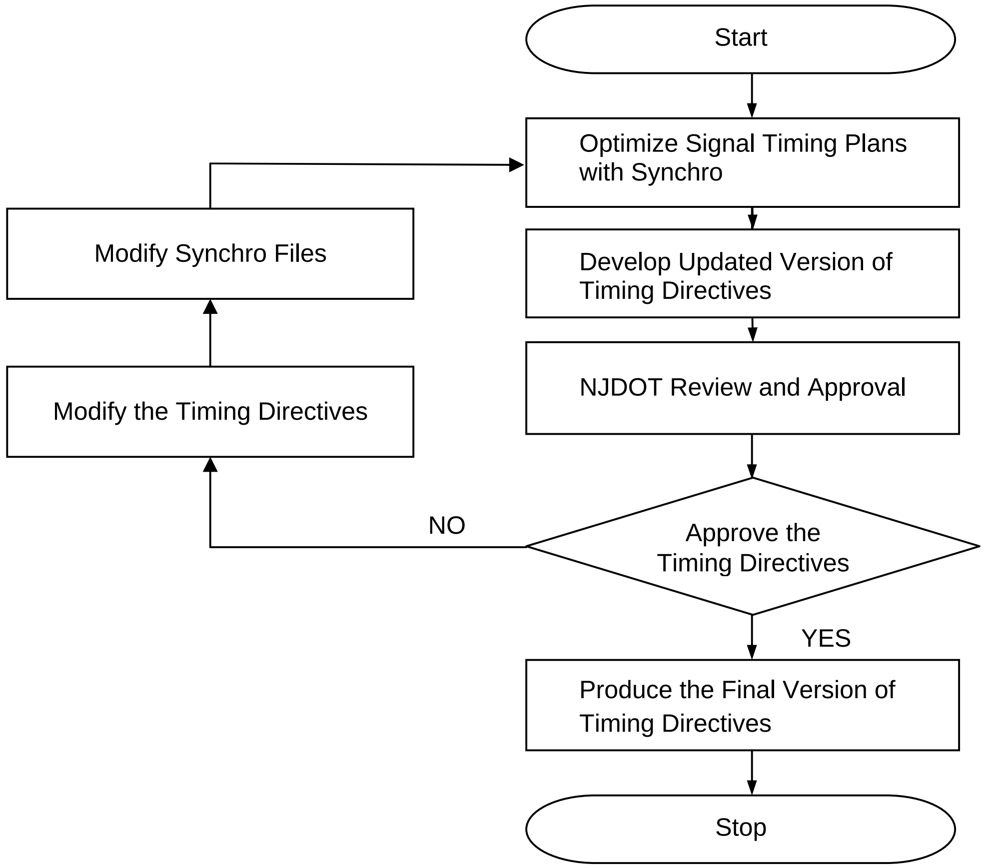


Figure 6. Procedure for Generating Signal Timing Directives

FINDINGS

Implementing optimized traffic signal timing plans based on the most updated traffic data is a relatively inexpensive way to improve performance at individual intersections as well as corridor-wide. As a follow-up to this research project, the NJIT team is undertaking a cost benefit analysis to quantify costs and benefits associated with the implementation of optimal timing directives

MOEs

While reductions in delay were not significant at some intersections, the accumulated delay incurred by the volume over the studied time period is considerable. Consider an average delay reduction is merely 5 seconds per each cycle during AM and PM peak hours, the volume of 1000 vph would result in a savings of nearly 24,000 vehicle-hours per year.

Note that the MOEs were not improved or debased at some locations to achieve a greater overall improvement. Thus, the signal timing optimization presented in this study can be further extended into several areas. One aspect is to extend the improvement at these locations, for example, by changing geometric conditions.

The MOEs for the Route 23 corridor are based on optimal signal timings and are summarized in Tables 3-a, 3-b, and 3-c for the peak periods of AM, NOON, and PM, respectively. MOEs for Route 42/322 are summarized in Tables 4-a, 4-b, 4-c, and 4-d for the peak periods of AM, NOON, PM, and OFF PEAK, respectively.

The complete MOE tables obtained from Synchro for Route 23 and Route 42/322 are summarized in Appendix E.

Table 3-a. MOEs comparison of Route 23 (AM)

	EXISTING			OPTIMIZED		
Intersection	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)
Vernon Stockholm(Rt.515)	15	7	35	15	8	35
Canister Rd.	40	4	70	35	4	57
Reservior Rd.	3	30	16	2	33	12
Doremus Rd.	3	30	22	2	34	12
Paradise Rd.	6	69	50	4	76	37
OaK Ridge Rd.	127	13	185	114	13	176
Clinton Rd.	36	18	77	20	34	54
LaRue Rd. (NB)	6	7	12	6	7	12
LaRue Rd. (SB)	83	11	164	56	15	137
Kanouse (Old Route23)	54	49	109	66	51	120
Echo Lake Rd.	86	6	123	74	9	130
Center Court	3	33	25	2	35	23
Kinnelon Rd. (Rt. 618)	18	17	68	5	11	11
Kiel Ave. & Ramp CC	4	11	10	4	12	9
Kakeout & Kinnelon Rd.	6	9	15	17	18	65
Casecade Way	31	29	123	10	54	59
Boonton Ave.	176	5	272	52	13	143
Morse Ave.	86	5	120	101	4	148
Cotluss Rd.	25	9	53	63	4	115
Total	**808**	**Avg. 19**	**1,549**	**648**	**Avg. 23**	**1,355**

Table 3-b. MOEs comparison of Route 23 (NOON)

	EXISTING			OPTIMIZED		
Intersection	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)
Vernon Stockholm(Rt.515)	3	20	13	4	19	14
Canister Rd.	3	23	17	3	25	13
Reservior Rd.	2	27	10	2	32	8
Doremus Rd.	1	35	10	1	42	7
Paradise Rd.	3	79	28	2	88	27
OaK Ridge Rd.	18	29	48	11	37	38
Clinton Rd.	6	37	21	4	44	17
LaRue Rd. (NB)	2	16	7	3	15	7
LaRue Rd. (SB)	1	44	18	2	40	20
Kanouse (Old Route23)	5	44	30	2	53	22
Echo Lake Rd.	4	48	15	4	47	17
Center Court	1	39	9	1	39	9
Kinnelon Rd. (Rt. 618)	13	14	41	12	15	38
Kiel Ave. & Ramp CC	3	14	10	3	16	9
Kakeout & Kinnelon Rd.	2	21	8	2	21	7
Casecade Way	5	63	37	3	75	24
Boonton Ave.	8	28	41	10	25	55
Morse Ave.	7	33	48	6	36	41
Cotluss Rd.	19	9	66	14	11	48

Total	**106**	**Avg. 33**	**477**	**89**	**Avg. 36**	**421**

Table 3-c. MOEs comparison of Route 23 (PM)

	EXISTING			OPTIMIZED		
Intersection	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)
Vernon Stockholm (Rt.515)	4	20	17	4	22	13
Cotluss Rd.	48	6	117	2	33	15
Morse Ave.	12	35	76	4	24	16
Boonton Ave.	34	16	98	2	32	20
Casecade Way	34	35	125	3	84	42
Kiel Ave. & Ramp CC	41	8	117	24	42	77
Kinnelon	11	7	22	62	15	109
Kakeout & Kinnelon Rd.	3	18	13	17	10	44
Center Court	5	25	23	1	44	15
Echo Lake Rd.	55	24	105	14	49	87
LaRue Rd. (NB)	2	40	18	32	29	78
LaRue Rd. (SB)	19	9	45	4	30	20
Clinton Rd.	74	14	135	32	10	109
OaK Ridge & Rt. 23	48	19	107	10	8	22
Paradise Rd.(N) & Rt. 23	5	80	49	3	20	9
Doremus Rd.& Rt. 23	10	15	45	18	53	84
Reservior Rd.& Rt. 23	19	9	58	65	10	144
Canister Rd. & Rt. 23	3	32	16	8	39	64
Kanouse (Old Route23)	20	42	100	30	9	91
Total	**447**	**Avg. 24**	**1286**	**335**	**Avg. 30**	**1,059**

Table 4-a. MOEs comparison of Route 42/322 (AM)

	EXISTING			OPTIMIZED		
Intersection	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)
Shopping Center Dr.	7	18	29	6	20	27
Greentree Rd.	61	4	93	24	9	60
Whitman Dr.	9	16	28	6	19	23
Gantown Rd.	40	4	74	12	12	35
Johnson Rd.(NB)	10	15	32	9	17	36
Fries Mill Rd.(SB)	15	11	29	7	20	21
Watson Dr.	14	20	46	9	24	38
Tuckahoe Rd.-Stagecoach Rd.	15	10	35	11	12	32
Berlin Cross Keys Rd.	15	15	41	14	16	38
Kennedy Dr. (SB)	2	31	11	2	32	9
Lake Ave.	3	35	21	3	34	20
Sicklerville Rd.	38	2	52	16	4	28
Poplar St.- New Brooklyn Rd.	10	15	29	7	19	24
Main St. (Rt.322)	2	21	9	1	25	5
Corkery Ln.	5	20	19	6	17	20
Malaga Rd.	3	17	11	4	14	9
White Hall Rd.-Corkery Ln.	2	14	8	3	11	8

Total	**251**	**Avg. 16**	**567**	**140**	**Avg. 18**	**433**

Table 4-b. MOEs comparison of Route 42/322 (NOON)

	EXISTING			OPTIMIZED		
Intersection	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)
Shopping Center Dr.	11	14	39	11	15	39
Greentree Rd.	55	5	80	20	12	53
Whitman Dr.	13	14	40	10	16	36
Gantown Rd.	33	6	68	15	12	44
Johnson Rd.(NB)	46	6	94	20	12	65
Fries Mill Rd.(SB)	13	19	41	10	22	36
Watson Dr.	13	26	61	9	29	50
Tuckahoe Rd.-Stagecoach Rd.	24	10	53	19	12	50
Berlin Cross Keys Rd.	19	15	54	18	16	51
Kennedy Dr. (SB)	3	29	20	3	29	18
Lake Ave.	4	34	31	5	33	29
Sicklerville Rd.	18	3	33	13	4	24
Poplar St.- New Brooklyn Rd.	12	15	35	10	17	30
Main St. (Rt.322)	2	22	9	2	22	7
Corkery Ln.	3	24	15	4	20	15
Malaga Rd.	2	22	7	2	19	6
White Hall Rd.-Corkery Ln.	1	19	5	2	15	5
Total	**272**	**Avg. 17**	**685**	**173**	**Avg.18**	**558**

Table 4-c. MOEs comparison of Route 42/322 (PM)

	EXISTING			OPTIMIZED		
Intersection	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)
Shopping Center Dr.	25	9	63	19	11	61
Greentree Rd.	72	5	105	55	6	88
Whitman Dr.	19	12	49	15	14	45
Gantown Rd.	82	3	115	43	6	83
Johnson Rd.(NB)	22	12	61	14	16	51
Fries Mill Rd.(SB)	15	16	42	9	21	30
Watson Dr.	23	18	68	13	24	56
Tuckahoe Rd.-Stagecoach Rd.	24	9	50	14	13	35
Berlin Cross Keys Rd.	35	12	76	28	14	70
Kennedy Dr. (SB)	7	21	30	8	21	28
Lake Ave.	5	29	31	6	28	31
Sicklerville Rd.	47	2	64	23	3	43
Poplar St.- New Brooklyn Rd.	12	18	41	11	19	38
Main St. (Rt.322)	4	15	27	2	24	9
Corkery Ln.	4	23	20	6	19	22
Malaga Rd.	3	18	14	5	15	12
White Hall Rd.-Corkery Ln.	3	14	11	3	13	11

Total	**402**	**Avg. 14**	**867**	**274**	**Avg. 16**	**713**

Table 4-d. MOEs comparison of. Route 42/322 (OFF PEAK)

	EXISTING			OPTIMIZED		
Intersection	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)	Signal Delay (veh-hr)	Average Speed (mph)	Fuel Use (gallons)
Shopping Center Dr.	11	14	39	2	23	8
Greentree Rd.	55	5	80	3	18	12
Whitman Dr.	13	14	40	2	20	9
Gantown Rd.	33	6	68	4	12	14
Johnson Rd.(NB)	46	6	94	3	21	13
Fries Mill Rd.(SB)	13	19	41	3	25	11
Watson Dr.	13	26	61	2	32	14
Tuckahoe Rd.-Stagecoach Rd.	24	10	53	4	16	13
Berlin Cross Keys Rd.	19	15	54	4	19	15
Kennedy Dr. (SB)	3	29	20	1	34	5
Lake Ave.	4	34	31	1	38	8
Sicklerville Rd.	18	3	33	3	5	7
Poplar St.- New Brooklyn Rd.	12	15	35	2	21	8
Main St. (Rt.322)	2	22	9	0	24	2
Corkery Ln.	3	24	15	1	24	4
Malaga Rd.	2	22	7	1	21	2
White Hall Rd.-Corkery Ln.	1	19	5	0	18	2
Total	**272**	**Avg. 17**	**685**	**36**	**Avg. 22**	**147**

Signal Optimization

Further investigation is needed on network partition and a procedure that allows a network with multiple zones and cycle lengths. When a large signalized network exists, breaking it into smaller networks becomes necessary. Thus, a guideline for partitioning a large scale network to manage queue if any on boundary of adjacent subnetworks should be developed.

The related optimal signal timing information such as controller types, cycle lengths, and offsets is summarized in Tables 5-a, 5-b, and 5-c for the peak periods of AM, NOON, and PM, respectively. Tables 5-a,5- b, and 5-c show that there are two cycle lengths in AM (e.g., 160 sec and 150 sec) and PM (e.g., 140 sec and 150 sec) periods and one cycle length in NOON (e.g., 90 sec) period. As discussed above, Route 23 was partitioned into three zones. These zones denominated were as zone B, zone F, and zone G in Synchro.

- Zone B (from Cotluss Road to Center Court Road)
- Zone F (from Echo Lake Road to Larue Road)
- Zone G (from Clinton Road to Lake Stockholm Road).

However, zone F and zone G were given the same cycle lengths. Thus, intersection of Route 23 and Echo Lake Road were selected as a reference point for zone F and Zone G, and intersection at Boonton Avenue was identified as a reference point for zone B.

Optimal signal timing plan of Route 42/322 was produced in four time periods (e.g., AM, NOON, PM, and OFFPEAK) with NJDOT's approval. Once splits and offsets were optimized, intersection of Route 42 and Shopping Center Drive was selected as a reference point of optimal signal timing plan. The related optimal signal timing information such as controller types, cycle lengths, and offsets is summarized in Tables 6-a, 6-b, 6-c, and 6-d for the peak period of AM, NOON, PM, and OFF PEAK, respectively.

Timing Directives

Another important result is the establishment of a process whereby traffic volume data can be updated and timing directives can be easily modified. While this process was initially thought to be well suited for automatic data transfer, this was shown not to be the case. Due to the complexity of the timing directives and the current desire to maintain the directives in a MS Word format, it was necessary to manually enter the green, red, yellow and all red times. However, now that the timing plans have been developed, they would be relatively easy to update in the future.

Table 5-a. Existing vs. Optimal Signal Timing of Route 23 (AM)

	Existing			Optimized		
Intersection	Controller Type	Cycle Length (sec)	Offset (sec)	Controller Type	Cycle Length (sec)	Offset (sec)
Vernon Stockholm Rd.(Rt.515)	AC*	160	108	AC	160	81
Canister Rd.	AC	160	42	AC	160	122
Reservior Rd.	AC	160	126	AC	160	24
Doremus	AC	160	2	AC	160	75
Paradise Rd.	AC	160	85	AC	160	138
Oak Ridge Rd.	AC	160	117	AC	160	135
Clinton Rd.	AC	160	151	AC	160	110
Larue Rd. (NB)	AC	160	43	AC	160	129
Larue Rd. (SB)	AC	160	43	AC	160	129
Kanhouse (Old Rt. 23)	AC	160	80	AC	160	73
Echo Lake Rd.	AC	160	0	AC	160	0
Center Court	AC	150	49	AC	150	92
Kiel Ave. &Ramp CC	AC	150	58	AC	150	112
Kinnelon Rd. (Rt.618)	AC	150	58	AC	150	93
Kakeout & Kinnelon Rd.	AC	150	54	AC	150	70
Cascade Way	AC	150	118	AC	150	3
Boonton Ave.	AC	150	0	AC	150	0
Morse Ave.	AC	150	30	AC	150	36
Cotluss Rd.	AC	150	57	AC	150	85

*:Actuated-Coordinate

Table 5-b. Existing vs. Optimal Signal Timing of Route 23 (NOON)

	Existing			Optimized		
Intersection	Controller Type	Cycle Length (sec)	Offset (sec)	Controller Type	Cycle Length (sec)	Offset (sec)
Vernon Stockholm Rd.(Rt.515)	AC	90	45	AC	90	39
Canister Rd.	AC	90	0	AC	90	80
Reservior Rd.	AC	90	0	AC	90	80
Doremus	AC	90	45	AC	90	58
Paradise Rd.	AC	90	0	AC	90	85
Oak Ridge Rd.	AC	90	87	AC	90	52
Clinton Rd.	AC*	90	35	AC	90	32
Larue Rd. (NB)	AC	90	59	AC	90	8
Larue Rd. (SB)	AC	90	49	AC	90	8
Kanhouse (Old Rt. 23)	AC	90	0	AC	90	44
Echo Lake Rd.	AC	90	0	AC	90	0
Center Court	AC	90	76	AC	90	83
Kiel Ave. &Ramp CC	AC	90	45	AC	90	16
Kinnelon Rd. (Rt.618)	AC	90	45	AC	90	52
Kakeout & Kinnelon Rd.	AC	90	41	AC	90	46
Cascade Way	AC	90	81	AC	90	11
Boonton Ave.	AC	90	0	AC	90	0
Morse Ave.	AC	90	56	AC	90	54
Cotluss Rd.	AC	90	16	AC	90	88

Table 5-c. Existing vs. Optimal Signal Timing of Route 23 (PM)

	Existing			Optimized		
Intersection	Controller Type	Cycle Length (sec)	Offset (sec)	Controller Type	Cycle Length (sec)	Offset (sec)
Vernon Stockholm Rd.(Rt.515)	AC	140	3	AC	140	82
Canister Rd.	AC	140	67	AC	140	15
Reservior Rd.	AC	140	114	AC	140	65
Doremus	AC	140	71	AC	140	60
Paradise Rd.	AC	140	133	AC	140	119
Oak Ridge Rd.	AC	140	78	AC	140	87
Clinton Rd.	AC	140	33	AC	140	92
Larue Rd. (NB)	AC	140	36	AC	140	97
Larue Rd. (SB)	AC	140	36	AC	140	97
Kanhouse (Old Rt. 23)	AC	140	107	AC	140	85
Echo Lake Rd.	AC	140	0	AC	140	0
Center Court	AC	150	120	AC	150	123
Kiel Ave. &Ramp CC	AC	150	77	AC	150	73
Kinnelon Rd. (Rt.618)	AC	150	77	AC	150	88
Kakeout & Kinnelon Rd.	AC	150	73	AC	150	77
Cascade Way	AC	150	30	AC	150	31
Boonton Ave.	AC	150	0	AC	150	0
Morse Ave.	AC	150	125	AC	150	133
Cotluss Rd.	AC	150	85	AC	150	80

Table 6-a Existing vs. Optimal Signal Timing of Route 42/322 (AM)

	Existing			Optimized		
Intersection	Controller Type	Cycle Length (sec)	Offset (sec)	Controller Type	Cycle Length (sec)	Offset (sec)
Shopping Center Dr.	AC*	120	0	AC	110	0
Greentree Rd.	AC	120	70	AC	110	55
Whitman Dr.	AC	120	63	AC	110	78
Gantown Rd.	AC	120	0	AC	110	92
Johnson Rd.(NB)	AC	120	3	AC	110	78
Fries Mill Rd.(SB)	AC	120	12	AC	110	34
Watson Dr.	AC	88	48	AC	110	82
Tuckahoe Rd.-Stagecoach Rd.	AC	125	71	AC	110	31
Berlin Cross Keys Rd.	AC	120	114	AC	110	76
Kennedy Dr. (SB)	Semi-A**	90	N/A	AC	110	10
Lake Ave.	Semi-A	92	N/A	AC	110	0
Sicklerville Rd.	Semi-A	120	0	AC	110	4
Poplar St.- New Brooklyn Rd.	Semi-A	120	62	AC	110	104
Main St. (Rt.322)	Semi-A	107	N/A	AC	110	10
Corkery Ln.	Semi-A	88	N/A	AC	110	16
Malaga Rd.	Semi-A	84	N/A	AC	110	57
White Hall Rd.-Corkery Ln.	Semi-A	88	N/A	AC	110	0

*:Actuated-Coordinate
**:Semi-Actuated

Table 6-b Existing vs. Optimal Signal Timing of Route 42/322 (NOON)

	Existing			Optimized		
Intersection	Controller Type	Cycle Length (sec)	Offset (sec)	Controller Type	Cycle Length (sec)	Offset (sec)
Shopping Center Dr.	AC	120	0	AC	110	0
Greentree Rd.	AC	120	71	AC	110	105
Whitman Dr.	AC	120	74	AC	110	19
Gantown Rd.	AC	120	0	AC	110	32
Johnson Rd.(NB)	AC	120	3	AC	110	18
Fries Mill Rd.(SB)	AC	120	21	AC	110	93
Watson Dr.	AC	88	48	AC	110	33
Tuckahoe Rd.-Stagecoach Rd.	AC	125	N/A	AC	110	88
Berlin Cross Keys Rd.	AC	120	114	AC	110	104
Kennedy Dr. (SB)	Semi-A	90	N/A	AC	110	0
Lake Ave.	Semi-A	92	N/A	AC	110	0
Sicklerville Rd.	Semi-A	120	0	AC	110	7
Poplar St.- New Brooklyn Rd.	Semi-A	120	62	AC	110	100
Main St. (Rt.322)	Semi-A	85	N/A	AC	110	98
Corkery Ln.	Semi-A	88	N/A	AC	110	2
Malaga Rd.	Semi-A	84	N/A	AC	110	48
White Hall Rd.-Corkery Ln.	Semi-A	88	N/A	AC	110	0

Table 6-c Existing vs. Optimal Signal Timing of Route 42/322 (PM)

	Existing			Optimized		
Intersection	Controller Type	Cycle Length (sec)	Offset (sec)	Controller Type	Cycle Length (sec)	Offset (sec)
Shopping Center Dr.	AC	120	75	AC	110	0
Greentree Rd.	AC	120	73	AC	110	33
Whitman Dr.	AC	120	84	AC	110	44
Gantown Rd.	AC	120	0	AC	110	75
Johnson Rd.(NB)	AC	120	3	AC	110	65
Fries Mill Rd.(SB)	AC	120	31	AC	110	28
Watson Dr.	AC	88	N/A	AC	110	90
Tuckahoe Rd.-Stagecoach Rd.	AC	125	N/A	AC	110	13
Berlin Cross Keys Rd.	AC	120	114	AC	110	16
Kennedy Dr. (SB)	Semi-A	90	N/A	AC	110	34
Lake Ave.	Semi-A	92	N/A	AC	110	0
Sicklerville Rd.	Semi-A	120	0	AC	110	20
Poplar St.- New Brooklyn Rd.	Semi-A	120	62	AC	110	12
Main St. (Rt.322)	Semi-A	40	N/A	AC	110	70
Corkery Ln.	Semi-A	88	N/A	AC	110	80
Malaga Rd.	Semi-A	84	N/A	AC	110	6
White Hall Rd.-Corkery Ln.	Semi-A	88	N/A	AC	110	0

Table 6-d Existing vs. Optimal Signal Timing of Route 42/322 (OFF PEAK)

	Existing			Optimized		
Intersection	Controller Type	Cycle Length (sec)	Offset (sec)	Controller Type	Cycle Length (sec)	Offset (sec)
Shopping Center Dr.	AC	120	0	AC	90	0
Greentree Rd.	AC	120	71	AC	90	24
Whitman Dr.	AC	120	74	AC	90	34
Gantown Rd.	AC	120	0	AC	90	58
Johnson Rd.(NB)	AC	120	3	AC	90	38
Fries Mill Rd.(SB)	AC	120	21	AC	90	85
Watson Dr.	AC	88	48	AC	90	46
Tuckahoe Rd.-Stagecoach Rd.	AC	125	N/A	AC	90	88
Berlin Cross Keys Rd.	AC	120	114	AC	90	64
Kennedy Dr. (SB)	Semi-A	90	N/A	AC	90	32
Lake Ave.	Semi-A	92	N/A	AC	90	0
Sicklerville Rd.	Semi-A	120	0	AC	90	52
Poplar St.- New Brooklyn Rd.	Semi-A	120	62	AC	90	24
Main St. (Rt.322)	Semi-A	85	N/A	AC	90	57
Corkery Ln.	Semi-A	88	N/A	AC	90	61
Malaga Rd.	Semi-A	84	N/A	AC*	90	5
White Hall Rd.-Corkery Ln.	Semi-A	88	N/A	AC*	90	0

CONCLUSIONS

While New Jersey has not seen significant increases in overall population, vehicles miles traveled (VMT) continues to increase and activity patterns are constantly changing. These tendencies significantly impact travel patterns. A programmatic updating of existing traffic signal timing plans provides an effective means to be responsive to these changes. And while the benefits of implementing these changes may not be as profound as adding new roadway capacity, new construction and associated property taking in a state which has earned the distinction of being the most densely populated in the nation, is often controversial and costly. Therefore, an important component to New Jersey's transportation success is extracting as much as possible from its existing infrastructure, which is also consistent with national transportation and environmental policies. Updating existing traffic signal timing plans based on current traffic volume conditions is a highly effective means for reducing driver delay, congestion and improving air quality.

The primary result of the optimal signal timing is that both studied corridors achieved their significant overall improvements (e.g., signal delay, average speed, fuel consumption, accident rate, vehicle emission rate, etc.). However, these improvements were not obtained in every intersection. For example, while signal delay at Boonton Avenue intersection in Route 23 was decreased by 142 veh-hr for AM period, it was increased nearly 4 veh-hr for AM period at Cotluss Road intersection in Route 23. Although entire network signal delay was drastically improved, some intersections were sacrificed to achieve better results. Thus, it is required to develop a new method enhancing the debased intersections.

Moreover, it was found that a systematic network partitioning process should be developed. Development of such procedure of network partitioning that can control queue management on the one network partition and the adjacent subnetworks would adopt multiple systems and cycle lengths into any types of network condition.

Finally, the project team suggests that traffic signal timing and coordination plans should be routinely updated to ensure system optimization.

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APPENDIX A: LITERATURE REVIEW

Signal Optimization Models

Over the past decades mathematical programming values has been carried out by various methods for optimizing signalized intersections. The theoretical concept as well as formulation was first discussed by Webster and Cobbe (1966). The basic assumption was that the traffic volume of the intersection did not exceed its capacity. Based upon this assumption, each approach of the intersection was given a predetermined ‘desired degree of saturation’ to limit the level of saturation. The objective was to minimize the total intersection delay during the entire period of operation subject to some typical constraints (e.g., cycle length, splits, and mean arrival rate of vehicles). However, this model did not respond to flow variation. Thus, the signal control would be far from real optimal control (Luo, et al., 2002). Following Webster’s concept, Allsop (1972) used a Linear Programming method to maximize the total departure of an intersection. Yagar (1974) extended Webster and Cobbe’s theory by considering stochastic vehicle arrivals at an intersection and reformulated Allsop’s model by considering changeable saturation flows in different calculation stages. Yagar’s model became one of the operational techniques to calculate cycle lengths and green times in the 1994 Highway Capacity Manual (HCM). However, it was not a real-time calculation model in lack of efficient dynamic queue formulation. Many models and simulators have been developed and already applied to the practice, among which, OPAC (1983), TRANSYT-7F (1991), PASSER (1991), and SCOOT (1996), are the major representatives. Shepherd (1992) and Wood (1993) summarized these models from the view of both theory and practice and concluded that most of them served well for under saturated or slightly congested condition and may be inaccurate while dealing with oversaturated situation (Liu, 2001).

For oversaturated traffic condition where queues persist and cannot be fully discharged, two models were firstly developed by Gazis (1964) and Michalopoulos and Stephanopoulos (1979). However, both models considered effects of traffic signal under a constant flow condition. In reality, traffic flow at a signalized intersection follows a step function. The exit flow is at saturation (zero) when the time of interest is in a green (red) phase. Secondly, both models considered a signal control system as a queuing network. More recently, a number of enhanced models were developed (Abu-Lebdeh, et al., 1997; and Wey, et al., 1997) to deal with over-saturated traffic condition.

Stephanopoulos et al. (1979) pointed out the problem of modeling congested traffic without the Fundamental Diagram (Figure 7). The study approach taken was macroscopic in nature (i.e. cars are treated as a continuum rather than individually) and is based on the theory of shock waves developed by Lighthill and Whitham (1955)

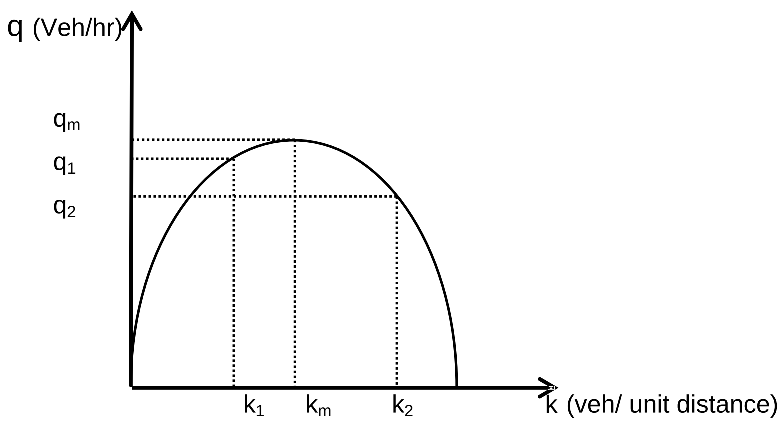

Figure A-1. Flow-density relationship

Frequent stop-and-go movements in congested situation generate traffic dynamics in the form of shockwaves. Density along the queue length was constantly in a state of transition, which rendered the assumptions of compact queue and constant average density questionable. In short, without the Fundamental Diagram, it is difficult for a model to describe queue dynamics accurately, which is needed to generate good timing plans for over-saturated traffic condition (Lo, et al., 2000).

Recently, Lo (1998, 1999a, 1999b) developed a cell-based dynamic signal control formulation designated as Dynamic Intersection Signal Control Optimization (DISCO). DISCO, a heuristic solution approach, considers the entire range of the Fundamental Diagram by encapsulating the Cell-Transmission Model (CTM) (Daganzo, 1994 and 1995). CTM provided a convergent approximation to the Lighthill and Whitham, and Richards (LWR) model and covered the entire Fundamental Diagram. The features and validation of CTM were discussed by Lin and Ahanotu (1995).

Basically, CTM can replicate kinematic waves, queue formation and dissipation in an explicit manner. This capability makes it a suitable platform for modeling dynamic traffic. While Lo (1998, 1999a, 1999b) applied DISCO to a range of demand scenarios to demonstrate its ability, the results were promising. For light to moderate traffic condition, DISCO produced timing plans consistent with the plan recommended by other models. Moreover for gridlock conditions, DISCO was able to produce a timing plan better than that using conventional queue management practices.

In highway networks, traffic interruptions occur at signalized intersections, while road users experience frequent stops and delay. Furthermore, for an arterial with more than two signalized intersections, vehicle arrivals are moving with platoons and traveling to downstream intersections. If appropriate signal coordination is designed on such an arterial, the platoon of vehicles can pass through downstream intersections with minimum number of stoppings, thus decreasing intersection delays experienced by the road users (Kovvali, et al., 2002). The majority of existing signal coordination algorithms did not consider the dynamic queue length at each intersection approach. Therefore, the application to oversaturated conditions may lead to sub-optimal results. Over saturation occurs when a signalized intersection cannot process all arrived vehicles at the end of a green period, thus a queue is developed and may be carried over to the next cycle. If corrective steps are not taken, the growing queue will block the upstream intersections and reduce the network capacity (Girianna, et al., 2002).

Considering a network with corrected multiple signalized arterials, coordination can be accomplished by changing offsets and splits. The coordination among the arterials is usually bounded by critical intersections of two arterials. The optimization of network wide arterial coordination is a combinatorial combination problem. A micro Genetic Algorithm (μGA) was developed (Goldberg, 1989) to solve the problem. GA regarded as an emerging optimization tool due to its simplicity, minimal problem restrictions and capability in solving large combinatorial combination problems, parallelism and productivity of global solutions. GAs simulate the genetic state or chromosome of an individual population by selecting the most influential individual through genetic operators, such as natural selection, mutation, and crossover, while the chromosome can represent the set of green times in signal coordination problems.

Currently, the most widely used signal coordination programs include PASSER, TRANSYT-7F, SCOOT, OPAC, and Synchro etc. They are discussed next.

PASSER

PASSER (Progression Analysis and Signal System Evaluation Routine) is the most widely used bandwidth optimization software for arterial streets. PASSER II was developed by the Texas Transportation Institute in the early 1980s. It is a macroscopic simulation model designed to optimize signal timing parameters and progression on arterials. PASSER II calculates splits using Webster's methodology. The program then adjusts the splits through minimizing delay for all intersections. While calculating splits, PASSER II applies a half-integer concept based on Brook's bandwidth algorithm for maximizing progression bandwidth along an arterial (Messer, et al., 1974). Thus, the interference to progression bands was minimized. The maximum progression efficiency in PASSER II along an arterial was obtained by optimizing cycle length, offsets and phasing sequences. (Kovvali, et al., 2002). As an enhanced version of PASSER II, PASSER II-90 can model multiple phase plans, one-way streets, variable cycle lengths and maximize arterial progression.

PASSER III is designed for under saturated conditions. It can optimize signal timings by minimizing delay at each intersection. Since the delay module in PASSER III applies vertical stacking of queues, the optimization could be inaccurate for short links even during under saturated conditions. PASSER III applies vertical stacking of queues and hence is not capable of modeling queue spillback conditions in its current form (Kovvali, et al., 2002).

In the early 1990s PASSER IV-96 was released. Based on the MAXBAND program, the DOS based PASSER IV-96 is used to optimize a network wide signalized traffic control through maximizing bandwidth. The bandwidth is maximized so that a car can potentially pass through a series of signalized intersections with minimal number of stoppings. It is able to optimize arterial signal timings as well as closed-loop networks in central business districts (CBD). Unlike PASSER II-90, PASSER IV-96 can handle multiple connected arterials with one-way and two-way traffic operations (Benekohal, et al., 2002).

TRANSYT-7F

TRANSYT-7F is a macroscopic simulation program with optimization feature originally developed by Robertson (1969). Since then, the program has been continuously enhanced. The first U.S. version of TRANSYT-7F was developed in 1981 by the Florida Transportation Center at the University of, and the most recent TRANSYT-7F is version 9.

TRANSYT-7F is a powerful tool, for signal optimization, within which the simulation module is a deterministic model that simulates macroscopic traffic flow in a stepwise fashion (Wallace, et al., 1998*)*. Before version 7, the simulation was performed in individual links whereby the model would complete all the time steps for one link, before proceeding to the next link. This approach, however, could not simulate spillback effects, and was thus refined in version 8 (Sadek, et al., 2002).

For signal optimization, TRANSYT-7F traditionally used a special application of the hill climbing search method with different step sizes, which is an iterative, gradient search algorithm that typically requires extensive computation. The process of searching the optimal solution will continue until no further improvement in the value of the objective function.

Various objective functions were applied before version 7, such as minimizing delay, minimizing the combination of delay and number of stops (the Disutility Index – DI), maximizing progression opportunities (PROS), and optimizing the combination of DI and PROS (Sadek, et al., 2002). Version 8 was developed to model oversaturated traffic conditions, where a step-wise simulation rather than link-wise simulation was applied. Four new additional functions were introduced to version8:

- Minimizing the product of queuing ratio (QR) and the DI.
- Maximizing the ratio of throughput (Thru) over DI (i.e. Thru/DI).
- Maximizing throughput, and then minimizing the DI without reducing the throughput.
- Maximizing throughput, with a penalty imposed if the volume/capacity (v/c) ratio exceeds a user-defined threshold was intruded in release.

By enhancing version 8, three major new features were introduced version 9, including: (1) a routine for thorough cycle length optimization (CYCOPT); (2) a method for modeling traffic-actuated controllers (T7FACT); and (3) a Genetic Algorithm (GA) routine to augment the traditional hill-climbing algorithm in determining optimal signal offsets. Although the use of the CYCOPT and T7FACT modules appears to yield superior timing plans to those developed using the older version of TRANSYT-7F, the GA routine is not very effective in improving the quality of the timing plans. (Sadek, et al., 2002).

SCOOT

SCOOT (Split, Cycle, and Offset Optimization Technique) is a third generation adaptive traffic signal control system introduced to the UK in early 1980’s (Hunt, et al., 1981). The goal of adaptive signal control systems is to improve flow conditions on urban networks by optimizing signal coordination, considering real-time traffic conditions. SCOOT is one of few adaptive control systems widely applied around the world (Hansen, et al., 2000).

SCOOT optimizes traffic signal timings (e.g., cycle length, offsets, and splits) that minimize Performance Index (PI), the measure of joint impacts of average queue length and number of stops. If a critical intersection is identified, it will influence the signal optimization for intersections of each section within the studied network. Embedded within SCOOT are models for handling queue accumulation, queue dissipation and platoon dispersion that receive real-time information (e.g., flow and occupancy information) for SCOOT’s optimization processes. SCOOT has been regarded as an "on-line TRANSYT" because a similar method to optimize off-line signal timings is employed. Unlike fixed signal timing plans that age rapidly and require costly data collection for updating, the optimal signal timings from SCOOT continuously respond to changing demands and thus do not require updating. SCOOT employs information from vehicle detectors to predict total delay and stops based on current signal timings over short rolling horizons. In this manner, frequent small alterations can adapt to the short-term fluctuations in traffic demand (Hansen, et al., 2000).

OPAC

The Optimized Policies for Adaptive Control (OPAC) strategy is a real-time signal timing optimization algorithm that has been developed by Parsons Brinkerhoff Farradyne Inc. and the University of Massachusetts at Lowell since 1980's (Gartner, 1982 and 1983). OPAC is a distributed control strategy featuring a dynamic optimization algorithm that calculates signal timings to minimize a performance function considering total intersection delay and stops without requiring a rigid, fixed cycle time. The algorithm uses a combination of measured and modeled demand to determine phase durations at signalized intersections subject to minimum and maximum green times. If it is running in a coordinated mode, the optimal cycle length and offsets can be updated based on real-time data. In the early 90's, a real-time traffic-adaptive signal control system (RT-TRACS) was developed by Federal Highway Administration (FHWA), which served as a platform for the implementation of a variety of traffic signal control algorithms. In a latest study, the OPAC strategy was developed on RT-TRACS that provided capabilities for both individual and coordinated control at signalized intersections. Reduced delays and number of stops maintained the progressions along a tested arterial were demonstrated after comparing that with a fixed time system (Kovvali, et al., 2002).

Synchro

Synchro was developed in the mid-1990s by Trafficware Inc., which performs simulation and optimization, based on a deterministic and macroscopic modeling approach. Synchro relies more on analytical relationships for estimating these effects (Washburn, et al., 2001). It adopts a window-based, menu-driven approach for data input and output processes (Husch, et al., 1999). Due to its simplicity of manipulation and flexibility of applications, it has gained popularity in signal optimization. Synchro has the following significant features:

- *Ability to simultaneously optimize lead-lag phase ordering in addition to cycle length, phase lengths, and coordination offsets*. Synchro can search for the best cycle length (within a user-specified range), determine appropriate phase lengths and offsets for the selected cycle length, and evaluate different lead/lag phase orderings. Separate optimization of multiple divided zones within the overall network can be managed. Synchro allows different cycle lengths within one coordinated network.

- *Percentile Delay estimation method which provides an alternative to model the effects of actuation and coordination in a more realistic manner*. Synchro offers users a choice between two types of signal delay calculations: 1) the 1997 HCM formulation or called Webster™s delay, and 2) percentile delay.

  Synchro integrates the area under the arrival-departure curve to calculate uniform delay, using a 0.1-second time slice resolution. This method, again, explicitly accounts for the effects of coordination. The component of delay is calculated according to the 1997 HCM formulation. For the Percentile Delay, the main distinction is in how the traffic volume was modeled. The HCM method utilizes a constant traffic volume for the entire hour, or peak 15 minutes, while the Percentile method uses five different traffic volume loadings10th, 30th, 50th, 70th and 90th –percentile based on a Poisson distribution. These loadings are used for a 15-minute analysis period (they are adjusted by the PHF) to calculate weighted delay measurement. Essentially, this technique is intended to more realistically model traffic demand variability experienced from cycle to cycle as well as calculate green times for actuated signals. This, in combination with the ability of actuated signals to efficiently respond to variable traffic loadings, usually results in more accurate modeling of actuated signals. Nearly- and over-saturated conditions can also result in significant differences between the Percentile and HCM delay estimation methods.

- *Easy data input and comprehensive output options*. Synchro allows the user to click and drag to create links (nodes are created implicitly). It also allows the use of a "background" Drawing Exchange Format (DXF) file as a template for tracing the studied street network. This graphical input method is very intuitive and user-friendly. Once the studied network has been created graphically, the remaining data are input in a format that basically mirrors the HCM worksheets, with an additional worksheet for actuated operations. A key feature of Synchro is that most of its calculations and analysis results are updated immediately following changes to user-adjustable values. In addition, Synchro networks can be easily converted to be used by other models (e.g., CORSIM, and TRANSYT) for extensive and comprehensive analysis. Synchro can produce various MOEs. The user can read basic operational analysis information directly from the input screens as parameter values are entered or changed. The user can also place a query for one or more reports of any operational statistics by lane group, approach, intersection, arterial, or network. Synchro can also create interactive time-space diagrams with immediate results.

Other beneficial features in Synchro include:

- *Capability of modeling right-turns on red, u-turns, and five-legged intersections.*
- *Multiple intersections can be controlled by a single controller, simplifying the process for modeling situations like diamond interchanges*.
- *Optimization objective function is to minimize delay.*
- *Modeling of Actuated Control*.

The modeling of pre-timed signal operation is fairly straight forward since phase durations are fixed at the same length for every cycle, while Synchro can model complicated actuated signal operations.

Synchro also employs its own green time calculator for actuated conditions. It estimates green times for each of the five different percentile volume loadings according to the Poisson distribution. Synchro uses formulas, which are based on the inputs from the actuated controller settings input page, to predict phase gapping and skipping probabilities for each of the five volume scenarios, and adjusts the average green times accordingly. The delay is calculated for each volume scenario and then averaged across all five volume loadings to determine the overall signal delay under actuated conditions. The Synchro documentation states that its actuated estimated green times will be consistent to those determined by the method in HCM, Chapter 9 and Appendix II. Synchro can handle dual-ring controllers, which allows it to accommodate overlapping phases.

For conducting this project, the selected computer software should have the following features:

- The ability to optimize signal timings and simulate operations over a network with signalized intersections;
- The flexibility in terms of data inputs; and
- Provision of results on MOEs required for feasibility studies.

Currently among the widely used signal timing optimization models (e.g., Synchro, TRANSYT, SCOOT, and OPAC etc.), Synchro is a widely used signal timing optimization software. According to significant features discussed above, Synchro 5.0 was selected as a tool for optimizing signal timings for this project.

Simulation Models

Computer modeling and simulating signalized highway networks have been widely and increasingly applied in traffic analysis and evaluation. The main reasons are classified into two folds. One fold is that the performance of signalized highway operations and traffic impact of tentative modifications can be tested and evaluated before field implementation. The other fold is that some critical MOEs such as signal delay, which are difficult to measure in the field can be obtained through simulation. The widely used simulation packages reviewed here include CORSIM, SimTraffic, PARAMICS, and VISSIM.

<u>CORSIM</u>

CORSIM (CORridor SIMulation) is a microscopic traffic simulation model developed by FHWA and embedded in TSIS (Traffic Software Integrated System), which integrates two microscopic simulation models: the arterial network model NETSIM and the freeway model FRESIM. It is a discrete time, stochastic, “state-of-the-practice” model used to simulate traffic operations. Visual simulation is realized by an animation processor called TRAFVU (TRAFfic simulation Visualization Utility) also embedded in TSIS. CORSIM is well recognized for its sophisticated algorithms in car-following and lane-changing models and is able to analyze a wide range of traffic, geometric, and control conditions. CORSIM can produce a rich set of MOEs, including delay, travel time, speed, number of stops, queue time, stop time, queue length, fuel consumption, and vehicle emission etc.

The most important MOEs when modeling and evaluating a signalized intersection are control delay and traffic throughput which are affected by driver and vehicle related factors such as car-following factor, acceleration and deceleration rates, reaction time, and turning speed etc. These traffic characteristics are required to be specified in CORSIM, and needed to calibrate. So that the real-world traffic operations of the studied network can be appropriately replicated.

CORSIM has the capability to simulate pre-timed, semi-actuated and actuated signal operations (including pedestrian-activated signal operation) as well as coordinated control strategies. However, CORSIM does not have built-in analytical and empirical optimization capability. A number of signal studies conducted by using CORSIM are shown below.

Bullock et al. (1999) applied CORSIM to evaluate the effectiveness of emergency vehicle signal preemption. The studied location consisted of three intersections on Leesburg Pike (Route 7, Virginia) near the location of a hospital. This geometric condition was coded into the CORSIM to determine the possible effects on providing emergency vehicle preemption on the three intersections. Results showed that the impact on other traffic is statistically significant, however, it is minimal with a 2.4% increase in average travel time when the priority is requested

Park et al. (2000) employed CORSIM to simulate three different genetic algorithm (GA) based optimization strategies, which are throughput maximization, delay minimization, and modified delay minimization with a penalty function. Simulation results revealed that the delay minimization strategy produced less queue time for all spacing examined. However, none of the strategies provided dominant performance in terms of system throughput. It should be noting that the minimum queue time did not correspond to maximum throughput.

INTEGRATION (Model integrates a number of unique capabilities),CORSIM and WATSim (Wide Area Traffic Simulation) were applied to three heavily loaded traffic networks in Honolulu for which detailed, simultaneous, and contemporaneous flow condition are known. The models produced satisfactory and comparable results on most of the tested network links. This study revealed that the main limitation of these models is the large number of parameters that need to be modified to replicate real traffic conditions (Wang and Prevedouros, 1998).

SimTraffic

Like Synchro, SimTraffic is the key simulation model developed by Trafficware. While Synchro is applied to conduct signal optimization and coordination, SimTraffic performs a microscopic simulation and realizes animation.

Similar to CORSIM, SimTraffic needs the input value of parameters (e.g., car-following factor, acceleration and deceleration rates, reaction time, and turning speed etc.) While modeling the traffic operation of the studied network, geometric conditions, such as link length, curb lines and curves, stop lines, left-turn or right-turn pockets, exclusive left turn lanes, median width etc. are required input to build p the network. The following studies are conducted by using SimTraffic.

Park et al. (2004) applied SimTraffic to determine time-of-day (TOD) breakpoints manually using one or two days' worth of traffic data. Signal control can be categorized as pre-timed, actuated and adaptive. Among these, both pre-timed and coordinated actuated controllers deploy multiple signal timing plans to account for traffic demand changes during a day, while adaptive control changes timing plan in real time according to traffic conditions.

Drummond et al. (2002) developed a method for using simulation models to evaluate the safety impacts of increased traffic signal density in suburban corridors. Using 10 years of data from two major arterials in Virginia, actual crash rates were compared to operational performance measures simulated by the Synchro/SimTraffic model. As expected, crash rates were positively correlated with stops per vehicle and delay per vehicle and negatively correlated with mainline speed.

PARAMICS

PARAMICS is a suite of software tools for microscopic, time-stepping traffic simulation (Lee, et al., 2001). The name PARAMICS is an acronym derived from Parallel Microscopic Simulation. As a suite of ITS-capable, user-programmable, high-performance microscopic traffic simulation package, PARAMICS offers very plausible detailed modeling for many components of an ‘ideal’ simulator. Individual vehicles are modeled in fine detail for the duration of their entire trips, providing accurate traffic flow, transit time and congestion information, as well as enabling the modeling of the interface between drivers and ITS facilities. In addition, PARAMICS provides users with an Application Programming Interface (API) through which users can customize and extend many features of the underlying simulation model.

Complementary modules could be any ITS application, such as signal optimization, adaptive ramp metering, incident management and so on. In this way, new control strategy can be easily tested and evaluated by the simulator before their implementation in the real world (Chu, et al., 2002). PARAMICS excels in modeling congested networks and ITS infrastructures (Algers, et al., 1998).

VISSIM

VISSIM (Hoyer, et al., 1997; Fellendorf, 1997) is a microscopic, time driven and behavior based simulation model developed to analyze full range of classified roadways and public transportation operations. VISSIM can model operations for various transportation models (buses, light rail, heavy rail, trucks, pedestrians, and bicycle) in an integrated roadway networks.

VISSIM consists of two primary components: (1) simulator and (2) signal state generator denoted as SSG. The simulator generates traffic onto the user graphically specified network. The user can import an aerial photo or schematic drawing of the studied area. Then, the network attributes (e.g., lane widths, speed zones, priority rules, etc.). Unlike other simulations, VISSIM models do not have traditional node structure, which provides the user with the flexibility to control traffic operations and vehicle paths within an intersection or interchange (Bloomberg, et al., 2000).

The SSG in VISSIM is separated from the simulator. It is where the signal control logic resides. The user has the ability to define the signal control system and thus emulate any type of control logic found in a signal controller manufacturer's firmware. The SSG permits the user to analyze the impact of signal operations including, but not be limited to: fixed time, actuated, adaptive, transit signal priority, and ramp metering. The SSG reads detector information from the simulator every time step and the SSG decides the status of the signal display during the subsequent time step can be decided (Bloomberg, et al., 2000).

As to assess and choose simulation software for this project, the reliability of the MOEs from simulation output; the reality of the network with signalized intersections; and the feasibility and simplicity of data exchange between the signal optimization model (e.g., Synchro) for comprehensive analysis are critical issues to be considered. Thus, the suitable simulation software for this project should be either CORSIM or SimTraffic. Because the traffic modeling process in SimTraffic is similar to CORSIM, both simulation models seem to produce very similar outcomes (Trafficware, 2001). As one of high quality, high credibility, matured simulation software (Trafficware, 2001), SimTraffic has the fast and efficient coding with Synchro, and it is deemed the solution simulation model to evaluate the optimal timing recommended by Synchro.

Model Calibration

Simulation models should be properly calibrated and then used to perform other analyses, such as evaluating the impact of signal timing changes discussed in this study. In order to calibrate the SimTraffic model and mimic the real-world traffic conditions, the calibrated parameters primarily include those related to driver behavior, vehicle performance and roadway throughput capability (e.g., free flow speed, headway factors, turning speed, saturated flow rate and pedestrian walking speed).

In general, there are two different approaches to calibrate microscopic traffic simulation models. The first approach is to establish the input-output relation and improve accuracy by changing the basic modules. The basic requirement is that the researchers have a good understanding of the details of the particular simulator modules. The second approach is referred to as parameter calibration, defined as the re-establishment the input-output relation to obtain the desired system accuracy by changing those parameters that govern the input-output relationship in the systems being modeled (Lee, et al., 2001). Parameter calibration in a simulation model may be regarded as an optimization problem in which a set of values for operating parameters that satisfy an objective function are to be searched (Cheu, el at., 1998).

It is difficult to assess the impact when varying several parameters at a time due to the interdependent influence to the simulation results. Thus, simulation results with respect to each varying parameter should be investigated, while other parameter values should be fixed. In order to identify key parameters influencing the simulation results, sensitivity analysis for various parameters should be conducted, while the impacts of changing those parameters should be observed.

The calibration procedure is composed by the following comparisons: Graphical Comparison, Aggregate Comparison, and Statistical Comparison.

Graphical Comparison

The graphical comparison is a subjective validation approach, which is especially useful for testing the results generated by the simulation model preliminarily. It makes the comparison easy and visible.

Aggregate Comparison

Aggregate means and standard deviations give general indication of system performances in real world and in simulation. However, they do not present accurate trend or indicate how variables perform over time, what patterns are created, and how much individual measurements deviate. Aggregate comparisons, along with the graphical comparisons of scattered plots, reveal the similarities and discrepancies by changing analyzed variables.

Statistic Comparison

The statistic analysis is crucial for validating the proposed model based on sample data collected from the real world and simulation. It can be used for assessing the model accuracy, testing various hypotheses and determining degree of correlation. The following equations are indices used for statistic comparison.

Mean Absolute Percent Error (MAPE) measures the percentage error between simulation results and field data, which can be given by Eq. 1:

$$\text{MAPE}=\frac{1}{n}\sum_{i=1}^{n}\frac{|S_i - O_i|}{O_i}*100\% \qquad (1)$$

where *n*, S_i and O_i are sample size, observation *i* of simulation output and observation *i* of field measurement respectively.

Root Mean Square Error (RMSE) denotes the error between simulation results and field data, which can be given by Eq. 2:

$$\text{RMSE}=\sqrt{\frac{1}{n}\sum_{i=1}^{n}(S_i - O_i)^2} \qquad (2)$$

where *n*, S_i and O_i were defined in Eq. 1.

Mean Absolute Relative Error (MARE) and Variance of Absolute Percentage Error (VAPE), predict accuracy between simulation results and field data, as formulated in Eqs.3 and 4, respectively.

$$\text{MARE}=\frac{1}{n}\sum_{i=1}^{n}\frac{|O_i - S_i|}{O_i} \qquad (3)$$

where *n*, S_i and O_i were defined in Eq. 1

$$\text{VAPE}= Var\left(\frac{|S_i - O_i|}{S_i}\right) \qquad (4)$$

where *n*, S_i and O_i were defined in Eq. 1

In addition to previous simulation prediction error indices, root relative square error (RRSE) and maximum relative error (MRE) are computed. These indices are defined as:

$$\text{RRSE}=\sqrt{\frac{\sum_{i=1}^{n}(S_i - O_i)}{\sum_{i=1}^{n}(O_i - \overline{O})^2}}\text{, and } \overline{O}=\frac{1}{n}\sum_{i=1}^{n}O_i \qquad (5)$$

where *n*, S_i and O_i were defined in Eq. 1,

$$\text{MRE} = \max_i \frac{|O_i - S_i|}{O_i} \tag{6}$$

where S_i and O_i were defined in Eq. 1,

MAPE (Eq. 1) and RMSE (Eq. 2) indices were adopted for statistic comparison in this study.

Model Validation

Once parameters of the simulation model were well calibrated, the results must be validated by comparing MOEs observed in the field against simulated MOEs (Cohoe, 2002). The validation process establishes the credibility of the model by demonstrating its ability to replicate actual network and traffic patterns (Jayakrishnan, et al., 2002), and that should only be performed after the model has been properly calibrated. Validation is largely dependent on two major issues: the context (i.e., model performance could drastically change with the context), and the extent of the calibration effort at the conceptual and operational levels. The context may be for studying safety, environmental effects, and capacity improvement or congestion mitigation. Context variable data is necessary for both calibration and validation. It is important noting that the validation must not rely on a single field data. The preliminary test of MOEs can be conducted through graphic comparison between the values of field observations and simulation results. The statistic analysis can be conducted by calculating MAPE and RMSE for the field and simulated MOEs.

Various optimization packages (PASSER II, TRANSYT-7F, and SYNCHRO, etc.) have been applied to optimize traffic signal timing plans. In order to demonstrate the performance of one is better than others, comparative analyses should be conducted. These packages would generate different optimal timing plans fixed cycle length and splits, etc. because the objective functions applied in these programs were different. Thus, the outputs from these optimization programs are recommended to be fairly evaluated through a series of simulation runs.

SUMMARY

According to the review of literature and current practice, traffic modeling software can be classified into two catalogs according to their functions on traffic analyses. They are signal timing optimization models (e.g., Synchro, TRANSYT, PASSER, SOAP, TSPP Draft, etc.) and simulation models (e.g., CORSIM, SimTraffic, PARAMICS, VISSIM, INTEGRATION, CINEMA, CORFLO, etc.). Synchro is one of the most widely used signal timing optimization software and has gained much attention in transportation industry because of its user friendly applications and creditable results. In addition, a micro-simulation program SimTraffic is complied with Synchro for evaluating the recommended optimal time plans. The project team of this study is therefore select Synchro and SimTraffic for modeling and simulating two studied signalized arterials (e.g., Route 23 and Route 42/322) for NJDOT.

APPENDIX B: AEROGRAPHIC INFORMATION FOR THE STUDIED INTERSECTIONS

Route 23

Figure B-1. Intersection of Route 23 and Vernon Stockholm Rd. (Rt. 515)

Figure B-2. Intersection of Route 23 and Canister Rd.

Figure B-3. Intersection of Route 23 and Reservoir Rd.

Figure B-4. Intersection of Route 23 and Doremus Rd.

Figure B-5. Intersection of Route 23 and Paradise Rd.

Figure B-6. Intersection of Route 23 and Oak Ridge Rd.

Figure B-7. Intersection of Route 23 and Clinton Rd.

Figure B-8. Intersection of Route 23 and Larue Rd. (NB)

Figure B-9. Intersection of Route 23 and Larue Rd. (SB)

Figure B-10. Intersection of Route 23 and Kanhouse (Old Rt. 23)

Figure B-11. Intersection of Route 23 and Echo Lake Rd.

Figure B-12. Intersection of Route 23 and Center Court

Figure B-13. Intersection of Route 23 and Kiel Ave. & Ramp CC

Figure B-14. Intersection of Route 23 and Kiel Ave. & Ramp CC

Figure B-15. Intersection of Route 23 and Kakeout Connector & Kinnelon Rd.

Figure B-16. Intersection of Route 23 and Cascade Way

Figure B-17. Intersection of Route 23 and Boonton Ave.

Figure B-18. Intersection of Route 23 and Morse Ave.

Figure B-19. Intersection of Route 23 and Cotluss Ave.

Route 42/322

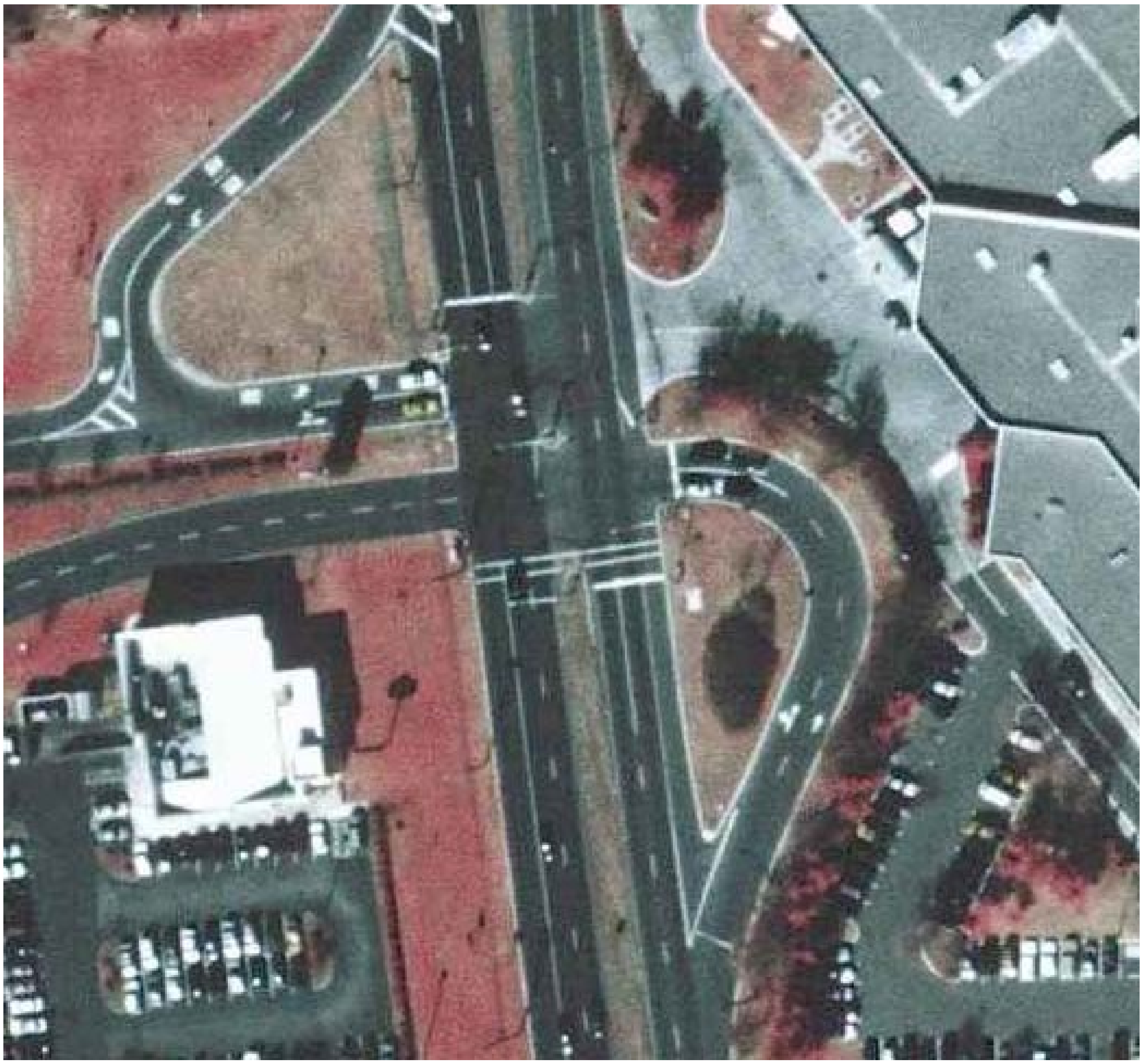

Figure B-20. Intersection of Route 42/322 and Shopping Center Dr.

Figure B-21. Intersection of Route 42/322 and Green tree Rd.

Figure B-22. Intersection of Route 42/322 and Whitman Dr.

Figure B-23. Intersection of Route 42 and Gantown Rd.

Figure B-24. Intersection of Route 42 and Johnson Rd (NB)

Figure B-25. Intersection of Route 42/322 and Fries Mill Rd. (SB)

Figure B-26. Intersection of Route 42/322 and Watson Dr.

Figure B-27. Intersection of Route 42/322 and Tuchahoe Rd. – Stagecoach Rd.

Figure B-28. Intersection of Route 42/322 and Berlin Cross Keys Rd.

Figure B-29. Intersection of Route 42/322 and Kennedy Dr. (SB)

Figure B-30. Intersection of Route 42/322 and Lake Ave.

Figure B-31. Intersection of Route 42/322 and Sicklerville Rd.

Figure B-32. Intersection of Route 42/322 and Poplar St. – New Brooklyn Rd.

Figure B-33. Intersection of Route 42/322 and Main St. (Rt. 322)

Figure B-34. Intersection of Route 42/322 and Corkery Ln. (Rt. 322)

Figure B-35. Intersection of Route 42/322 and Malaga Rd. (Rt. 322)

Figure B-36. Intersection of Route 42/322 and White Hall Rd. – Corkery Ln.

APPENDIX C: ROUTE 23 TIMING DIRECTIVES

1903102 **Directive No. 266-03**

Page 1 of 2

Route 23 and County Road 515
(Vernon-Stockholm Road)
Hardyston Twp., Sussex Co.

		Signals			Timing		
Movement		**1-6, 12,13**	**7,8,11**	**9,10**	**I 90 Seconds**	**II 140 Seconds**	**III 160 Seconds**
2	**Route 23**	**G**	**R**	**R**	**58 - 44**	**108 - 90**	**128 - 84**
	Change	**Y**	**R**	**R**	**6 *****	**6 ****	**6 ***
	Clearance	**R**	**R**	**R**	**2**	**2**	**2**
3	**County Route 515**	**R**	**G**	**R**	**7 - 17**	**7 - 19**	**7 - 47**
	Change	**R**	**Y**	**R**	**3**	**3**	**3**
	Clearance	**R**	**R**	**R**	**3**	**3**	**3**
4	**Ramp "CR-A"**	**R**	**R**	**G**	**5 - 9**	**5 - 11**	**5 - 9**
	Change	**R**	**R**	**Y**	**3**	**3**	**3**
	Clearance	**R**	**R**	**R**	**3**	**3**	**3**
	Emergency Flash	**Y**	**R**	**R**	**-**	**-**	**-**

Hours of Operation:

160-Second Cycle - 5:30 A.M. to 9:00 A.M. (Monday-Friday)
140-Second Cycle - 3:00 P.M. to 7:30 P.M. (Monday-Friday)
90-Second Cycle - All other times.

(T-III) ***From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 81 seconds is to be provided measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 traffic at this intersection.**

(T-II) ****From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 82 seconds is to be provided measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 traffic at this intersection.**

(T-I) *****All other times (90-Second Cycle) an offset of 39 seconds is to be provided measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 traffic at this intersection.**

The Movements 3 and 4 vehicular memories are to be disconnected and their extensions set at 2.0 seconds.

Pedestrian push button is to provide minimum calls to Movements 3 and 4.

Manual control is to be removed.

1903102 **Directive No. 266-03**

Page 2 of 2

Route 23 and County Road 515
(Vernon-Stockholm Road)
Hardyston Twp., Sussex Co.

EMERGENCY PRE-EMPTION SEQUENCE

Movement		Signals 1-6, 12,13	7,8,11	9,10	Timing	
			Route 23 R.O.W.			
2	Route 23	G	R	R	-	Minimum
			Upon Railroad Actuation			of 10
2	Route 23	G	R	R	-	Seconds
	Change	Y	R	R	6	
	Clearance	R	R	R	3	
3	County Road 515	R	G	R	10	
	Change	R	Y	R	3	
	Clearance	R	R	R	3	
2	Route 23 (Rail R.O.W.)	G	R	R	-	(Hold until released)
			Resume Normal Operation			
			Ramp 515 R.O.W.			
3	County Road 515	R	G	R	-	Minimum
			Upon Railroad Actuation			of
	County Road 515	R	G	R	-	10 Seconds
	Change	R	Y	R	3	
	Clearance	R	R	R	3	
2	Route 23 (Rail R.O.W.)	G	R	R	-	(Hold until released)
			Resume Normal Operation			
			Ramp "CR-A" R.O.W.			
4	Ramp "CR-A"	R	R	G	-	Total
			Upon Railroad Actuation			of
4	Ramp "CR-A"	R	R	G	-	10 Seconds
	Change	R	R	Y	6	
	Clearance	R	R	R	3	
3	County Road 515	R	G	R	10	
	Change	R	Y	R	3	
	Clearance	R	R	R	3	
2	Route 23 (Rail R.O.W.)	G	R	R	-	(Hold until released)
			Resume Normal Operation			

1605107

Route 23 and Canistear Road
West Milford Twp., Passaic Co.

Directive No. 265-03

Phase		Signals 1-8	Signals 9-12	Timing I 90 Seconds	Timing II 140 Seconds	Timing III 160 Seconds
A.	**Route 23 R.O.W.**	**G**	**R**	**70 - 56**	**120 - 106**	**140 - 119**
	Change	**Y**	**R**	**6 *****	**6 ****	**6 ***
	Clearance	**R**	**R**	**2**	**2**	**2**
B.	**Canistear Road R.O.W.**	**R**	**G**	**7 - 21**	**7 - 21**	**7 - 28**
	Change	**R**	**Y**	**3**	**3**	**3**
	Clearance	**R**	**R**	**2**	**2**	**2**

(T-III) ***From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 122 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 15 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-I) *****An offset of 80 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 2 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation: **160-second cycle is to be in effect from 5:30 A.M. to 9:00 A.M., Monday-Friday.**
140-second cycle is to be in effect from 3:00 P.M. to 7:30 P.M., Monday-Friday.
90-second cycle is to be in effect all other times.

Emergency Flashing Operation: **Flash yellow to Route 23 (Signal Faces #1-8).**
Flash red to Canistear Road (Signal Faces #9-12).

1605110

Route 23 and Reservoir Road
West Milford Twp., Passaic Co.

Directive No. 264-03

		Signals		Timing		
				I	II	III
Phase		**1-9**	**10-14**	**90 Seconds**	**140 Seconds**	**160 Seconds**
A.	**Route 23 R.O.W.**	**G**	**R**	**70 - 61**	**120 - 103**	**140 - 128**
	Change	**Y**	**R**	**6 *****	**6 ****	**6 ***
	Clearance	**R**	**R**	**2**	**2**	**2**
B.	**Reservoir Road R.O.W.**	**R**	**G**	**7 - 16**	**7 - 24**	**7 - 19**
	Change	**R**	**Y**	**3**	**3**	**3**
	Clearance	**R**	**R**	**2**	**2**	**2**

(T-III) ***From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 24 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 65 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-I) *****An offset of 80 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 2 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation:
160-second cycle is to be in effect from 5:30 A.M. to 9:00 A.M., Monday-Friday.
140-second cycle is to be in effect from 3:00 P.M. to 7:30 P.M., Monday-Friday.
90-second cycle is to be in effect all other times.

Emergency Flashing Operation: **Flash yellow to Route 23 (Signal Faces #1-9).**
Flash red to Reservoir Road (Signal Faces #10-14).

1605108

Route 23 and Doremus Road
West Milford Twp., Passaic Co.

Directive No. 263-03

		Signals		Timing		
				I	II	III
Phase		**1-8**	**9-12**	**90 Seconds**	**140 Seconds**	**160 Seconds**
A.	**Route 23 R.O.W.**	**G**	**R**	**70 - 62**	**120 - 108**	**140 - 124**
	Change	**Y**	**R**	**6 *** **	**6 ** **	**6 * **
	Clearance	**R**	**R**	**2**	**2**	**2**
B.	**Doremus Road R.O.W.**	**R**	**G**	**7 - 15**	**7 - 19**	**7 - 23**
	Change	**R**	**Y**	**3**	**3**	**3**
	Clearance	**R**	**R**	**2**	**2**	**2**

(T-III) ***From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 75 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 60 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-I) *****An offset of 58 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 2 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation:

160-second cycle is to be in effect from 5:30 A.M. to 9:00 A.M., Monday-Friday.
140-second cycle is to be in effect from 3:00 P.M. to 7:30 P.M., Monday-Friday.
90-second cycle is to be in effect all other times.

Emergency Flashing Operation:

Flash yellow to Route 23 (Signal Faces #1-8).
Flash red to Doremus Road (Signal Faces #9-12).

1605109

Route 23 and Paradise Road
West Milford Twp., Passaic Co.

Directive No. 262-03

		Signals		Timing		
				I	II	III
Phase		**1-6**	**7-18**	**90 Seconds**	**140 Seconds**	**160 Seconds**
A.	**Route 23 R.O.W.**	**G**	**R**	**67 - 61**	**117 - 109**	**137 - 129**
	Change	**Y**	**R**	**6 *****	**6 ****	**6 ***
	Clearance	**R**	**R**	**2**	**2**	**2**
B.	**Paradise Road R.O.W.**	**R**	**G**	**10 - 16**	**10 - 18**	**10 - 18**
	Change	**R**	**Y**	**3**	**3**	**3**
	Clearance	**R**	**R**	**2**	**2**	**2**

(T-III) ***From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 138 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 119 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-I) *****An offset of 85 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 3 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation:

160-second cycle is to be in effect from 5:30 A.M. to 9:00 A.M., Monday-Friday.
140-second cycle is to be in effect from 3:00 P.M. to 7:30 P.M., Monday-Friday.
90-second cycle is to be in effect all other times.

Emergency Flashing Operation:

Flash yellow to Route 23 (Signal Faces #1-6).
Flash red to Paradise Road (Signal Faces #7-18).

NOTE: A call on Oak Ridge Road will also call minimum green to Paradise Road.

1605103

Route 23 and Oak Ridge Road
West Milford Twp., Passaic Co.

Directive No. 261-03

Phase		Signals 1-7,14	Signals 8,9, 11-13	Signals 10,15	Timing I 90 Seconds	Timing II 140 Seconds	Timing III 160 Seconds
A.	Route 23 R.O.W.	G	R	R	69 - 56	119 - 90	139 - 96
	Change	Y	R	R	6 ***	6 **	6 *
	Clearance	R	R	R	2	2	2
B.	Oak Ridge Road R.O.W.	R	G	-G>	7 - 20	7 - 36	7 - 44
	Change	R	Y	-Y>	3	3	3
	Clearance	R	R	R	3	3	3
Emergency Flash		Y	R	R			

(T-III) *From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 135 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.

(T-II) **From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 87 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.

(T-I) ***An offset of 52 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 2 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation:

160-second cycle is to be in effect from 5:30 A.M. to 9:00 A.M., Monday-Friday.
140-second cycle is to be in effect from 3:00 P.M. to 7:30 P.M., Monday-Friday.
90-second cycle is to be in effect all other times.

1605111 **Route 23 N/B and Clinton Road**
West Milford Twp., Passaic Co.

Directive No. 259-03

		Signals		Timing		
				I	II	III
Phase		**11-13**	**14-20**	**90 Seconds**	**140 Seconds**	**160 Seconds**
A.	**Route 23 R.O.W.**	**G**	**R**	**70 - 56**	**120 - 103**	**140 - 123**
	Change	**Y**	**R**	**6 *****	**6 ****	**6 ***
	Clearance	**R**	**R**	**2**	**2**	**2**
B.	**Clinton Road R.O.W.**	**R**	**G**	**7 - 21**	**7 - 24**	**7 - 24**
	Change	**R**	**Y**	**3**	**3**	**3**
	Clearance	**R**	**R**	**2**	**2**	**2**

(T-III) ***From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 110 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 92 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-I) *****An offset of 32 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 2 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation:
160-second cycle is to be in effect from 5:30 A.M. to 9:00 A.M., Monday-Friday.
140-second cycle is to be in effect from 3:00 P.M. to 7:30 P.M., Monday-Friday.
90-second cycle is to be in effect all other times.

Emergency Flashing Operation:
Flash yellow to Route 23 (Signal Faces #11-13).
Flash red to Clinton Road (Signal Faces #14-20).

1605112

Route 23 S/B and Clinton Road
West Milford Twp., Passaic Co.

Directive No. 260-03

Phase		Signals 11-13	Signals 14-20	Timing I 90 Seconds	Timing II 140 Seconds	Timing III 320 Seconds
A.	Route 23 R.O.W.	G	R	70 - 56	120 - 103	300 - 283
	Change	Y	R	6 ***	6 **	6 *
	Clearance	R	R	2	2	2
B.	Clinton Road R.O.W.	R	G	7 - 21	7 - 24	7 - 24
	Change	R	Y	3	3	3
	Clearance	R	R	2	2	2

(T-III) ***From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 110 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 92 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-I) *****An offset of 32 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 2 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation:
160-second cycle is to be in effect from 5:30 A.M. to 9:00 A.M., Monday-Friday.
140-second cycle is to be in effect from 3:00 P.M. to 7:30 P.M., Monday-Friday.
90-second cycle is to be in effect all other times.

Emergency Flashing Operation:
Flash yellow to Route 23 (Signal Faces #11-13).
Flash red to Clinton Road (Signal Faces #14-20).

1605105

Route 23 N/B and LaRue Road
Jefferson Twp., Morris Co.

Directive No. 258-03

		Signals		Timing		
				I	II	III
Phase		**1-2,11**	**3-10**	**90 Seconds**	**140 Seconds**	**160 Seconds**
A.	**Route 23 S/B R.O.W.**	**G**	**R**	**70 - 59**	**120 - 108**	**140 - 127**
	Change	**Y**	**R**	**6 *****	**6 ****	**6 ***
	Clearance	**R**	**R**	**2**	**2**	**2**
B.	**LaRue Road R.O.W.**	**R**	**G**	**7 - 18**	**7 - 19**	**7 - 20**
	Change	**R**	**Y**	**3**	**3**	**3**
	Clearance	**R**	**R**	**2**	**2**	**2**

(T-III) ***From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 129 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 97 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-I) *****An offset of 8 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 2 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation:
160-second cycle is to be in effect from 5:30 A.M. to 9:00 A.M., Monday-Friday.
140-second cycle is to be in effect from 3:00 P.M. to 7:30 P.M., Monday-Friday.
90-second cycle is to be in effect all other times.

Emergency Flashing Operation:
Flash yellow to Route 23 S/B (Signal Faces #1,2,11).
Flash red to LaRue Road (Signal Faces #3-10).

1605106

Route 23 S/B and LaRue Road
Jefferson Twp., Morris Co.

Directive No. 257-03

BACKGROUND CYCLES

		Signals		Timing		
				I	II	III
Phase		1-2,11	3-10	90 Seconds	140 Seconds	160 Seconds
A.	Route 23 S/B R.O.W.	G	R	70 - 59	120 - 108	140 - 127
	Change	Y	R	6 ***	6 **	6 *
	Clearance	R	R	2	2	2
B.	LaRue Road R.O.W.	R	G	7 - 18	7 - 19	7 - 20
	Change	R	Y	3	3	3
	Clearance	R	R	2	2	2

(T-III) *From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 129 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.

(T-II) **From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 97 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.

(T-I) ***An offset of 8 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 2 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation:
160-second cycle is to be in effect from 5:30 A.M. to 9:00 A.M., Monday-Friday.
140-second cycle is to be in effect from 3:00 P.M. to 7:30 P.M., Monday-Friday.
90-second cycle is to be in effect all other times.

Emergency Flashing Operation:
Flash yellow to Route 23 S/B (Signal Faces #1,2,11).
Flash red to LaRue Road (Signal Faces #3-10).

1605101

Route 23 and Old Route 23
(Kanouse Road)
West Milford Twp., Passaic Co.

Directive No. 256-03

BACKGROUND CYCLES

		Signals		Timing		
Phase		**1-3, 6,7,11**	**4,5, 8-10**	**I 90 Seconds**	**II 140 Seconds**	**III 160 Seconds**
A.	**Route 23 R.O.W.**	**G**	**R**	**70 - 56**	**120 - 103**	**140 - 125**
	Change	**Y**	**R**	**6 *****	**6 ****	**6 ***
	Clearance	**R**	**R**	**2**	**2**	**2**
B.	**Old Route 23 R.O.W.**	**R**	**G**	**7 - 21**	**7 - 24**	**7 - 22**
	Change	**R**	**Y**	**3**	**3**	**3**
	Clearance	**R**	**R**	**2**	**2**	**2**

(T-III) ***From 5:30 A.M. to 9:00 A.M., Monday-Friday, an offset of 73 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 P.M. to 7:30 P.M., Monday-Friday, an offset of 85 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

(T-I) *****An offset of 44 seconds is to be measured from the beginning of yellow to Route 23 at Echo Lake Road to the beginning of yellow to Route 23 at this intersection.**

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 4 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation:

160-second cycle is to be in effect from 5:30 A.M. to 9:00 A.M., Monday-Friday.
140-second cycle is to be in effect from 3:00 P.M. to 7:30 P.M., Monday-Friday.
90-second cycle is to be in effect all other times.

Emergency Flashing Operation:

Flash yellow to Route 23 (Signal Faces #1-3,6,7,11).
Flash red to Old Route 23 (Signal Faces #4,5,8-10).

1605102

Route 23 and Echo Lake Road
West Milford Twp., Passaic Co.

Directive No. 255-03

BACKGROUND CYCLES

		Signals		Timing		
		1-5,	6-11,	I	II	III
Phase		12-18	19-26	90 Seconds	140 Seconds	160 Seconds
A.	Route 23 R.O.W.	G	R	67 - 60	117 - 115	137 - 120
	Change	Y	R	6 ***	6 **	6 *
	Clearance	R	R	2	2	2
B.	Echo Lake Road R.O.W.	R	G	10 - 17	10 - 12	10 - 27
	Change	R	Y	3	3	3
	Clearance	R	R	2	2	2

(T-III) *From 5:30 AM to 9:00 AM, Monday-Friday, an offset of 0 seconds is to be measured from the beginning of yellow to Route 23 at this intersection.

(T-II) **From 3:00 PM to 7:30 PM, Monday-Friday, an offset of 0 seconds is to be measured from the beginning of yellow to Route 23 at this intersection.

(T-I) ***An offset of 0 seconds is to be measured from the beginning of yellow to Route 23 at this intersection.

The memory is to be disconnected for Phase B and the vehicle extension time is to be set at 3 seconds.

Actuation of pedestrian push button is to guarantee 15 seconds of green time during Phase B.

Phase A recall shall be in the "ON" position.

Phase B recall is to be in the "OFF" position.

Manual control is to be disconnected.

Hours of Operation:
160-Second Cycle is to be in effect from 5:30 AM to 9:00 AM, Monday-Friday.
140-Second Cycle is to be in effect from 3:00 PM to 7:30 PM, Monday-Friday.
90-Second Cycle is to be in effect all other times.

Emergency Flashing Operation:
Flash yellow to Route 23 (Signal Faces #1-5, 12-18).
Flash red to Echo Lake Road (Signal Faces #6-11, 19-26).

1405116 **Directive No. 254-03**

Route 23 and Center Court - Ramp "DD"
Butler Boro., Morris Co.

BACKGROUND CYCLES

Phase		Signals		Timing		
				I	II	III
		1-8	7-11	150 Sec.	150 Sec.	90 Sec.
1)	Route 23 ROW	G	R	130 - 122	130 - 122	70 - 62
	Change	Y	R	5 *	5 **	5 ***
	Clearance	R	R	2	2	2
2)	Center Ct. - Ramp "DD"	R	G	7 - 15	7 - 15	7 - 15
	Change	R	Y	4	4	4
	Clearance	R	R	2	2	2

(T-I) From 5:30 - 9:30 A.M., Monday - Friday, an offset of 92 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.

(T-II) **From 3:00 - 7:30 P.M., Monday - Friday, an offset of 123 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.

(T-III) ***An offset of 83 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.

Vehicle Extension - 2 Seconds

Recall - Off

Memory - Off

Pedestrian actuation is to provide a minimum green of 27 seconds to Phase 2.

The manual cord is to be disconnected.

Flashing Operation:
Indications #1 - 6 / Yellow
Indications #7 - 11 / Red

Hours of Operation:
The 150 - second cycle is to be in effect 5:30 - 9:30 a.m. and 3:00 - 7:30 P.M., Monday - Friday.
The 90 - second cycle is to be in effect all other times.

Flashing "Red Signal Ahead" sign is to begin flashing 11 seconds prior to the beginning of yellow to Route 23 at this intersection and stop flashing upon the beginning of green to Route 23 at this intersection.

1405120 **Directive No. 252-03**

Route 23 Ramp "AA" - Kakeout Connector and Kinnelon Road
Kinnelon Boro., Morris Co.

BACKGROUND CYCLES

Phase		Signals 1-7	8-11	12,13	Timing I 150 Sec.	II 150 Sec.	III 90 Sec.
Vehicle Actuation							
1)	Kinnelon Road	G	R	DW	131 - 109	131 - 113	71 - 61
	Change	Y	R	DW	5 *	5 **	5 ***
	Clearance	R	R	DW	2	2	2
2)	Ramp "AA" - Kakeout Connector	R	G	DW	7 - 29	7 - 25	7 - 17
	Change	R	Y	DW	3	3	3
	Clearance	R	R	DW	2	2	2
Pedestrian Actuation (Ramp "AA")							
1)	Kinnelon Road	G	R	DW	121 - 109	121 - 113	61 - 57
	Change	Y	R	DW	5 *	5 **	5 ***
	Clearance	R	R	DW	2	2	2
2)	Ramp "AA" - Kakeout Connector	R	G	W	7	7	7
	Pedestrian Clearance	R	G	FDW	10	10	10
	Vehicle Clearance	R	G	DW	0 - 12	0 - 8	0 - 4
	Change	R	Y	DW	3	3	3
	Clearance	R	R	DW	2	2	2
	Emergency Flashing Operation	Y	R	DARK	-	-	-

(T-I) *From 5:30 - 9:30 A.M., Monday - Friday, an offset of 70 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Kinnelon Road at this intersection.

(T-II) **From 3:00 - 7:30 P.M., Monday - Friday, an offset of 77 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Kinnelon Road at this intersection.

(T-III) ***All other time, an offset of 46 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Kinnelon Road at this intersection.

Vehicle Extension - 2 Seconds

Recall - Off

Memory - Off

The manual cord is to be disconnected.

1405103 **Directive No. 251-03**

Route 23 & Kiel Avenue-Kinnelon Road
Butler Boro., Morris Co.

BACKGROUND CYCLES

Phase		Signals				Timing		
		1-6, 19,20	7-10	11-14	15-18	I 150 Sec.	II 150 Sec.	III 90 Sec.
1)	Route 23 ROW	G	R	W	DW	109 - 85	109 - 74	49 - 29
	Pedestrian Clearance	G	R	FDW	DW	19	19	19
	Change	Y	R	DW	DW	5 *	5 **	5 ***
	Clearance	R	R	DW	DW	2	2	2
2)	Kinnelon Rd.-Kiel Ave. ROW	R	G	DW	DW	7 - 31	7 - 42	7 - 27
	Change	R	Y	DW	DW	5	5	5
	Clearance	R	R	DW	DW	3	3	3
			Pedestrian Actuation					
1)	Route 23 ROW	G	R	W	DW	76	76 - 74	16
	Pedestrian Clearance	G	R	FDW	DW	19	19	19
	Change	Y	R	DW	DW	5	5	5
	Clearance	R	R	DW	DW	2	2	2
2)	Kinnelon Rd.-Kiel Ave. ROW	R	G	DW	W	7	7	7
	Pedestrian Clearance	R	G	DW	FDW	33	33	33
	Vehicle Extension	R	G	DW	DW	0	0 - 2	0
	Change	R	Y	DW	DW	5	5	5
	Clearance	R	R	DW	DW	3	3	3

I *From 5:30 - 9:30 A.M., Monday - Friday, an offset of 93 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.

II **From 3:00 - 7:30 P.M., Monday - Friday, an offset of 88 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.

III ***An offset of 52 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.

Actuated Phases:
- **Vehicle Extension - 2 Seconds**
- **Recall - Off**
- **Memory - Off**

The manual control is to be disconnected.

Flashing Operation:
- **Indications #1 - 6, 19, 20 / Yellow**
- **Indications #7 - 10 / Red**
- **Indications #11 - 18 / Dark**

Hours of Operation:
- **The 150-second cycle is to be in effect 5:30 - 9:30 A.M. and 3:00 - 7:30 P.M., Monday - Friday.**
- **The 90-second cycle is to be in effect all other times.**

1405115

Directive No. 253-03
Route 23 Ramp "CC"
and Kiel Avenue
Butler Boro., Morris Co.

BACKGROUND CYCLES

Phase		Signals			Timing								
						I			II			III	
		21-24	25,26	27,28		150 Sec.			150 Sec.			90 Sec.	
1)	Kiel Avenue	G	R	DW	133	-	107	133	-	101	73	-	55
	Change	Y	R	DW	4	*		4	**		4	***	
	Clearance	R	R	DW	1			1			1		
2)	Ramp "CC"	R	G	DW	7	-	33	7	-	39	7	-	25
	Change	R	Y	DW	3			3			3		
	Clearance	R	R	DW	2			2			2		

Pedestrian Actuation (Ramp "CC")

1)	Kiel Avenue	G	R	DW	125	-	107	125	-	101	65	-	55
	Change	Y	R	DW	4			4			4		
	Clearance	R	R	DW	1			1			1		
2)	Ramp "CC"	R	G	W	7			7			7		
	Pedestrian Clearance	R	G	FDW	8			8			8		
	Vehicle Clearance	R	G	DW	0	-	18	0	-	24	0	-	10
	Change	R	Y	DW	3			3			3		
	Clearance	R	R	DW	2			2			2		

(T-I) ***From 5:30 - 9:30 A.M., Monday - Friday, an offset of 112 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Kiel Avenue at this intersection.**

(T-II) ****From 3:00 - 7:30 P.M., Monday - Friday, an offset of 73 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Kiel Avenue at this intersection.**

(T-III) *****All other time, an offset of 16 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Kiel Avenue at this intersection.**

Vehicle Extension - 2 Seconds

Recall - Off

Memory - Off

The manual cord is to be disconnected.

Flashing Operation:
Indications #21 - 24 / Yellow
Indications #25, 26 / Red
Indications #27, 28 / Dark

Hours of Operation:
The 150-second cycle is to be in effect 5:30 - 9:30 A.M. and 3:00 - 7:30 P.M., Monday - Friday.
The 90-second cycle is to be in effect all other times.

1405118 **Directive No. 250-03**

Page 1 of 2 **Route 23 and Ramp "Y"-Adalist Street**
Butler Boro., Morris Co.

BACKGROUND CYCLES

Phase		Signals 1-3	4,5	6-8	9,10	13-15	18,19	20,21	Timing I 150 Sec.	II 150 Sec.	III 90 Sec.
1	Route 23 ROW	G	G	R	G	G	R	DW	126 - 115	126 - 115	66 - 58
	Outside Change	Y	G	R	G	Y	R	DW	5 *	5 **	5 ***
	Inside Change	R	Y	R	Y	R	R	DW	5	5	5
	Clearance	R	R	R	R	R	R	DW	2	2	2
3	Ramp "Y" ROW	R	R	G	R	R	R	DW	7 - 18	7 - 18	7 - 15
	Change	R	R	Y	R	R	R	DW	3	3	3
	Clearance	R	R	R	R	R	R	DW	2	2	2

PEDESTRIAN ACTUATION

Phase		1-3	4,5	6-8	9,10	13-15	18,19	20,21	I	II	III
1	Route 23 ROW	G	G	R	G	G	R	DW	104	104	44
	Outside Change	Y	G	R	G	Y	R	DW	5	5	5
	Inside Change	R	Y	R	Y	R	R	DW	5	5	5
	Clearance	R	R	R	R	R	R	DW	2	2	2
3	Ramp "Y" ROW	R	R	G	R	R	R	W	7	7	7
	Ped. Clearance	R	R	G	R	R	R	FDW	22	22	22
	Change	R	R	Y	R	R	R	DW	3	3	3
	Clearance	R	R	R	R	R	R	DW	2	2	2

EMERGENCY VEHICLE OPERATION

ROW TO ROUTE 23

Phase		1-3	4,5	6-8	9,10	13-15	18,19	20,21	I	II	III
1	Route 23 ROW	G	G	R	G	G	R	DW	7 Min.	7 Min.	7 Min.
	Outside Change	Y	G	R	G	Y	R	DW	5	5	5
	Inside Change	R	Y	R	G	R	R	DW	5	5	5
	Clearance	R	R	R	G	R	R	DW	2	2	2

Call Phase 4

ROW TO RAMP "Y"

Phase		1-3	4,5	6-8	9,10	13-15	18,19	20,21	I	II	III
3	Ramp "Y" ROW	R	R	G	R	R	R	DW	7 Min.	7 Min.	7 Min.
	Change	R	R	Y	R	R	R	DW	3	3	3
	Clearance	R	R	R	R	R	R	DW	2	2	2

Call Phase 4

PHASE 4

Phase		1-3	4,5	6-8	9,10	13-15	18,19	20,21	I	II	III
4	Adalist St. (Emer. ROW)	R	R	R	G	R	G	DW	18	18	18
	Change	R	R	R	G	R	Y	DW	3	3	3
	Clearance	R	R	R	G	R	R	DW	5	5	5

Resume Normal Operation

1405118 **Directive No. 250-03**

Page 2 of 2 **Route 23 and Ramp "Y"-Adalist Street**
Butler Boro., Morris Co.

Notes:

If call to Phase 4 during pedestrian interval of Phase 3, a minimum of 7 seconds "Walk" and 22 seconds flashing "Don't Walk" will be given in Phase 3.

Signal to rest in Phase 1.

(T-I) ***From 5:30 - 9:30 A.M., Monday - Friday, an offset of 3 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 - 7:30 P.M., Monday - Friday, an offset of 31 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.**

(T-III) *****All other time, an offset of 11 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.**

Vehicle Extension - 2 Seconds

Recall - Off

Memory - Off

The manual cord is to be disconnected.

Flashing Operation:
Indications #1 - 5, 9, 10, 13 - 15 / Yellow
Indications #6 - 8, 18, 19 / Red
Indications #20, 21 / Dark

Hours of Operation:
The 150-second cycle is to be in effect 5:30 - 9:30 A.M. and 3:00 - 7:30 P.M., Monday - Friday.
The 90-second cycle is to be in effect all other times.

1405102/9

Route 23 & Boonton Avenue
Butler Borough
Morris County
Directive No. 249-03

Background Cycles

Phase		Vehicular Actuation							Timing		
		1-8	9, 10,12	11	14, 15,17	16	19-22	23,24	I 150 Sec.	II 150 Sec.	III 90 Sec.
1	Route 23 ROW	G	R	R	R	R	W	DW	96 - 70	96 - 73	36 - 21
	Pedestrian Clearance	G	R	R	R	R	FDW	DW	21	21	21
	Change	Y	R	R	R	R	DW	DW	5 *	5 **	5 ***
	Clearance	R	R	R	R	R	DW	DW	2	2	2
2	Boonton Ave. W/B	R	<-G/G	G	R	R	DW	DW	7 - 23	7 - 20	7 - 16
	Change	R	Y	Y	R	R	DW	DW	4	4	4
	Clearance	R	R	R	R	R	DW	DW	2	2	2
3	Boonton Ave. E/B	R	R	R	<-G/G	G	DW	DW	7 - 17	7 - 17	7 - 13
	Change	R	R	R	Y	Y	DW	DW	4	4	4
	Clearance	R	R	R	R	R	DW	DW	2	2	2
					Pedestrian Actuation						
1	Route 23 ROW	G	R	R	R	R	W	DW	69 - 51	69 - 51	9 - 5
	Pedestrian Clearance	G	R	R	R	R	FDW	DW	21	21	21
	Change	Y	R	R	R	R	DW	DW	5	5	5
	Clearance	R	R	R	R	R	DW	DW	2	2	2
2	Boonton Ave. W/B	R	<-G/G	G	R	R	DW	DW	7 - 25	7 - 25	7 - 11
	Change	R	Y	Y	R	R	DW	DW	4	4	4
	Clearance	R	R	R	R	R	DW	DW	2	2	2
3	Boonton Ave. E/B	R	R	R	<-G/G	G	DW	W	5	5	5
	Pedestrian Clearance	R	R	R	<-G/G	G	DW	FDW	29	29	29
	Change	R	R	R	Y	Y	DW	DW	4	4	4
	Clearance	R	R	R	R	R	DW	DW	2	2	2
	Emergency Flash	Y	R	R	R	R	DARK	DARK	-	-	-

(T-I) *From 5:30 - 9:30am, Monday - Friday, an offset of 0 seconds is to be measured from the beginning of yellow to Route 23 at this intersection.

(T-II) **From 3:00 - 7:30pm, Monday - Friday, an offset of 0 seconds is to be measured from the beginning of yellow to Route 23 at this intersection.

(T-III) ***An offset of 0 seconds is to be measured from the beginning of yellow to Route 23 at this intersection.

Actuated Phases: Vehicle Extension - 2 Seconds
Recall - Off
Memory - Off

Hours of Operation: The 150 second cycle is to be in effect 5:30 - 9:30am and 3:00 - 7:30pm, Monday - Friday.
The 90 second cycle is to be in effect all other times.

The Red Signal Ahead Electric sign is to begin flashing 21 seconds before the beginning of yellow to Route 23 at Boonton Avenue and stop flashing upon the beginning of green to Route 23 traffic at Boonton Avenue.

1405119 **Directive No. 248-03**

Route 23 and Ramp "W" - Morse Avenue
Butler Boro., Morris Co.

BACKGROUND CYCLE

Phase				Timing I 150 Sec.	Timing II 150 Sec.	Timing III 90 Sec.
		1-6	7-12			
1)	Route 23 ROW	G	R	131 - 112	131 - 112	71 - 58
	Change	Y	R	5 *	5 **	5 ***
	Clearance	R	R	1	1	1
2)	Morse Avenue - Ramp "W"	R	G	7 - 26	7 - 26	7 - 20
	Change	R	Y	3	3	3
	Clearance	R	R	3	3	3

(T-I) ***From 5:30 - 9:30 A.M., Monday - Friday, an offset of 36 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 - 7:30 P.M., Monday - Friday, an offset of 133 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.**

(T-III) *****All other time, an offset of 54 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.**

Vehicle Extension - 2 Seconds

Phase 2 - Recall - Off

Phase 2 - Memory - Off

Pedestrian actuation is to provide a minimum green of 26 seconds to Phase 2.

The manual cord is to be disconnected.

Flashing Operation:
Indications # 1 - 6 / Yellow
Indications # 7 - 12 / Red

Hours of Operation:
The 150-second cycle is to be in effect 5:30 - 9:30 A.M., and 3:00 - 7:30 P.M., Monday - Friday.
The 90-second cycle is to be in effect all other times.

1405117 **Directive No. 247-03**

Page 1 of 2 **Route 23 and Cotlass Road - Ramp T**
Riverdale Boro., Morris Co.

BACKGROUND CYCLES

Phase		Signals					Timing		
		1-6, 12	7, 8,10	11,14	9	13	I 150 Sec.	II 150 Sec.	III 90 Sec.
1	Route 23 ROW	G	R	R	R	R	122 - 114	122 - 108	62 - 42
	Change	Y	R	R	R	R	5 *	5 **	5 ***
	Clearance	R	R	R	R	R	1	1	1
2	Cotlass Road	R	G/<G-	R	R	G	5 - 9	5 - 9	5 - 10
	Change	R	Y	R	R	Y	3	3	3
	Clearance	R	R	R	R	R	3	3	3
3	Ramp T	R	R	G/<G-	G	R	5 - 9	5 - 15	5 - 20
	Change	R	R	Y	Y	R	3	3	3
	Clearance	R	R	R	R	R	3	3	3
	Emergency Flash	Y	R	R	R	R	-	-	-

(T-I) ***From 5:30 - 9:30 A.M., Monday - Friday, an offset of 85 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.**

(T-II) ****From 3:00 - 7:30 P.M., Monday - Friday, an offset of 80 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.**

(T-III) *****All other time, an offset of 88 seconds is to be measured from the beginning of yellow to Route 23 at Boonton Avenue to the beginning of yellow to Route 23 at this intersection.**

Vehicle Extension - 2 Seconds

Phases 2/3 - Recall - Off

Phases 2/3 - Memory - Off

Actuation of pedestrian push-button #1 is to provide a minimum green of 26 seconds to Phase 2.

Actuation of pedestrian push-button #2 is to provide a minimum green of 26 seconds to Phase 3.

The manual cord is to be disconnected.

Hours of Operation:
The 150-second cycle is to be in effect 5:30 - 9:30 A.M. and 3:00 - 7:30 P.M., Monday - Friday.
The 90-second cycle is to be in effect all other times.

1405117 **Directive No. 247-03**

Page 2 of 2 **Route 23 and Cotlass Road - Ramp T**
Riverdale Boro., Morris Co.

Pre-Emption Notes

1. The intersection shall have a controller with internal pre-emption features.

2. Remote control pre-emption is permitted from the Route 23 northbound approach and the Cotluss Road - Ramp T westbound approach.

3. The device shall only select a phase displayed in the normal operation.

4. The controller shall guarantee all vehicular and pedestrian minimums, change and clearance times.

5. Normal operation shall commence at the point in the sequence where pre-emption was terminated and coordination shall be re-established.

6. A minimum guaranteed green time of 25 seconds shall be provided to either approach before servicing a pre-emption ROW to another direction (phase).

7. Pre-emption from one of the permitted approaches shall provide ROW only to that approach.

8. Pre-emption shall occur by remote control.

9. Pre-emption ROW on either approach is to be held until the emergency vehicle clears the intersection.

APPENDIX D: ROUTE 42/322 TIMING DIRECTIVES

0803104

Route 42 & Shopping Center Drive/
Jughandle/ Bus Garage Access
Washington Township
Gloucester County

110/90 Second Background Cycle

SIGNAL FACES

PHASE		1-8	9,10, 11,13	12,14,15	TIME A 110-SEC.	TIME B 110-SEC.	TIME C 110-SEC.	TIME D 90-SEC.
A.	Route 42	G	R	R	78-72	78-70	78-73	58-53
	Change	Y	R	R	6	6	6	6
	Clearance	R	R	R	2	2	2	2
B.	Shopping Center Drive and Jughandles	R	G	R	7-13	7-15	7-12	7-12
	Change	R	Y	R	3	3	3	3
	Clearance	R	R	R	2	2	2	2
C.	Bus Garage	R	R	G	7	7	7	7
	Change	R	R	Y	3	3	3	3
	Clearance	R	R	R	2	2	2	2
	EMERGENCY FLASH	Y	R	R	-	-	-	-

HOURS OF OPERATION

		Cycle Length (second s)	Offset (seconds)
TIME A	6 AM - 10 AM M-F	110	0
TIME B	10AM - 3 PM M-F 8AM-6PM, Sat& Sun	110	0
TIME C	3PM-7 PM M-F	110	0
TIME D	All Other Times	90	0

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at this intersection.

The manual control is to be disconnected.

The memory circuit is to be disconnected and the vehicle interval is to be 2 seconds for Phase B.
The memory circuit is to be disconnected and the vehicle interval is to be 5 seconds for Phase C.

Actuation of a pedestrian push button shall guarantee 20 seconds of green time to Phase B.

0803103
Route 42 & Greentree Road (County Road 651)
Washington Township
Gloucester County

110/90 Second Background Cycle

PHASE		SIGNAL FACES 1-6 11,12	9,10,13	7,8	15	14,16,17	TIME A 110 SEC.	TIME B 110 SEC.	TIME C 110 SEC.	TIME D 90 SEC.
		Normal Operation								
A.	Route 42	G	R	R	DW	DW	79-45	79-53	79-64	59-53
	Change	Y	R	R	DW	DW	5	5	5	5
	Clearance	R	R	R	DW	DW	2	2	2	2
B.	Greentree Road	R	R	G	DW	DW	7-26	7-20	7-21	7-10
	Change	R	R	Y	DW	DW	3	3	3	3
	Clearance	R	R	R	DW	DW	2	2	2	2
C.	Jughandle	R	G	R	DW	DW	7-22	7-20	7-8	7-10
	Change	R	Y	R	DW	DW	3	3	3	3
	Clearance	R	R	R	DW	DW	2	2	2	2
		Pedestrian Actuation								
A.	Route 42	G	R	R	DW	DW	66-45	66-53	66-52	46-43
	Change	Y	R	R	DW	DW	5	5	5	5
	Clearance	R	R	R	DW	DW	2	2	2	2
B.	Greentree Road	R	R	G	W	DW	7	7	7	7
	Vehicle Extension	R	R	G	W	DW	0-19	0-13	0-14	0-3
	Change	R	R	Y	W	DW	3	3	3	3
	Clearance	R	R	R	W	DW	2	2	2	2
C.	Jughandle	R	G	R	W	W	7	7	7	7
	Pedestrian Clearance	R	G	R	FDW	FDW	13	13	13	13
	Vehicle Extension	R	G	R	DW	DW	0-2	0	0	0
	Change	R	Y	R	DW	DW	3	3	3	3
	Clearance	R	R	R	DW	DW	2	2	2	2
	EMERGENCY FLASH	Y	R	R	DARK	DARK	-	-	-	

HOURS OF OPERATION

		Cycle Length	Offset (Seconds)
TIME A	6 AM - 10 AM M-F	110	55
TIME B	10AM - 3 PM M-F 8AM-6PM, Sat& Sun	110	105
TIME C	3PM-7 PM M-F	110	33
TIME D	All Other Times	90	24

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

An actuation of pedestrian push buttons will operate signal head #15 and place a call for Phase C (both vehicle and pedestrian Intervals)
The memory circuit is to be disconnected, and the vehicle interval is to be set at 2 seconds for Phases B and C.
The manual control is to remain connected.
The controller is to be capable of skipping phases not actuated.

0803102
Route 42 & Whitman Drive
Washington Township
Gloucester County

110/90 Second Background Cycle

SIGNAL FACES

PHASE		1-8	9,10	11-13	TIME A 110 SEC.	TIME B 110 SEC.	TIME C 110 SEC.	TIME D 90 SEC.
A.	Route 42	G	R	R	79-70	79-69	79-73	59-46
	Change	Y	R	R	5	5	5	5
	Clearance	R	R	R	2	2	2	2
B.	Jughandle	R	G	R	7-12	7-8	7-12	7-15
	Change	R	Y	R	3	3	3	3
	Clearance	R	R	R	2	2	2	2
C.	Whitman Drive	R	R	G	7-11	7-16	7-8	7-12
	Change	R	R	Y	3	3	3	3
	Clearance	R	R	R	2	2	2	2
	EMERGENCY FLASH	Y	R	R	-	-	-	-

	Hours of Operation	Cycle Length	Offset (Seconds)
TIME A	6 AM - 10 AM M-F	110	78
TIME B	10AM - 3 PM M-F	110	19
	8AM-6PM, Sat& Sun		
TIME C	3PM-7 PM M-F	110	44
TIME D	All Other Times	90	34

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.
The memory circuits are to be disconnected.

The manual control is to be connected.

The vehicle interval is to be 2 seconds.

Actuation of a pedestrian push button shall guarantee 21 seconds of green time to Phase B.

0803107
Route 42 Ganttown Road Shopping Center Drive
Washington Twp.
Gloucester County

110/90 Second Background Cycle

Phase		Signal Faces 1,2	5,6	3,4	7,8	9,10	11,12	13,14	Time A 110 Sec.	Time B 110 Sec.	Time C 110 Sec.	Time D 90 Sec.
A)	Route 42 Left Turns	<G-	<G-	R	R	R	R	DW	5-17	5-17	5-16	5-15
	Change	<Y-	<Y-	R	R	R	R	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R	R	DW	3	3	3	3
B)	Route 42	<R-	<R-	G	G	R	R	DW	66-42	66-45	66-41	46-25
	Change	<R-	<R-	Y	Y	R	R	DW	5	5	5	5
	Clearance	<R-	<R-	R	R	R	R	DW	2	2	2	2
C)	Ganttown Road	<R-	<R-	R	R	G	R	DW	7-17	7-13	7-17	7-15
	Change	<R-	<R-	R	R	Y	R	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R	R	DW	3	3	3	3
D)	Shopping Center Drive	<R-	<R-	R	R	R	G	DW	7-9	7-10	7-11	7-10
	Change	<R-	<R-	R	R	R	Y	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R	R	DW	3	3	3	3

Pedestrian Actuation		Signal Faces 1,2	5,6	3,4	7,8	9,10	11,12	13,14	Time A 110 Sec.	Time B 110 Sec.	Time C 110 Sec.	Time D 90 Sec.
A)	Route 42 Left Turns	<G-	<G-	R	R	R	R	DW	5-11	5-11	5-10	5-15
	Change	<Y-	<Y-	R	R	R	R	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R	R	DW	3	3	3	3
B)	Route 42	<R-	<R-	G	G	R	R	DW	52-42	52-45	52-41	33-15
	Change	<R-	<R-	Y	Y	R	R	DW	5	5	5	5
	Clearance	<R-	<R-	R	R	R	R	DW	2	2	2	2
C)	Ganttown Road	<R-	<R-	R	R	G	R	DW	7-11	7-8	7-13	7-15
	Change	<R-	<R-	R	R	Y	R	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R	R	DW	3	3	3	3
D)	Shopping Center Drive	<R-	<R-	R	R	R	G	W	7	7	7	6
	Pedestrian Clearance	<R-	<R-	R	R	R	G	FDW	14	14	14	14
	Change	<R-	<R-	R	R	R	Y	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R	R	DW	3	3	3	3
	EMERGENCY FLASH	<R-	<R-	Y	Y	R	R	DARK	-	-	-	-

	Hours of Operation	Cycle Length		Offset (Seconds)
TIME A	6 AM - 10 AM M-F	110		92
TIME B	10AM - 3 PM M-F	110		32
	8AM-6PM, Sat& Sun			
Time C	3PM-7 PM M-F	110		75
Time D	All Other Times	90		58

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

The manual control and memory circuits are to be disconnected.

The vehicle interval is to be 2 seconds.

The left-turn slots (Phase A) are to be separate phases but concurrently timed if actuation occurs in both slots. Each left-turn slot is to have the capability of terminating or extending independently of each other, thereby reverting the timing to the non-conflicting Phase B movement.

080312
Route 42 & Johnson Road
Washington Township
Gloucester County

110/90 Second Background Cycle

SIGNAL FACES

PHASE		1,2,3	4,5,6	7,8, 9,10	11,12 13,14, 15	TIME A 110 sec	TIME B 110 sec	TIME C 110 sec	TIME D 90 sec
A.	Route 42 Left Turns	<G-	G	R	R	7-23	7-17	7-18	7-15
	Route 42 SB Change	<Y-	G	R	R	5	5	5	5
	Route 42 SB Clearance	<R-	G	R	R	2	2	2	2
B.	Route 42	<R-	G	G	R	76-54	76-66	76-62	56-40
	Route 42 NB Change	<R-	Y(1)	Y	R	5	5	5	5
	Route 42 NB Clearance	<R-	R(1)	R	R	2	2	2	2
C.	Johnson Road	<R-	R	R	G	7-13	7	7-10	7-15
	Change	<R-	R	R	Y	4	4	4	4
	Clearance	<R-	R	R	R	2	2	2	2
	EMERGENCY FLASH	<R-	Y	Y	R				

(1) Indication to remain G if Phase C is skipped.

	Hours of Operation	Cycle Length	Offset (Seconds)
Time A	6 AM - 10 AM M-F	110	78
Time B	10AM - 3 PM M-F	110	18
	8AM-6PM, Sat& Sun		
Time C	3PM-7 PM M-F	110	65
Time D	All Other Times	90	38

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

The manual control and memory circuits are to be disconnected.
The vehicle interval shall be 2 seconds.
Actuation of a pedestrian push button shall guarantee 21 seconds of green time to Phase C
An internal fire pre-emption sequence shall be provided.

Upon actuation of the emergency button, a delay of 15 seconds shall be provided before acceptance of the pre-emption.

Upon actuation of the fire pre-emption, all minimum green, yellow change, red clearance and pedestrain intervals shall be guaranteed followed by 40 seconds of green time to signal heads numbered 11,12 and 15.

The phasing for southbound Route 42 shall be an independent overlap, thereby omitting northbound Route 42 should a pre-emption occur during Phase A.

(NOTE: Phase B minimum green time to be 10 seconds.)

0803106
Route NJ 42 and Fries Mill Road (CR 655)
Washington Twp., Gloucester Co.

110/90 Second Background Cycle

Phase		SIGNAL FACES 1-6	7-9	Times A 110-Sec.	Times B 110-Sec.	Times C 110-Sec.	Time D 90-Sec.
A)	Route NJ 42	G	R	82-60	82-65	82-53	62-56
	Change	Y	R	5	5	5	5
	Clearance	R	R	2	2	2	2
B)	Fries Mill Road	R	G	16-38	16-33	16-45	16-22
	Change	R	Y	3	3	3	3
	Clearance	R	R	2	2	2	2
	Emergency Flash	Y	R	-	-	-	-

Hours of Operation

	Time Period	Cycle Length	Offset (Seconds)
Time A	6 AM - 10 AM M-F	110	34
Time B	10AM - 3 PM M-F	110	93
	8AM-6PM, Sat& Sun		
Time C	3PM-7 PM M-F	110	28
Time D	All Other Times	90	85

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

The memory circuit for Phase B is to be connected.

The manual control is to be disconnected.

The vehicle interval for Phase B is to be set at 5 seconds.

Signal shall operate in minimum recall to Phase B.

0803111
Route NJ 42 & Watson Drive
Washington Township
Gloucester County

Page 1 of 2

110/90 Second Background Cycle

Signal Faces

No Pedestrian Actuation

Phase		1,4,6	2,3,5	7,8,20	9,10,19	11,12	13,14	15,16	17,18	Time 110 sec. A	Time 110 sec. B	Time 110 sec. C	Time 90 sec. D
A.	Route 42 Left	<G-	<G-	R	R	R	R	DW	DW	5-21	5-13	5-20	5-16
	Change	<Y-	<Y-	R	R	R	R	DW	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R	R	DW	DW	2	2	2	2
B.	Route 42	<R-	<R-	G	G	R	R	DW	W	49-20	49-27	49-31	29-9
	Pedestrian Clearance	<R-	<R-	G	G	R	R	DW	FL-DW	17	17	17	17
	Change	<R-	<R-	Y	Y	R	R	DW	DW	5	5	5	5
	Clearance	<R-	<R-	R	R	R	R	DW	DW	2	2	2	2
C.	Watson Drive	<R-	<R-	R	R	G	R	DW	DW	7-15	7-20	7-10	7-13
	Change	<R-	<R-	R	R	Y	R	DW	DW	4	4	4	4
	Clearance	<R-	<R-	R	R	R	R	DW	DW	3	3	3	3
D.	Car Wash	<R-	<R-	R	R	R	G	DW	DW	7-12	7-8	7	7-10
	Change	<R-	<R-	R	R	R	Y	DW	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R	R	DW	DW	3	3	3	3
	Emergency Flash	<R-	<R-	Y	Y	R	R	Dark	Dark	-	-	-	-

With Pedestrian Actuation

Phase		1,4,6	2,3,5	7,8,20	9,10,19	11,12	13,14	15,16	17,18	Time 110 sec. A	Time 110 sec. B	Time 110 sec. C	Time 90 sec. D
A.	Route 42 Left	<G-	<G-	R	R	R	R	DW	DW	5-21	5-13	5-15	5-16
	Change	<Y-	<Y-	R	R	R	R	DW	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R	R	DW	DW	2	2	2	2
B.	Route 42	<R-	<R-	G	G	R	R	DW	W	41-20	41-27	41-31	21-10
	Pedestrian Clearance	<R-	<R-	G	G	R	R	DW	FL-DW	17	17	17	17
	Change	<R-	<R-	Y	Y	R	R	DW	DW	5	5	5	5
	Clearance	<R-	<R-	R	R	R	R	DW	DW	2	2	2	2
C.	Watson Drive	<R-	<R-	R	R	G	R	W	DW	7	7	7	7
	Pedestrian Clearance	<R-	<R-	R	R	G	R	FL-DW	DW	8	8	8	8
	Vehicle Extension	<R-	<R-	R	R	G	R	DW	DW	0	0-5	0	0
	Change	<R-	<R-	R	R	Y	R	DW	DW	4	4	4	4

	Clearance	**<R-**	**<R-**	**R**	**R**	**R**	**R**	**DW**	**DW**	**3**	**3**	**3**	**3**
D.	**<u>Car Wash</u>**	**<R-**	**<R-**	**R**	**R**	**R**	**G**	**DW**	**DW**	**7-12**	**7-8**	**7**	**7**
	Change	**<R-**	**<R-**	**R**	**R**	**R**	**Y**	**DW**	**DW**	**3**	**3**	**3**	**3**
	Clearance	**<R-**	**<R-**	**R**	**R**	**R**	**R**	**DW**	**DW**	**3**	**3**	**3**	**3**
										-	**-**	**-**	**-**
	Emergency Flash	**<R-**	**<R-**	**Y**	**Y**	**R**	**R**	**Dark**	**Dark**				

Route NJ 42 & Watson Drive
Washington Township
Gloucester County

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	Hours of Operation	Cycle Length		Offset (Seconds)	
Time A	**6 AM - 10 AM M-F**	**110-Second Cycle**		**82**	
Time B	**10AM - 3 PM M-F**	**110-Second Cycle**		**33**	
	8AM-6PM, Sat& Sun				
Time C	**3PM-7 PM M-F**	**110-Second Cycle**		**90**	
Time D	**All Other Times**	**90-Second Cycle**		**46**	

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

1. **The manual control and memory circuits are to be disconnected.**

2. **The vehicle interval is to be set at 2 seconds for actuated phases.**

3. **Left-turn slots (Phase A) are to be separate phases but concurrently timed if actuations occurs in both slots. Each left-turn slot is to have the capability of terminating or extending independently of each other, thereby reverting the timing to the non- conflicting Phase B movement.**

0803108
Route NJ 42 & Stage Coach Road / Tuckahoe Road
Washington Township
Gloucester County
Page 1 of 2

110/90 Second Background Cycle

Signal Faces

Phase		1,4	5,6	2,3	7,8,9	10,11	12, 13,14	15, 16,17	18,19 20,21	22,23 26,27	24,25	Time 110-Secs A	Time 110-Secs B	Time 110-Secs C	Time 90 Sec D
	Normal Operation - No Pedestrian Actuation														
A.	Route 42 Left Turns	<G-	<G-	R	R	R/-G>	R	R	DW	DW	DW	5-6	5-6	5	5
	Change	<Y-	<Y-	R	R	R/-G>	R	R	DW	DW	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R/-G>	R	R	DW	DW	DW	3	3	3	3
B.	Route 42	<R-	<R-	G	G	G/-G>	R	R	DW	W	DW	31-19	31-17	31-17	11-7
	Pedestrian Clearance	<R-	<R-	G	G	G/-G>	R	R	DW	FLDW	DW	30	30	30	30
	Change	<R-	<R-	Y	Y	Y/-G>	R	R	DW	DW	DW	6	6	6	6
	Clearance	<R-	<R-	R	R	R/-G>	R	R	DW	DW	DW	2	2	2	2
C.	Stage Coach Road	<R-	<R-	R	R	R/-G>	G	R	DW	DW	DW	7-8	7-8	7-16	7-9
	Change	<R-	<R-	R	R	R/-G>	Y	R	DW	DW	DW	5	5	5	5
	Clearance	<R-	<R-	R	R	R/-G>	R	R	DW	DW	DW	3	3	3	3
D.	Tuckahoe Road	<R-	<R-	R	R	R/-G>	R	G	DW	DW	DW	7-17	7-19	7-12	7-9
	Change	<R-	<R-	R	R	R/-G>	R	Y	DW	DW	DW	5	5	5	5
	Clearance	<R-	<R-	R	R	R/-G>	R	R	DW	DW	DW	3	3	3	3

Pedestrian Actuation

Phase		1,4	5,6	2,3,	7,8,9	10,11	12, 13,14	15, 16,17	18,19 20,21	22,23 26,27	24,25	Time 110-Secs A	Time 110-Secs B	Time 110-Secs C	Time 110 Sec D
A.	Route 42 Left Turns	<G-	<G-	R	R	R/-G>	R	R	DW	DW	DW	5	5	5	5
	Change	<Y-	<Y-	R	R	R/-G>	R	R	DW	DW	DW	3	3	3	3
	Clearance	<R-	<R-	R	R	R/-G>	R	R	DW	DW	DW	3	3	3	3
B.	Route 42	<R-	<R-	G	G	G/-G>	R	R	DW	W	DW	8	8	8	8
	Pedestrian Clearance	<R-	<R-	G	G	G/-G>	R	R	DW	FLDW	DW	30	30	30	30
	Change	<R-	<R-	Y	Y	Y	R	R	DW	DW	DW	6	6	6	6
	Clearance	<R-	<R-	R	R	R	R	R	DW	DW	DW	2	2	2	2
C.	Stage Coach Road	<R-	<R-	R	R	R	G	R	DW	DW	W	7	7	7	7
	Pedestrian Clearance	<R-	<R-	R	R	R	G	R	DW	DW	FDW	5	5	5	5
	Change	<R-	<R-	R	R	R	Y	R	DW	DW	DW	5	5	5	5
	Clearance	<R-	<R-	R	R	R	R	R	DW	DW	DW	3	3	3	3
D.	Tuckahoe Road	<R-	<R-	R	R	R	R	G	W	DW	DW	7	7	7	7
	Pedestrian Clearance	<R-	<R-	R	R	R	R	G	FDW	DW	DW	18	18	18	18

Change	**<R-**	**<R-**	**R**	**R**	**R**	**R**	**Y**	**DW**	**DW**	**DW**	**5**	**5**	**5**	**5**
Clearance	**<R-**	**<R-**	**R**	**R**	**R**	**R**	**R**	**DW**	**DW**	**DW**	**3**	**3**	**3**	**3**
EMERGENCY FLASH	**<R-**	**<R-**	**Y**	**Y**	**Y**	**R**	**R**	**DARK**	**DARK**	**DARK**				

Route NJ 42 & Stage Coach Road / Tuckahoe Road
Washington Township
Gloucester County
Page 2 of 2

	Hours of Operation	Cycle Length		Offset (Seconds)
TIME A	6 AM - 10 AM M-F	110		31
TIME B	10AM - 3 PM M-F	110		88
	8AM-6PM, Sat& Sun			
Time C	3PM-7 PM M-F	110		13
Time D	All Other Times	90		88

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

Vehicle interval set at 2 seconds

The memory circuits OFF.

Recall OFF Phases A, C and D.

Pedestrian call on Push Button #1 to call Phase D.

Pedestrian call on Push Button #2 to call Phase C.

The Route 42 left-turn slots are to operate simultaneously and independently. Upon termination of either left turn phase, due to no vehicle demand, the opposing non-conflicting movements shall commence.

The manual control is to be disconnected.

EMERGENCY FLASH:
Route 42 Yellow.
Route 42 left-turn slots Red.
Stage Coach Road/Tuckahoe Road
Red.
Pedestrian indications DARK.

0803105
TIMING SCHEDULE
State Route 42 (Black Horse Pike) and County Route 689 (Berlin-Cross Keys Road)
Townships of Monroe and Washington, Gloucester County

110/90 Second Background Cycle

Normal Operation — **Signal Faces**

		1-3	4-6	7-9	10	11-13	14-15	16-17	18-21	22-25	TIME A 110 SEC.	TIME B 110 SEC.	TIME C 110 SEC.	TIME D 90 SEC.
A.	Route 42 Through	G	G	R	R	R	<R-	<R-	W	DW	52-38	52-31	52-23	32-17
	Pedestrian Clearance	G	G	R	R	R	<R-	<R-	FL-DW	DW	18	18	18	18
	Change	Y	Y	R	R	R	<R-	<R-	DW	DW	5*	5*	5*	5*
	Clearance	R	R	R	R	R	<R-	<R-	DW	DW	2	2	2	2
B.	Berlin-Cross Keys Rd WBD Lead Left	R	R	G/<G-	G	R	<R-	<R-	DW	DW	5-10	5-8	5-15	5-10
	Lead Change	R	R	G/<Y-	G	R	<R-	<R-	DW	DW	3	3	3	3
C.	Berlin-Cross Keys Rd	R	R	G	G	G	<R-	<R-	DW	DW	7-11	7-9	7-12	7
	Change	R	R	Y	Y	Y	<R-	<R-	DW	DW	5	5	5	5
	Clearance	R	R	R	R	R	<R-	<R-	DW	DW	3	3	3	3
D.	Route 42 Left Turn	R	R	R	R	R	<G-	<G-	DW	DW	5-10	5-21	5-19	5-15
	Change	R	R	R	R	R	<Y-	<Y-	DW	DW	3	3	3	3
	Clearance	R	R	R	R	R	<R-	<R-	DW	DW	2	2	2	2

Pedestrian Actuation

		1-3	4-6	7-9	10	11-13	14-15	16-17	18-21	22-25	TIME A 110 SEC.	TIME B 110 SEC.	TIME C 110 SEC.	TIME D 90 SEC.
A.	Route 42 Through	G	G	R	R	R	<R-	<R-	W	DW	34	34-31	34-23	14-9
	Pedestrian Clearance	G	G	R	R	R	<R-	<R-	FL-DW	DW	18	18	18	18
	Change	Y	Y	R	R	R	<R-	<R-	DW	DW	5*	5*	5*	5*
	Clearance	R	R	R	R	R	<R-	<R-	DW	DW	2	2	2	2
B.	Berlin-Cross Keys Rd WBD Lead Left	R	R	G/<G-	G	R	<R-	<R-	DW	DW	5	5	5	5-10
	Lead Change	R	R	G/<Y-	G	R	<R-	<R-	DW	DW	3	3	3	3
C.	Berlin-Cross Keys Rd	R	R	G	G	G	<R-	<R-	DW	W	7	7	7	7
	Pedestrian Clearance	R	R	G	G	G	<R-	<R-	DW	FDW	18	18	18	18
	Change	R	R	Y	Y	Y	<R-	<R-	DW	DW	5	5	5	5
	Clearance	R	R	R	R	R	<R-	<R-	DW	DW	3	3	3	3
D.	Route 42 Left Turn	R	R	R	R	R	<G-	<G-	DW	DW	5	5-12	5-16	5
	Change	R	R	R	R	R	<Y-	<Y-	DW	DW	3	3	3	3
	Clearance	R	R	R	R	R	<R-	<R-	DW	DW	2	2	2	2
	EMERGENCY FLASH	Y	Y	R	R	R	<R-	<R-	DARK	DARK				

	HOURS OF OPERATION		Cycle Length (Seconds)		Offset (Seconds)
TIME A	6 AM - 10 AM M-F		110		76
TIME B	10AM - 3 PM M-F		110		104
	8AM-6PM, Sat& Sun				
TIME C	3PM-7 PM M-F		110		16
TIME D	All Other Times		90		64

NOTES

1 The vehicle interval is to be set at 2 seconds for Phase B, C, and D.
2 Any unactuated phase will be skipped.
3 The left turn slots (Phase D) are to be separate phases but concurrently timed if actuation occurs in both slots.
Each left turn slot is to have the capability of terminating or extending independently of each other, thereby reverting the timing to the non- conflicting Phase A movement.
4 Phase C shall always follow Phase B.
5 The manual control and memory circuits are to be disconnected.
***6 Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.**
7 Detector switching shall be provided such that the detection within the left turn slots on County Route 689 are capable of extending the Phase C through movement.
8 Phase B shall never follow Phase C.

0803110
Route 42 &Kennedy Avenue
Monroe Township
Gloucester County

110/90 Second Background Cycle

PHASE		SIGNAL FACES 1,2	3,4	5,6,7	8,9	TIME (SECONDS) A,B -110secs	TIME (SECONDS) C -110secs	TIME (SECONDS) D 90secs
A.	Route NJ 42 NBD Lead	<G-	G	R	R	5-15	5-16	5-10
	Change	<Y-	G	R	R	3	3	3
	Clearance	<R-	G	R	R	2	2	2
B.	Route NJ 42	<R-	G	G	R	79-59	79-52	59-45
	Change	<R-	Y(1)	Y	R	5	5	5
	Clearance	<R-	R(1)	R	R	2	2	2
C.	Kennedy Avenue	<R-	R	R	G	7-17*	7-23*	7-16*
	Change	<R-	R	R	Y	3	3	3
	Clearance	<R-	R	R	R	4	4	4
	EMERGENCY FLASH	<R-	Y	Y	R	--	--	--

	Hours of Operation	Cycle Length	Offset (Seconds)
TIME A	6 AM - 10 AM M-F	110	10
TIME B	10AM - 3 PM M-F 8AM-6PM, Sat& Sun	110	0
TIME C	3PM-7 PM M-F	110	34
TIME D	All Other Times	90	32

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

(1) To remain green if Phase C is skipped.

*** Activation of a pedestrian push button shall guarantee 16 seconds of green time to Phase C.**

The manual control and the memory circuits are to be disconnected.

The vehicle intervals shall be set at 2 seconds.

0803109
Route 42 & Lake Avenue
Monroe Township
Gloucester County

110/90 Second Background Cycle

PHASE		1,2,5,6	3,4,7,8	9,10,11,12	TIME 110-sec. A,B	TIME 110-sec) C	TIME 90-sec) D
A.	Route NJ 42 Left	<G-	R	R	5-17	5-16	5-12
	Change	<Y-	R	R	3	3	3
	Clearance	<R-	R	R	2	2	2
B.	Route NJ 42	<R-	G	R	79-55	79-54	59-45
	Change	<R-	Y	R	5	5	5
	Clearance	<R-	R	R	2	2	2
C.	Lake Ave.	<R-	R	G	7-19*	7-21*	7-14*
	Change	<R-	R	Y	3	3	3
	Clearance	<R-	R	R	4	4	4
	EMERGENCY FLASH	<R-	Y	R	--	--	--

	Hours of Operation	Cycle Length	Offset
TIME A	6 AM - 10 AM M-F	110	0
TIME B	10AM - 3 PM M-F	110	0
TIME C	8AM-6PM, Sat& Sun 3PM-7 PM M-F	110	0
TIME D	All Other Times	90	0

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

*** Activation of a pedestrian push button shall guarantee 16 seconds of green time to Phase C.**

The manual control and the memory circuits are to be disconnected.

The vehicle intervals shall be set at 2 seconds.

The Phase A left turn slots shall be separate phases but concurrently times should actuations occur in both slots.

Each left turn slot shall have the capability of terminating or extending independently, thereby reverting the timing to the non-conflicting Phase B movement.

0803101
Route 42 / 322 & Sicklerville Road (CR 536)
Monroe Township
Gloucester County

110/90 Second Background Cycle

PHASE	NORMAL OPERATION	Signal Faces 1,2,3,4, 5,6	7,8,9,10, 13,14	10,11,12, 15	TIME A 110 SEC. CYCLE	TIME B 110 SEC. CYCLE	TIMEC 110 SEC. CYCLE	TIME D 90 SEC. CYCLE
A.	Route 42/322 ROW	G	R	R	75-45	75-44	75-44	55-29
	Change	Y	R	R	5	5	5	5
	Clearance	R	R	R	2	2	2	2
B.	Sicklerville Rd (CR 536)	R	G	R	7-18*	7-27*	7-28*	7-20*
	Change	R	Y	R	5	5	5	5
	Clearance	R	R	R	2	2	2	2
C.	Route US 322	R	R	G	7-26**	7-18**	7-17**	7-20**
	Change	R	R	Y	5	5	5	5
	Clearance	R	R	R	2	2	2	2

HOURS OF OPERATION

	Hours of Operation	Cycle Length	Offset (Seconds)
TIME A	6 AM - 10 AM M-F	110	4
TIME B	10AM - 3 PM M-F	110	7
	8AM-6PM, Sat& Sun		
TIME C	3PM-7 PM M-F	110	20
TIME D	All Other Times	90	52

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.
The manual control and the memory circuits are to be disconnected.

The vehicle intervals shall be set at 2 seconds.

Any unactuated phase shall be skipped.

***Actuation of pedestrian push button "B" shall guarantee 32 seconds of green time to Phase B.**

***Actuation of pedestrian push button "C" shall guarantee 32 seconds of green time to Phase C.**

0826105
Route US 322 & Poplar Street & New Brooklyn Road
Monroe Township Gloucester County

110/90 Second Background Cycle

NORMAL OPERATION

Phase		Signal Faces 1,2,	3,4,	5,6	7,8	9,10 13,14	11-12	15,16	TIME A 110 Sec Cycle	TIME B 110 Sec Cycle	TIME C 110 Sec Cycle	TIME D 90 Sec Cycle
A.	Route US 322 Lead Left	<G-	R	<G-	R	R	DW	DW	5-9	5-12	5-13	5-10
	Change	<Y-	R	<Y-	R	R	DW	DW	3	3	3	3
	Clearance	<R-	R	<R-	R	R	DW	DW	2	2	2	2
B.	Route US 322	<R-	G	<R-	G	R	DW	W	64-39	64-37	64-38	44-26
	Pedestrian Clearance	<R-	G	<R-	G	R	DW	FDW	15	15	15	15
	Change	<R-	Y	<R-	Y	R	DW	DW	5	5	5	5
	Clearance	<R-	R	<R-	R	R	DW	DW	2	2	2	2
C.	New Brooklyn Road-Poplar Street	<R-	R	<R-	R	G	DW	DW	7-28	7-27	7-25	7-20
	Change	<R-	R	<R-	R	Y	DW	DW	4	4	4	4
	Clearance	<R-	R	<R-	R	R	DW	DW	3	3	3	3
	Emergency Flash	<R-	Y	<R-	Y	R	DARK	DARK				

WITH PEDESTRIAN ACTUATION

Phase		Signal Faces 1,2,	3,4,	5,6	7,8	9,10 13,14	11-12	15,16	TIME A 110 Sec Cycle	TIME B 110 Sec Cycle	TIME C 110 Sec Cycle	TIME D 90 Sec Cycle
		NORMAL OPERATION										
A.	Route US 322 Lead Left	<G-	R	<G-	R	R	DW	DW	5-9	5-12	5-13	5-10
	Change	<Y-	R	<Y-	R	R	DW	DW	3	3	3	3
	Clearance	<R-	R	<R-	R	R	DW	DW	2	2	2	2
B.	Route US 322	<R-	G	<R-	G	R	DW	W	64-39	64-37	64-38	27-22
	Pedestrian Clearance	<R-	G	<R-	G	R	DW	FDW	15	15	15	15
	Change	<R-	Y	<R-	Y	R	DW	DW	5	5	5	5
	Clearance	<R-	R	<R-	R	R	DW	DW	2	2	2	2
C.	New Brooklyn Road-Poplar Street	<R-	R	<R-	R	G	W	DW	7	7	7	7
	Pedestrian Clearance	<R-	R	<R-	R	G	FDW	DW	17	17	17	17
	Vehicle Extension	<R-	R	<R-	R	G	DW	DW	0-4	0-3	0-1	0
	Change	<R-	R	<R-	R	Y	DW	DW	4	4	4	4
	Clearance	<R-	R	<R-	R	R	DW	DW	3	3	3	3
	Emergency Flash	<R-	Y	<R-	Y	R	DARK	DARK				

HOURS OF OPERATION

	Hours of Operation		Cycle Length	Offset Seconds)
TIME A	6 AM - 10 AM M-F		110	104
TIME B	10AM - 3 PM M-F		110	100
	8AM-6PM, Sat& Sun			
TIME C	3PM-7 PM M-F		110	12
TIME D	All Other Times		90	24

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.
The vehicle intervals are to be set at 2 seconds.
The left-turn slots (Phase A) are to be separate phases but concurrently timed should actuation occur in both slots.
Each slot shall have the capability of terminating or extending independently of each other, thereby reverting the timing to the non-conflicting Phase B movement.
Any unactuated phases are to be skipped.
The manual control and the memory circuits shall be disconnected.

0827103
Route US 322 & Main Street
Monroe Twp.
Gloucester County

110/90 Second Background Cycle

PHASE		**Signal Faces**		**TIME (SECONDS)** A 110 Sec. Cycle	B 110 Sec. Cycle	C 110 Sec. Cycle	D 90 Sec. Cycle
		1,2,3,4,5,6	7-10				
A.	Route 322	G	R	89-51	89-66	89-56	55-47
	Change	Y	R	6	6	6	6
	Clearance	R	R	2	2	2	2
B.	Main Street/Jug	R	G	7-45	7-30	7-40	7-13
	Change	R	Y	4	4	4	4
	Clearance	R	R	2	2	2	2
	EMERGENCY FLASH	Y	R	-	-	-	-

	Hours of Operation	Cycle Length	Offset (Seconds)
Time A	6 AM - 10 AM M-F	110	10
Time B	10AM - 3 PM M-F	110	98
	8AM-6PM, Sat& Sun		
Time C	3PM-7 PM M-F	110	70
Time D	All Other Times	90	57

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.
The manual control shall be disconnected.

The memory circuit is to be OFF.

The vehicle extension is to be 2 seconds.

Traffic signal to rest in Phase C green.

0827106
Route US 322 and Corkery Lane
Monroe Twp.,
Gloucester Co.

110/90 Second Background Cycle

Phase

		1,2	4,5	3,6	7-12	TIME A 110 sec.	TIME B 110 sec	TIME C 110 sec	TIME D 90 sec
A)	Route US 322 Left Turn	R/<G-	R/<G-	R	R	5-8	5-13	5-11	5-10
	Change	R/<Y-	R/<Y-	R	R	3	3	3	3
B)	Route US 322	G	G	G	R	80-47*	80-52*	80-50*	51
	Change	Y	Y	Y	R	6	6	6	6
	Clearance	R	R	R	R	2	2	2	2
C)	Corkery Lane	R	R	R	G	7-37*	7-27*	7-31*	7-13
	Change	R	R	R	Y	4	4	4	4
	Clearance	R	R	R	R	3	3	3	3
	Emergency Flash			Y	R	-			

	Hours of Operation	Cycle Length	Offset (Seconds)
TIME A	6 AM - 10 AM M-F	110	16
TIME B	10AM - 3 PM M-F	110	2
	8AM-6PM, Sat& Sun		
TIME C	3PM-7 PM M-F	110	80
TIME D	All Other Times	90	61

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

The manual control is to be disconnected.

The memory circuit is to be disconnected.

The vehicle interval is to be set at 2 seconds.

An actuation of a pedestrian push button is to guarantee 20 seconds of green time to Corkery Lane without causing recall.

0827101
Route US 322 & Malaga Road
Monroe Township
Gloucester County

110/90 SECOND BACKGROUND CYCLE

		SIGNAL HEADS					
		1,2,3,	7,8,	TIME A	TIME B	TIME C	TIME D
PHASE		4,5,6	9,10	110-SECONDS	110-SECONDS	110-SECONDS	90 SECONDS
A.	Route US 322	G	R	88-66	88-67	88-66	68-54
	Change	Y	R	6	6	6	6
	Clearance	R	R	2	2	2	2
B.	Malaga Road	R	G	7-29	7-28	7-29	7-21
	Change	R	Y	5	5	5	5
	Clearance	R	R	2	2	2	2
	FLASH	Y	R	-	-	-	-

	Hours of Operation	Cycle Length	Offset (Seconds)
TIME A	6 AM - 10 AM M-F	110	57
TIME B	10AM - 3 PM M-F 8AM-6PM, Sat& Sun	110	48
TIME C	3PM-7 PM M-F	110	6
TIMED	All Other Times	90	5

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

The memory circuit is to be disconnected.

The manual control is to be disconnected.

The vehicle extension is to be set at 2 seconds.

Actuation of a pedestrian push button is to guarantee 17 seconds of green time to Malaga Road.

0827102
Route US 322 & Corkery Lane
White Hall Road
Monroe Township
Gloucester County

110/90 Second Background Cycle

NORMAL OPERATION

PHASE		SIGNAL HEADS 1-4	5-9,12	10,11	TIME A 110-SECONDS	TIME B 110-SECONDS	TIME C 110-SECONDS	TIME D 90-SECONDS
A.	Route US 322	G	R	DW	84-62	84-65	84-66	64-56
	Change	Y	R	DW	6	6	6	6
	Clearance	R	R	DW	2	2	2	2
B.	Corkery Lane/ Whitehall Road	R	G	DW	12-34	12-31	12-30	12-20
	Change	R	Y	DW	4	4	4	4
	Clearance	R	R	DW	2	2	2	2
			WITH PEDESTRIAN ACTUATION					
A.	Route US 322	G	R	DW	60	60	60	40
	Change	Y	R	DW	6	6	6	6
	Clearance	R	R	DW	2	2	2	2
B.	Corkery Lane/ Whitehall Road	R	G	W	7	7	7	7
	Pedestrian Clearance	R	G	FDW	29	29	29	29
	Change	R	Y	DW	4	4	4	4
	Clearance	R	R	DW	2	2	2	2
	EMERGENCY FLASH	Y	R	DARK	-	-	-	-

HOURS OF OPERATION

	Hours of Operation	Cycle Length	Offset (Seconds)
TIME A	6 AM - 10 AM M-F	110	0
TIME B	10AM - 3 PM M-F 8AM-6PM, Sat& Sun	110	0
TIME C	3PM-7 PM M-F	110	0
TIME D	All Other Times	90	0

The memory circuit is to be disconnected.

The manual control is to be connected.

The vehicle extension is to be set at 2 seconds.

Offsets (in seconds) are measured from the beginning of yellow to Route 42 traffic at Shopping Center Drive/Bus Garage Access to the beginning of yellow to Route 42 traffic at this intersection.

APPENDIX E: SYNCHRO MOE RESULTS TABLES

Table E-1. MOEs Results for Route 23 (AM-EXISTING)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Vernon Stockholm(Rt.515)	27	15	0.62	1,245	7	18	35	2.44	0.47	0.56	349
Canister Rd.	58	40	0.90	2,246	4	44	70	4.87	0.95	1.13	646
Reservior Rd.	4	3	0.20	493	30	7	16	1.15	0.22	0.27	0
Doremus Rd.	4	3	0.39	922	30	6	22	1.56	0.30	0.36	24
Paradise Rd.	18	6	0.66	1,106	69	23	50	3.48	0.68	0.81	23
OaK Ridge Rd.	154	127	1.64	4,441	13	141	185	12.96	2.53	3.01	434
Clinton Rd.	50	36	0.98	2,856	18	40	77	5.37	1.05	1.24	427
LaRue Rd. (NB)	26	6	0.43	375	7	7	12	0.84	0.16	0.20	68
LaRue Rd. (SB)	86	83	1.20	4,150	11	106	164	11.44	2.23	2.65	1,187
Kanouse (Old Route23)	64	54	1.24	3,566	49	63	109	7.65	1.49	1.77	736
Echo Lake Rd.	163	86	1.57	3,284	6	93	123	8.64	1.68	2.00	1,056
Center Court	2	3	0.21	904	33	9	25	1.78	0.35	0.41	143
Kinnelon Rd. (Rt. 618)	13	18	0.50	2,480	17	28	68	4.74	0.92	1.10	297
Kiel Ave. & Ramp CC	21	4	0.47	330	11	5	10	0.69	0.13	0.16	0
Kakeout & Kinnelon Rd.	19	6	0.53	555	9	7	15	1.03	0.20	0.24	68
Casecade Way	23	31	1.09	5,258	29	43	123	8.63	1.68	2.00	623
Boonton Ave.	110	176	1.26	7,286	5	195	272	19.04	3.70	4.41	2,107
Morse Ave.	56	86	0.49	2,765	5	95	120	8.40	1.63	1.95	2,205
Cotluss Rd.	15	25	0.28	1,666	9	31	53	3.72	0.72	0.86	649
Total	828	808	0.77*	45,928	19.1*	961	1,549	108.43	21.09	25.13	11,042

*: Average

Table E-2. MOEs Results for Route 23 (NOON-EXISTING)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Vernon Stockholm(Rt.515)	7	3	0.33	543	20	6	13	0.92	0.18	0.21	0
Canister Rd.	6	3	0.36	713	23	7	17	1.19	0.23	0.28	0
Reservior Rd.	4	2	0.15	283	27	5	10	0.69	0.13	0.16	0
Doremus Rd.	2	1	0.17	304	35	4	10	0.70	0.14	0.16	0
Paradise Rd.	11	3	0.42	441	79	17	28	2.01	0.40	0.46	0
OaK Ridge Rd.	40	18	1.28	2,002	29	26	48	3.40	0.67	0.79	333
Clinton Rd.	14	6	0.63	894	37	9	21	1.42	0.27	0.33	100
LaRue Rd. (NB)	7	2	0.26	331	16	5	7	0.49	0.10	0.11	0
LaRue Rd. (SB)	3	1	0.14	188	44	10	18	1.26	0.24	0.29	0
Kanouse (Old Route23)	15	5	0.86	986	44	16	30	2.14	0.42	0.49	64
Echo Lake Rd.	10	4	0.45	641	48	9	15	1.03	0.20	0.24	18
Center Court	1	1	0.09	224	39	4	9	0.65	0.13	0.15	0
Kinnelon Rd. (Rt. 618)	13	13	0.50	1,832	14	18	41	2.90	0.56	0.67	221
Kiel Ave. & Ramp CC	14	3	0.49	404	14	5	10	0.70	0.14	0.16	0
Kakeout & Kinnelon Rd.	6	2	0.25	304	21	4	8	0.55	0.11	0.13	0
Casecade Way	6	5	0.38	1,252	63	13	37	2.54	0.50	0.59	0
Boonton Ave.	7	8	0.32	1,275	28	20	41	2.86	0.56	0.66	0
Morse Ave.	7	7	0.35	1,364	33	22	48	3.36	0.65	0.78	332
Cotluss Rd.	16	19	0.74	3,225	9	23	66	4.62	0.90	1.07	704
Total	189	106	0.43*	17,206	32.8*	223	477	33.43	6.53	7.73	1,772

*: Average

Table E-3. MOEs Results for Route 23 (PM-EXISTING)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Vernon Stockholm(Rt.515)	8	4	0.32	614	20	7	17	1.18	0.23	0.27	0
Canister Rd.	4	3	0.15	388	32	7	16	1.12	0.22	0.26	0
Reservior Rd.	23	19	0.78	2,411	9	24	58	4.06	0.79	0.94	473
Doremus Rd.	12	10	0.67	1,997	15	14	45	3.14	0.61	0.73	259
Paradise Rd.	11	5	0.49	751	80	25	49	3.48	0.68	0.80	0
OaK Ridge Rd.	66	48	1.26	3,565	19	59	107	7.49	1.45	1.73	1,020
Clinton Rd.	92	74	1.64	4,528	14	81	135	9.46	1.84	2.19	1,081
LaRue Rd. (NB)	23	19	0.53	1,587	9	23	45	3.13	0.61	0.73	287
LaRue Rd. (SB)	6	2	0.32	334	40	9	18	1.26	0.24	0.29	0
Kanouse (Old Route23)	35	20	1.29	2,894	42	44	100	6.97	1.36	1.62	412
Echo Lake Rd.	67	55	1.30	3,566	24	61	105	7.33	1.43	1.70	713
Center Court	4	5	0.14	653	25	11	23	1.60	0.31	0.37	0
Kinnelon Rd. (Rt. 618)	23	41	0.75	4,780	8	49	117	8.21	1.60	1.90	1,252
Kiel Ave. & Ramp CC	36	11	0.64	713	7	13	22	1.55	0.30	0.36	149
Kakeout & Kinnelon Rd.	8	3	0.38	521	18	5	13	0.93	0.18	0.22	25
Casecade Way	22	34	0.93	5,087	35	46	125	8.71	1.69	2.02	1,175
Boonton Ave.	20	34	0.47	2,983	16	51	98	6.88	1.34	1.60	429
Morse Ave.	7	12	0.24	1,378	35	39	76	5.31	1.03	1.23	388
Cotluss Rd.	27	48	0.73	4,649	6	55	117	8.20	1.60	1.90	1,221
Total	494	447	0.69*	43,399	23.9*	623	1,286	90.01	17.51	20.86	8,884

*: Average

Table E-4. MOEs Results for Route 23 (AM-OPTIMIZED)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Vernon Stockholm(Rt.515)	26	15	0.62	1,252	8	18	35	2.42	0.47	0.56	341
Canister Rd.	50	35	0.68	1,691	4	38	57	3.99	0.78	0.93	442
Reservior Rd.	3	2	0.1	232	33	6	12	0.84	0.16	0.19	0
Doremus Rd.	3	2	0.13	309	34	6	12	0.86	0.17	0.2	0
Paradise Rd.	14	4	0	372	76	20	37	3	1	1	0
OaK Ridge Rd.	139	114	1.66	4,491	13	128	176	12.34	2.4	2.86	301
Clinton Rd.	25	20	0.77	2,182	34	23	54	3.8	0.74	0.88	166
LaRue Rd. (NB)	25	6	0.43	380	7	7	12	0.84	0.16	0.2	64
LaRue Rd. (SB)	59	56	1.07	3,684	15	80	137	9.58	1.86	2.22	548
Kanouse (Old Route23)	68	66	1.13	3,655	51	75	120	8.39	1.63	1.94	440
Echo Lake Rd.	98	74	1.63	4,294	9	80	130	9.06	1.77	2.1	1,131
Center Court	2	2	0.18	800	35	8	23	1.64	0.32	0.38	116
Kinnelon Rd. (Rt. 618)	16	5	0.32	333	11	6	11	0.74	0.14	0.17	66
Kiel Ave. & Ramp CC	19	4	0.4	282	12	5	9	0.63	0.12	0.15	0
Kakeout & Kinnelon Rd.	12	17	0.49	2,392	18	26	65	4.55	0.89	1.05	197
Casecade Way	8	10	0.42	2,039	54	23	59	4.15	0.81	0.96	66
Boonton Ave.	32	52	0.82	4,757	13	71	143	9.97	1.94	2.31	520
Morse Ave.	65	101	0.69	3,890	4	110	148	10.38	2.02	2.41	1,193
Cotluss Rd.	38	63	0.66	3,932	4	68	115	8.07	1.57	1.87	668
Total	702	648	0.66*	40,967	22.9*	798	1,355	94.81	18.45	21.97	6,259

*: Average

Table E-5. MOEs Results for Route 23 (NOON-OPTIMIZED)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Vernon Stockholm(Rt.515)	8	4	0.34	566	19	6	14	0.95	0.19	0.22	0
Canister Rd.	5	3	0.25	487	25	6	13	0.92	0.18	0.21	0
Reservior Rd.	3	2	0.12	219	32	5	8	0.58	0.11	0.13	0
Doremus Rd.	1	1	0.07	132	42	3	7	0.49	0.09	0.11	0
Paradise Rd.	6	2	0.32	339	88	15	27	1.90	0.37	0.44	0
OaK Ridge Rd.	25	11	0.99	1,549	37	20	38	2.70	0.52	0.63	72
Clinton Rd.	11	4	0.46	670	44	9	17	1.18	0.23	0.27	103
LaRue Rd. (NB)	7	3	0.32	404	15	5	7	0.52	0.10	0.12	0
LaRue Rd. (SB)	6	2	0.17	237	40	11	20	1.39	0.27	0.32	0
Kanouse (Old Route23)	6	2	0.35	438	53	14	22	1.56	0.31	0.36	0
Echo Lake Rd.	11	4	0.55	759	47	9	17	1.18	0.23	0.28	15
Center Court	1	1	0.09	224	39	4	9	0.65	0.13	0.15	0
Kinnelon Rd. (Rt. 618)	12	12	0.45	1,634	15	18	38	2.66	0.52	0.62	219
Kiel Ave. & Ramp CC	11	3	0.48	399	16	4	9	0.66	0.13	0.15	0
Kakeout & Kinnelon Rd.	5	2	0.21	254	21	4	7	0.51	0.10	0.12	0
Casecade Way	4	3	0.17	570	75	11	24	1.71	0.33	0.40	0
Boonton Ave.	9	10	0.54	2,115	25	22	55	3.87	0.75	0.90	0
Morse Ave.	5	6	0.25	976	36	20	41	2.85	0.55	0.66	300
Cotluss Rd.	12	14	0.52	2,246	11	19	48	3.35	0.65	0.78	408
Total	148	89	0.35*	14,218	35.8*	205	421	29.63	5.76	6.87	1,117

*: Average

Table E-6. MOEs Results for Route 23 (PM-OPTIMIZED)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Vernon Stockholm(Rt.515)	7	4	0.21	405	22	6	13	0.93	0.18	0.21	0
Canister Rd.	3	2	0.13	340	33	7	15	1.06	0.21	0.24	0
Reservior Rd.	5	4	0.13	409	24	8	16	1.14	0.22	0.26	0
Doremus Rd.	3	2	0.24	701	32	7	20	1.38	0.27	0.32	0
Paradise Rd.	8	3	0.21	285	84	25	42	2.97	0.58	0.69	0
OaK Ridge Rd.	28	24	0.95	2,786	42	34	77	5.40	1.06	1.25	1,072
Clinton Rd.	78	62	1.29	3,399	15	69	109	7.62	1.49	1.77	1,203
LaRue Rd. (NB)	20	17	0.55	1,643	10	21	44	3.10	0.60	0.72	522
LaRue Rd. (SB)	3	1	0.15	162	44	8	15	1.02	0.20	0.24	0
Kanouse (Old Route23)	26	14	1.06	2,360	49	38	87	6.09	1.19	1.41	274
Echo Lake Rd.	40	32	1.02	2,914	29	38	78	5.45	1.06	1.27	477
Center Court	3	4	0.11	514	30	9	20	1.37	0.27	0.32	0
Kinnelon Rd. (Rt. 618)	18	32	0.73	4,664	10	40	109	7.61	1.48	1.76	963
Kiel Ave. & Ramp CC	34	10	0.64	709	8	12	22	1.51	0.29	0.35	143
Kakeout & Kinnelon Rd.	7	3	0.20	272	20	4	9	0.63	0.12	0.15	0
Casecade Way	12	18	0.58	3,168	53	32	84	5.86	1.15	1.36	217
Boonton Ave.	37	65	0.72	4,516	10	81	144	10.08	1.96	2.34	1,172
Morse Ave.	5	8	0.14	835	39	35	64	4.51	0.88	1.04	378
Cotluss Rd.	17	30	0.59	3,797	9	36	91	6.33	1.23	1.47	1,124
Total	354	335	0.51*	33,879	29.6*	510	1,059	74.06	14.44	17.17	7,545

*: Average

Table E-7. MOEs Results for Route 42/322 (AM-EXISTING)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Shopping Center Dr.	8	7	0.35	1,173	18	12	29	2.00	0.39	0.46	149
Greentree Rd.	65	61	1.02	3,470	4	69	93	6.49	1.26	1.50	1,086
Whitman Dr.	11	9	0.35	1,071	16	14	28	1.98	0.39	0.46	427
Gantown Rd.	45	40	0.93	2,951	4	44	74	5.16	1.00	1.20	909
Johnson Rd.(NB)	13	10	0.35	1,050	15	16	32	2.23	0.43	0.52	44
Fries Mill Rd.(SB)	28	15	0.52	1,031	11	20	29	1.99	0.39	0.46	438
Watson Dr.	26	14	0.78	1,485	20	24	46	3.24	0.63	0.75	102
Tuckahoe Rd.-Stagecoach Rd.	30	15	0.71	1,300	10	20	35	2.42	0.47	0.56	281
Berlin Cross Keys Rd.	27	15	0.68	1,392	15	25	41	2.85	0.55	0.66	170
Kennedy Dr. (SB)	5	2	0.27	345	31	5	11	0.77	0.15	0.18	0
Lake Ave.	7	3	0.36	513	35	10	21	1.45	0.28	0.34	2
Sicklerville Rd.	57	38	0.95	2,315	2	40	52	3.66	0.71	0.85	937
Poplar St-New Brooklyn Rd.	24	10	0.66	999	15	17	29	2.05	0.40	0.47	7
Main St. (Rt.322)	5	2	0.33	384	21	3	9	0.63	0.12	0.15	0
Corkery Ln.	12	5	0.52	695	20	9	19	1.30	0.25	0.30	0
Malaga Rd.	8	3	0.40	492	17	4	11	0.75	0.15	0.17	0
White Hall Rd.-Corkery Ln.	8	2	0.40	387	14	3	8	0.56	0.11	0.13	12
Total	379	251	0.56*	21,053	15.7*	335	567	39.53	7.68	9.16	4,564

*: Average

Table E-8. MOEs Results for Route 42/322 (NOON-EXISTING)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Shopping Center Dr.	12	11	0.45	1,618	14	16	39	2.69	0.52	0.62	628
Greentree Rd.	52	55	0.72	2,763	5	64	80	5.57	1.08	1.29	1,195
Whitman Dr.	13	13	0.46	1,599	14	19	40	2.76	0.54	0.64	432
Gantown Rd.	32	33	0.68	2,572	6	39	68	4.74	0.92	1.10	1,138
Johnson Rd.(NB)	39	46	0.75	3,226	6	53	94	6.60	1.28	1.53	1,048
Fries Mill Rd.(SB)	15	13	0.52	1,584	19	21	41	2.88	0.56	0.67	538
Watson Dr.	16	13	0.63	1,863	26	29	61	4.30	0.84	1.00	112
Tuckahoe Rd.-Stagecoach Rd.	32	24	0.75	2,026	10	32	53	3.74	0.73	0.87	394
Berlin Cross Keys Rd.	26	19	0.65	1,737	15	33	54	3.74	0.73	0.87	429
Kennedy Dr. (SB)	6	3	0.34	671	29	8	20	1.42	0.28	0.33	0
Lake Ave.	9	4	0.42	780	34	14	31	2.14	0.42	0.50	10
Sicklerville Rd.	29	18	0.73	1,609	3	19	33	2.30	0.45	0.53	801
Poplar St-New Brooklyn Rd.	24	12	0.69	1,250	15	19	35	2.47	0.48	0.57	4
Main St. (Rt.322)	4	2	0.28	384	22	3	9	0.64	0.12	0.15	0
Corkery Ln.	9	3	0.42	513	24	6	15	1.02	0.20	0.24	0
Malaga Rd.	6	2	0.31	305	22	3	7	0.50	0.10	0.12	0
White Hall Rd.-Corkery Ln.	5	1	0.3	244	19	2	5	0.38	0.07	0.09	0
Total	329	272	0.54*	24,744	16.6*	380	685	47.89	9.32	11.12	6,729

*: Average

Table E-9. MOEs Results for Route 42/322 (PM-EXISTING)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Shopping Center Dr.	20	25	0.67	2,966	9	32	63	4.40	0.86	1.02	1,057
Greentree Rd.	60	72	0.87	3,734	5	82	105	7.36	1.43	1.71	1,724
Whitman Dr.	16	19	0.49	2,120	12	27	49	3.44	0.67	0.80	625
Gantown Rd.	63	82	0.94	4,413	3	89	115	8.06	1.57	1.87	1,256
Johnson Rd.(NB)	18	22	0.58	2,586	12	32	61	4.26	0.83	0.99	964
Fries Mill Rd.(SB)	15	15	0.49	1,762	16	24	42	2.93	0.57	0.68	841
Watson Dr.	28	23	0.76	2,259	18	39	68	4.75	0.92	1.10	284
Tuckahoe Rd.-Stagecoach Rd.	31	24	0.78	2,117	9	30	50	3.51	0.68	0.81	602
Berlin Cross Keys Rd.	38	35	0.79	2,672	12	55	76	5.34	1.04	1.24	486
Kennedy Dr. (SB)	11	7	0.49	1,214	21	15	30	2.12	0.41	0.49	21
Lake Ave.	10	5	0.46	861	29	17	31	2.14	0.42	0.50	17
Sicklerville Rd.	56	47	0.91	2,749	2	49	64	4.45	0.87	1.03	1,472
Poplar St-New Brooklyn Rd.	18	12	0.63	1,450	18	20	41	2.84	0.55	0.66	5
Main St. (Rt.322)	8	4	0.67	1,284	15	6	27	1.90	0.37	0.44	0
Corkery Ln.	9	4	0.45	715	23	8	20	1.43	0.28	0.33	2
Malaga Rd.	8	3	0.40	617	18	5	14	0.96	0.19	0.22	0
White Hall Rd.-Corkery Ln.	9	3	0.45	464	14	3	11	0.80	0.15	0.18	0
Total	418	402	0.64*	33,983	13.9*	533	867	60.69	11.81	14.07	9,356

*: Average

Table E-10. MOEs Results for Route 42/322 (AM-OPTIMIZED)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Shopping Center Dr.	6	6	0.34	1,141	20	10	27	1.89	0.37	0.44	32
Greentree Rd.	25	24	0.71	2,400	9	31	60	4.20	0.82	0.97	1,319
Whitman Dr.	8	6	0.27	842	19	11	23	1.59	0.31	0.37	391
Gantown Rd.	13	12	0.48	1,535	12	16	35	2.43	0.47	0.56	138
Johnson Rd.(NB)	10	9	0.47	1,405	17	14	36	2.51	0.49	0.58	217
Fries Mill Rd.(SB)	12	7	0.44	863	20	11	21	1.48	0.29	0.34	356
Watson Dr.	18	9	0.56	1,080	24	19	38	2.64	0.51	0.61	59
Tuckahoe Rd.-Stagecoach Rd.	22	11	0.71	1,312	12	16	32	2.22	0.43	0.51	106
Berlin Cross Keys Rd.	24	14	0.64	1,312	16	24	38	2.66	0.52	0.62	119
Kennedy Dr. (SB)	4	2	0.17	223	32	5	9	0.64	0.12	0.15	0
Lake Ave.	8	3	0.30	429	34	10	20	1.38	0.27	0.32	2
Sicklerville Rd.	24	16	0.62	1,512	4	18	28	1.97	0.38	0.46	706
Poplar St-New Brooklyn Rd.	17	7	0.54	820	19	14	24	1.67	0.33	0.39	3
Main St. (Rt.322)	3	1	0.15	178	25	2	5	0.35	0.07	0.08	0
Corkery Ln.	17	6	0.53	709	17	11	20	1.40	0.27	0.32	2
Malaga Rd.	11	4	0.30	378	14	5	9	0.64	0.12	0.15	0
White Hall Rd.-Corkery Ln.	11	3	0.37	364	11	4	8	0.56	0.11	0.13	36
Total	233	140	0.45*	16,503	17.9*	221	433	30.23	5.88	7.00	3,486

*: Average

Table E-11. MOEs Results for Route 42/322 (NOON-OPTIMIZED)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Shopping Center Dr.	11	11	0.47	1,658	15	16	39	2.70	0.53	0.63	618
Greentree Rd.	19	20	0.54	2,062	12	29	53	3.70	0.72	0.86	1,223
Whitman Dr.	11	10	0.43	1,492	16	16	36	2.49	0.48	0.58	529
Gantown Rd.	14	15	0.51	1,927	12	20	44	3.09	0.60	0.72	230
Johnson Rd.(NB)	17	20	0.59	2,527	12	28	65	4.54	0.88	1.05	733
Fries Mill Rd.(SB)	12	10	0.44	1,336	22	19	36	2.49	0.48	0.58	519
Watson Dr.	11	9	0.43	1,291	29	25	50	3.49	0.68	0.81	63
Tuckahoe Rd.-Stagecoach Rd.	25	19	0.76	2,030	12	26	50	3.50	0.68	0.81	247
Berlin Cross Keys Rd.	24	18	0.64	1,709	16	31	51	3.60	0.70	0.83	360
Kennedy Dr. (SB)	6	3	0.26	513	29	8	18	1.24	0.24	0.29	0
Lake Ave.	9	5	0.36	661	33	15	29	2.03	0.40	0.47	9
Sicklerville Rd.	21	13	0.57	1,248	4	14	24	1.68	0.33	0.39	491
Poplar St-New Brooklyn Rd.	20	10	0.55	998	17	17	30	2.09	0.41	0.49	4
Main St. (Rt.322)	4	2	0.19	256	22	3	7	0.48	0.09	0.11	0
Corkery Ln.	12	4	0.42	510	20	8	15	1.07	0.21	0.25	0
Malaga Rd.	8	2	0.2	198	19	3	6	0.39	0.08	0.09	0
White Hall Rd.-Corkery Ln.	7	2	0.28	227	15	2	5	0.38	0.07	0.09	0
Total	231	173	0.45*	20,643	17.9*	280	558	38.96	7.58	9.05	5,026

Table E-12. MOEs Results for Route 42/322 (PM-OPTIMIZED)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Shopping Center Dr.	16	19	0.72	3,152	11	26	61	4.27	0.83	0.99	784
Greentree Rd.	46	55	0.83	3,590	6	65	88	6.14	1.20	1.42	709
Whitman Dr.	12	15	0.47	2,024	14	23	45	3.14	0.61	0.73	448
Gantown Rd.	33	43	0.80	3,757	6	51	83	5.81	1.13	1.35	879
Johnson Rd.(NB)	12	14	0.51	2,290	16	23	51	3.58	0.70	0.83	493
Fries Mill Rd.(SB)	10	9	0.32	1,147	21	18	30	2.10	0.41	0.49	530
Watson Dr.	16	13	0.63	1,871	24	30	56	3.93	0.76	0.91	165
Tuckahoe Rd.-Stagecoach Rd.	19	14	0.55	1,486	13	21	35	2.47	0.48	0.57	48
Berlin Cross Keys Rd.	30	28	0.75	2,550	14	48	70	4.87	0.95	1.13	439
Kennedy Dr. (SB)	11	8	0.42	1,041	21	15	28	1.99	0.39	0.46	49
Lake Ave.	12	6	0.44	831	28	17	31	2.15	0.42	0.50	15
Sicklerville Rd.	28	23	0.73	2,204	3	26	43	3.01	0.59	0.70	1,317
Poplar St-New Brooklyn Rd.	17	11	0.56	1,302	19	19	38	2.64	0.51	0.61	5
Main St. (Rt.322)	4	2	0.18	346	24	4	9	0.65	0.13	0.15	13
Corkery Ln.	13	6	0.46	732	19	10	22	1.52	0.30	0.35	10
Malaga Rd.	11	5	0.31	474	15	7	12	0.81	0.16	0.19	0
White Hall Rd.-Corkery Ln.	9	3	0.40	416	13	4	11	0.74	0.14	0.17	0
Total	299	274	0.53*	29,213	15.7*	407	713	49.82	9.71	11.55	5,904

Table E-13. MOEs Results for Route 42/322 (OFFPEAK-OPTIMIZED)

Intersection	Signal Delay / Veh (s)	Total Signal Delay (hr)	Stops / Veh	Stops	Average Speed (mph)	Total Travel Time (hr)	Fuel Consumed (gal)	CO Emissions (kg)	NOx Emissions (kg)	VOC Emissions (kg)	Queuing Penalty (veh)
Shopping Center Dr.	5	2	0.26	304	23	3	8	0.54	0.10	0.12	0
Greentree Rd.	10	3	0.37	465	18	6	12	0.82	0.16	0.19	94
Whitman Dr.	7	2	0.32	376	20	4	9	0.66	0.13	0.15	97
Gantown Rd.	13	4	0.47	593	12	6	14	0.96	0.19	0.22	0
Johnson Rd.(NB)	7	3	0.32	466	21	5	13	0.90	0.17	0.21	0
Fries Mill Rd.(SB)	9	3	0.38	386	25	5	11	0.74	0.14	0.17	22
Watson Dr.	8	2	0.33	330	32	8	14	1.01	0.20	0.23	1
Tuckahoe Rd.-Stagecoach Rd.	16	4	0.57	511	16	7	13	0.89	0.17	0.21	24
Berlin Cross Keys Rd.	17	4	0.53	476	19	9	15	1.03	0.20	0.24	0
Kennedy Dr. (SB)	4	1	0.21	136	34	2	5	0.35	0.07	0.08	0
Lake Ave.	5	1	0.23	141	38	4	8	0.56	0.11	0.13	0
Sicklerville Rd.	15	3	0.52	379	5	4	7	0.47	0.09	0.11	11
Poplar St-New Brooklyn Rd.	13	2	0.45	275	21	5	8	0.58	0.11	0.13	0
Main St. (Rt.322)	4	0	0.16	74	24	1	2	0.14	0.03	0.03	0
Corkery Ln.	9	1	0.33	131	24	2	4	0.28	0.06	0.07	0
Malaga Rd.	6	1	0.23	77	21	1	2	0.13	0.03	0.03	0
White Hall Rd.-Corkery Ln.	6	0	0.26	70	18	1	2	0.11	0.02	0.02	0
Total	154	36	0.35*	5,190	21.8*	73	147	10.17	1.98	2.34	249

*: Average