

TRAFFIC CONTROL WARRANT STUDY

PID 107235



City of Warren
Trumbull County, Ohio

May, 2020

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1. Introduction and Purpose

The City of Warren's traffic signal system is comprised of 61 signalized intersections. The last major system upgrade took place in 2003. During this project 27 unwarranted signals were removed, three new signals were installed, 18 signals were reconstructed, and the remaining signals received equipment upgrades including new controllers, improved vehicle detections, fiber-optic interconnect and emergency vehicle preemption. This project also installed new coordinated traffic signal timings.

Several elements of the current signal system are reaching their useful life expectancy and are no longer functioning as originally intended. Over the nearly 20-year period, traffic volumes around and through the City have significantly changed, resulting in less than optimal coordination timings.

This study serves as the first step in the City's plan to improve traffic flow by removing unwarranted traffic signals and upgrading the remaining signals. Additional traffic flow improvements will be realized through the removal of unwarranted multi-way stop-controlled intersections. At multi-way stop-controlled intersections, traffic on all approaches to the intersection must come to a stop before traveling through the intersection. Where determined to be unwarranted, the stop signs on the major street approaches to these intersections will be removed, and only side-street traffic will be required to stop.

This document contains the data we have collected, our methodology in analyzing the data and the results of our analysis.

2. Data Collection

Turning Movement Traffic Counts at Signalized Intersections

Weekday turning movement traffic counts were collected using video cameras for a 12-hour period on October 22 and October 23, 2019. The video was processed for nine hours (7:00 AM to 10:00 AM), (11:00 AM to 2:00 PM), and (3:00 PM to 6:00 PM) for use in the analysis. A list of the signalized study intersections is provided below, the raw traffic count data is contained in **Appendix A**.

- 1) Parkman Rad NW & Leavitt Road NW
- 2) Parkman Road NW & Tod Avenue NW / Lovers Lane
- 3) Parkman Road NW & Southern Boulevard
- 4) Parkman Road NW & Coit Avenue
- 5) Parkman Road NW & Denison Drive NW / Northwest Boulevard NW
- 6) Parkman Road NW & Drexel Avenue
- 7) Parkman Road NW & Summit Street NW
- 8) Summit Street NW & Tod Avenue NW
- 9) Summit Street NW & Mahoning Avenue NW
- 10) Mahoning Avenue NW & Hall Street NW
- 11) Tod Avenue & Dunstan Drive NW / Bridge Road
- 12) West Market Street & Southern Boulevard
- 13) West Market Street & Nevada Avenue
- 14) West Market Street & Austin Avenue
- 15) West Market Street & Parkman Road
- 16) West Market Street & Tod Avenue
- 17) West Market Street & South Street / Highland Avenue
- 18) South Street & Main Avenue
- 19) South Street & Park Avenue
- 20) South Street & Pine Avenue
- 21) South Street & Elm Road
- 22) South Street & Chestnut Avenue / Niles Road
- 23) Youngstown Road & Laird Avenue
- 24) Youngstown Road & Central Parkway
- 25) Youngstown Road & Ridge Avenue
- 26) West Market Street & Main Avenue / Mahoning Avenue
- 27) West Market Street & S Park Avenue / N Park Avenue
- 28) East Market Street & Pine Avenue
- 29) East Market Street & Elm Road
- 30) East Market Street & Chestnut Avenue
- 31) East Market Street & Laird Avenue
- 32) East Market Street & Genesee Avenue
- 33) East Market Street & Belvedere Avenue
- 34) East Market Street & Perkinswood Boulevard
- 35) East Market Street & Eastland Avenue
- 36) East Market Street & Country Club Drive
- 37) East Market Street & North Road
- 38) High Street & Mahoning Avenue
- 39) High Street & Mid-Block Pedestrian Crossing

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- 40) High Street & N Park Avenue
- 41) High Street & Elm Road
- 42) N Park Avenue & Washington Street
- 43) N Park Avenue & Atlantic Street
- 44) N Park Avenue & Dana Street
- 45) Woodland Street & Elm Road
- 46) Woodland Street & Laird Avenue
- 47) Woodland Street & Genesee Avenue
- 48) Atlantic Street & Paige Avenue
- 49) Atlantic Street & Elm Road
- 50) Atlantic Street & Laird Avenue
- 51) Atlantic Street & Genesee Avenue
- 52) Atlantic Street & North Road
- 53) Elm Road & Dana Street / Edgewood Street
- 54) Elm Road & Larchmont Avenue
- 55) Elm Road & Gretchen Drive
- 56) Reeves Road & North Road
- 57) Tod Avenue & Palmyra Road
- 58) Tod Avenue & 5th Street
- 59) Main Avenue & Fulton Street
- 60) Pine Avenue & Industrial Park Driveway
- 61) Youngstown Road and Willard Avenue

A preliminary review of the traffic count data was conducted with respect to the traffic signal warrant criteria. After this review, additional hours of traffic count data were processed for 13 of the study intersections. This information has been integrated into the count data contained in **Appendix A**.

Multi-Way Stop Intersection Traffic Count Data

Traffic count information at the City's multi-way stop-controlled intersections was obtained using StreetLight Data. StreetLight collects real-time geospatial data from smart phones and navigation devices in connected cars and commercial trucks. This data is then processed through StreetLight's Route Science AADT model using machine learning based on inputs such as: parcel data, digital road network data, road network maps, weather, urban density speed limit and census data. StreetLight uses permanent traffic recording stations to validate the model output.

The Average Annual Daily Traffic (AADT) output report from StreetLight includes a confidence range for the AADT data. A confidence range, commonly referred to as a prediction interval in statistics, is an estimated range, within a given probability confidence, in which the true value will fall. StreetLight uses a 90 percent confidence range for AADT analysis. This means there is a 90 percent certainty that the true AADT value for a StreetLight zone is between the low and high end of the confidence range. For example, if StreetLight reports an AADT value of 5,000 for a roadway with a confidence range of (-16 percent, 10 percent), StreetLight is 90 percent confident that the true AADT value is between 4,200 and 5,500. This percentage range will differ across different AADT analyses and even across zones within the same AADT analysis.

StreetLight AADT volume and confidence range information can be found in **Appendix B**.

3. Traffic Signal Warrant and Removal Analysis

A signal warrant analysis was completed for the 61 existing signals to assess the need for continued signalization per guidance in the *Manual on Uniform Traffic Control Devices* (MUTCD). The MUTCD has nine warrants to determine whether an intersection merits consideration for a traditional traffic control signal based on the existing operations and safety of the study location. The warrants are as follows:

- **Warrant 1. Eight-Hour Vehicular Volume:** Warrant 1, the Eight-Hour Vehicular Volume signal warrant, assesses two conditions regarding intersecting traffic. The Minimum Vehicular Volume, Condition A, is intended for application where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal. The Interruption of Continuous Traffic, Condition B, is intended for application where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay or conflict in entering or crossing the major street. Warrant 1 must be met for eight hours of the day.
- **Warrant 2. Four-Hour Vehicular Volume:** The Four-Hour Vehicular Volume signal warrant conditions are intended for application where the volume of intersecting traffic is the principal reason to consider installing a traffic signal. Volume 2 must be met for four hours of the day.
- **Warrant 3. Peak Hour:** The Peak Hour signal warrant applies only to “special case” locations serving a facility that attracts or discharges a large number of vehicles over a short time. At these locations, Warrant 3 is satisfied if traffic conditions are such that for a minimum of one hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street.
- **Warrant 4. Pedestrian Volume:** The Pedestrian Volume signal warrant is intended for application where the traffic volume on a major street is so heavy that pedestrians experience excessive delay in crossing the major street. The need for a traffic control signal at an intersection or midblock crossing would be considered if:
 - Pedestrian volume crossing the major street during an average day is more than 100 for any four hours or 190 during any one hour; and
 - The number of adequate gaps per hour in the traffic stream is less than 60 gaps during the same hours that the volume criterion is satisfied.
- **Warrant 5. School Crossing:** This warrant is intended for application where the principal reason to consider installing a traffic control signal is where schoolchildren are crossing the major street.
- **Warrant 6. Coordinated Signal System:** Warrant 6 considers progressive movement in a coordinated signal system, which sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed to maintain proper platooning of vehicles.
- **Warrant 7. Crash Experience:** The Crash Experience signal warrant conditions are intended for application where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal. The warrant is satisfied if all the following criteria are met:
 - The intersection has been observed and enforcement has not reduced crash frequency;

- Five or more crashes that could be corrected by a traffic control signal have occurred at the intersection within a 12-month period; and
- Vehicular volume or pedestrian volume thresholds are met.
- **Warrant 8. Roadway Network:** Warrant 8 applies to the intersection of two or more major routes where a traffic control signal might be justified to encourage concentration and organization of traffic flow on a roadway network.
- **Warrant 9. Intersection Near a Grade Crossing:** Warrant 9 is intended for use at a location where none of the other eight warrants are satisfied, but the intersection is near a grade crossing.

Upon completion of evaluating signal warrants 1 through 9, a traffic signal removal analysis was completed for each intersection not meeting the warrant criteria. The *User Guide for the Removal of Not Needed Traffic Signal* outlines the process for analyzing signalized intersections for possible removal. The first step, once an intersection inventory has been taken, is completion of a screening checklist. This screening is made up of four criteria, each with a yes/no decision.

- Intersection sight distance
- Special site considerations precluding removal – located near major traffic or pedestrian generator
- Will future traffic volumes meet traffic signal installation warrants
- Special justification for original signal installation still exists

The user guide states that if any of the above criteria are answered with a “yes”, the signal removal at that intersection should be deferred.

Traffic Signal Warrant sheets and Traffic Signal Removal Analysis worksheets can be found in **Appendix C**.

Traffic Signals Warranted Based on 8-Hour Warrants

The following 20 traffic signals are warranted based on MUTCD Warrant 1 (Eight-Hour Vehicular Volume):

- 1) Intersection 1: Parkman Road NW & Leavitt Road NW
- 2) Intersection 7: Parkman Road NW & Summit Street NW
- 3) Intersection 15: West Market Street & Parkman Road
- 4) Intersection 16: West Market Street & Tod Avenue
- 5) Intersection 17: West Market Street & West Market Street
- 6) Intersection 18: South Street & Main Avenue
- 7) Intersection 21: South Street & Elm Road
- 8) Intersection 22: South Street & Chestnut Avenue
- 9) Intersection 24: Youngstown Road & Central Parkway
- 10) Intersection 25: Youngstown Road & Ridge Avenue
- 11) Intersection 26: West Market Street & Main Avenue
- 12) Intersection 29: East Market Street & Elm Road
- 13) Intersection 30: East Market Street & Chestnut Avenue
- 14) Intersection 32: East Market Street & Genesee Avenue
- 15) Intersection 34: East Market Street & Perkinswood Boulevard
- 16) Intersection 35: East Market Street & Eastland Avenue
- 17) Intersection 37: East Market Street & North Road

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- 18) Intersection 49: Atlantic Street & Elm Road
- 19) Intersection 52: Atlantic Street & North Road
- 20) Intersection 55: Elm Road & Gretchen Drive

Traffic Signals Warranted Based on Four-Hour Warrants

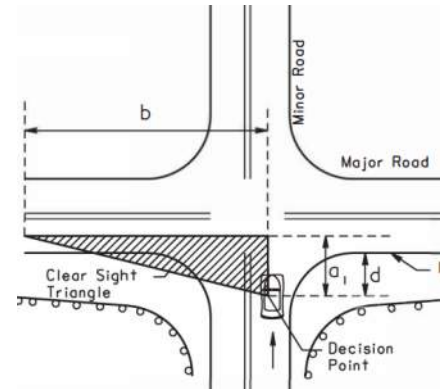
The following four traffic signals are warranted based on MUTCD Warrant 2 (Four-Hour Vehicular Volume):

- 1) Intersection 9: Summit Street NW & Mahoning Avenue NW
- 2) Intersection 20: South Street & Pine Avenue
- 3) Intersection 31: East Market Street & Laird Avenue
- 4) Intersection 54: Elm Road & Larchmont Avenue

Traffic Signals Warranted Based on Intersection Geometry and Sight Distance Limitations

The following eight traffic signals are not warranted based on traffic volumes, but are recommended to remain installed based on the intersection geometry and/or sight distance limitations:

- 1) Intersection 2: Parkman Road NW & Tod Avenue NW
- 2) Intersection 8: Summit Street NW & Tod Avenue NW
- 3) Intersection 14: West Market Street & Austin Avenue
- 4) Intersection 23: Youngstown Road & Laird Avenue
- 5) Intersection 27: West Market Street & S Park Avenue
- 6) Intersection 28: East Market Street & Pine Avenue
- 7) Intersection 38: High Street & Mahoning Avenue
- 8) Intersection 45: Elm Road & Woodland Street



Ohio Department of Transportation
Location and Design Manual, Figure 201-4
Intersection Sight Triangle

Traffic Signals Warranted Based on Walking Routes to Schools

The following five traffic signals are not warranted based on traffic volume, but are recommended to remain installed based on the Safe Route to School (SRTS) pathways, or based on the proximity to a school:

- 1) Intersection 11: Tod Avenue & Dunstan Drive NW / Bridge Road
- 2) Intersection 41: High Street & Elm Road
- 3) Intersection 51: Atlantic Street & Genesee Avenue
- 4) Intersection 58: Tod Avenue & Fifth Street
- 5) Intersection 61: Youngstown Road & Willard Avenue

Traffic Signals Warranted Based on Location

The following two traffic signals are not warranted based on traffic volume, but are recommended to remain installed based on their location in the downtown district and their proximity to numerous County buildings and the related pedestrian activity:

- 1) Intersection 39: High Street & Mid-Block Pedestrian Crossing
- 2) Intersection 40: High Street & N Park Avenue

Unwarranted Traffic Signals

The following 21 traffic signals are recommended for removal:

- 1) Intersection 3: Parkman Road NW & Southern Boulevard
- 2) Intersection 4: Parkman Road NW & Coit Avenue
- 3) Intersection 5: Parkman Road NW & Denison Drive NW / Northwest Boulevard NW
- 4) Intersection 6: Parkman Road NW & Drexel Avenue
- 5) Intersection 10: Mahoning Avenue NW & Hall Street NW
- 6) Intersection 12: West Market Street & Southern Boulevard
- 7) Intersection 13: West Market Street & Nevada Avenue
- 8) Intersection 19: South Street & Park Avenue
- 9) Intersection 33: East Market Street & Belvedere Avenue
- 10) Intersection 36: East Market Street & Country Club Drive
- 11) Intersection 42: N Park Avenue & Washington Street
- 12) Intersection 43: N Park Avenue & Atlantic Street
- 13) Intersection 44: N Park Avenue & Dana Street
- 14) Intersection 46: Woodland Street & Laird Avenue
- 15) Intersection 47: Woodland Street & Genesee Avenue
- 16) Intersection 48: Atlantic Street & Paige Avenue
- 17) Intersection 50: Atlantic Street & Laird Avenue
- 18) Intersection 53: Elm Road & Dana Street / Edgewood Street
- 19) Intersection 57: Tod Avenue & Palmyra Road
- 20) Intersection 59: Main Avenue & Fulton Street
- 21) Intersection 60: Pine Avenue & Industrial Park Driveway

Prior to removing the traffic signals at these locations, the City could elect to place the signals in flash-mode, flashing yellow on the main street and flashing red on the side street, and monitor the operation of the intersection. Monitoring could include field observations and a review of crash reports.

4. Traffic Flow Analysis

Capacity Analysis

Capacity analysis was conducted using Synchro software with results reported using the *Highway Capacity Manual* methodology for the Existing and Proposed conditions during the AM and PM peak hours. Existing represents the current conditions and Proposed represents the current volumes under stop control, or with proposed improvements.

Analysis results for the for the AM and PM peak hours are illustrated in **Tables 1-10**. Output from Synchro is provided in **Appendix D**.

As outlined in the *State Highway Access Management Manual*, the goals for the traffic analysis are a minimum Level of Service (LOS) of D for the overall intersection and LOS D for each individual movement during the peak hour. As shown in Tables 1-10, all of the study intersections currently meet operational goals under existing conditions with the following exceptions:

- Intersection 37: East Market Street & North Road
 - Northbound a.m. Peak: LOS F
 - Northbound p.m. Peak: LOS E
 - Southbound p.m. Peak: LOS E

As shown in Tables 1-10, all of the study intersections are expected to continue to meet operational goals under the proposed conditions with the following exceptions:

- Intersection 36: East Market Street & Country Club Drive
 - Southbound a.m. Peak: LOS E
 - Southbound p.m. Peak: LOS E

Intersection 36 does not currently meet traffic signal warrants and was identified as an intersection for signal removal. LOS E is common on minor streets with major thoroughfares and it is not recommended to retain this signal based on capacity.

Under the proposed conditions, the following improvements were made in order to meet the operational goal of LOS D or better at Intersection 37: East Market Street & North Road:

- Construct a westbound left-turn lane on East Market Street
- Modify the signal phasing from split phase operation to a traditional eight phase operation with protected-permitted side street left-turns

The County Engineer has obtained Congestion, Mitigation and Air Quality (CMAQ) funding to construct these improvements. The project is currently in the design phase.

Table 1: Weekday AM and PM Peak Hour Traffic Analysis Results (Intersections 1-6)				
Movement	Existing 2019 AM Peak Hour LOS/Delay	Proposed 2019 AM Peak Hour LOS/Delay	Existing 2019 PM Peak Hour LOS/Delay	Proposed 2019 PM Peak Hour LOS/Delay
1. Parkman Road NW & Leavitt Road NW (Signal Retained)				
Eastbound	B / 13.7	B / 13.7	B / 14.6	B / 14.6
Westbound	B / 14.1	B / 14.1	B / 15.0	B / 15.0
Northbound	B / 11.3	B / 11.3	B / 12.2	B / 12.2
Southbound	B / 11.6	B / 11.6	B / 12.2	B / 12.2
Overall	B / 13.1	B / 13.1	B / 13.9	B / 13.9
2. Parkman Road NW & Tod Avenue / Lovers Lane (Signal Retained)				
Eastbound	B / 17.1	B / 17.1	C / 24.3	C / 24.3
Westbound	A / 2.8	A / 2.8	A / 9.9	A / 9.9
Northbound	B / 14.1	B / 14.1	C / 21.4	C / 21.4
Southbound	B / 13.0	B / 13.0	C / 21.2	C / 21.2
Overall	B / 11.5	B / 11.5	B / 18.7	B / 18.7
3. Parkman Road NW & Southern Boulevard (Signal Removed)				
Eastbound	A / 3.6	--	A / 2.1	--
Westbound	B / 11.1	[A / 7.9]	A / 9.9	[A / 8.6]
Northbound (Stop)	B / 12.1	B / 11.2	B / 14.6	B / 14.6
Overall	A / 7.3	A / 1.3	A / 6.3	A / 1.4
4. Parkman Road NW & Coit Avenue (Signal Removed)				
Eastbound	A / 8.6	[A / 7.8]	B / 10.7	[A / 8.3]
Westbound	B / 18.6	[A / 7.8]	C / 23.6	[A / 8.2]
Northbound (Stop)	B / 14.8	B / 12.2	B / 13.5	C / 16.2
Southbound (Stop)	B / 16.1	B / 11.1	B / 14.7	B / 14.2
Overall	B / 13.6	A / 2.1	B / 16.3	A / 2.1
5. Parkman Road NW & Denison Drive NW / Northwest Boulevard NW (Signal Removed)				
Eastbound	B / 10.4	[A / 7.7]	B / 14.9	[A / 8.2]
Westbound	A / 9.9	[A / 7.9]	B / 15.3	[A / 8.4]
Northbound (Stop)	B / 15.5	B / 12.9	C / 26.5	C / 19.2
Southbound (Stop)	B / 14.4	B / 13.2	C / 24.0	C / 22.4
Overall	B / 11.2	A / 2.9	B / 16.4	A / 3.1
6. Parkman Road NW & Drexel Avenue (Signal Removed)				
Eastbound	B / 10.9	[A / 7.8]	A / 9.5	[A / 8.4]
Westbound	A / 10.0	--	A / 9.8	--
Southbound (Stop)	B / 14.1	B / 11.4	B / 17.5	B / 14.0
Overall	B / 10.6	A / 0.6	B / 10.1	A / 0.9

Table 2: Weekday AM and PM Peak Hour Traffic Analysis Results (Intersections 6-12)				
Movement	Existing 2019 AM Peak Hour LOS/Delay	Proposed 2019 AM Peak Hour LOS/Delay	Existing 2019 PM Peak Hour LOS/Delay	Proposed 2019 PM Peak Hour LOS/Delay
7. Parkman Road NW & Summit Street NW (Signal Retained)				
Eastbound	B / 14.0	B / 14.0	B / 13.1	B / 13.1
Westbound	C / 24.1	C / 24.1	C / 30.3	C / 30.3
Northbound	C / 21.3	C / 21.3	C / 24.5	C / 24.5
Southbound	C / 23.7	C / 23.7	D / 42.3	D / 42.3
Overall	B / 18.8	B / 18.8	C / 26.0	C / 26.0
8. Summit Street NW & Tod Avenue NW (Signal Retained)				
Eastbound	C / 28.8	C / 28.8	C / 31.8	C / 31.8
Westbound	B / 15.5	B / 15.5	C / 14.6	C / 14.6
Northbound	C / 21.7	C / 21.7	C / 25.8	C / 25.8
Southbound	B / 11.1	B / 11.1	B / 12.0	B / 12.0
Overall	B / 19.5	B / 19.5	C / 20.0	C / 20.0
9. Summit Street NW & Mahoning Avenue NW (Signal Retained)				
Eastbound	B / 10.9	B / 10.9	B / 11.5	B / 11.5
Westbound	C / 23.1	C / 23.1	C / 23.7	C / 23.7
Northbound	B / 12.4	B / 12.4	B / 19.4	B / 19.4
Southbound	D / 37.6	D / 37.6	C / 30.9	C / 30.9
Overall	C / 22.0	C / 22.0	C / 20.4	C / 20.4
10. Mahoning Avenue NW & Hall Street NW (Signal Removed)				
Eastbound (Stop)	B / 13.9	B / 14.3	B / 16.9	C / 18.4
Westbound (Stop)	B / 14.0	B / 12.4	C / 17.6	C / 16.4
Northbound	A / 0.9	[A / 8.1]	C / 18.9	[A / 8.1]
Southbound	B / 10.4	[A / 7.8]	A / 8.7	[A / 8.6]
Overall	A / 7.2	A / 0.8	B / 14.5	A / 1.3
11. Tod Avenue & Dunstan Drive NW / Bridge Road (Signal Retained)				
Eastbound	B / 13.5	B / 13.5	A / 6.2	A / 6.2
Westbound	B / 13.8	B / 13.8	A / 9.1	A / 9.1
Northbound	A / 10.0	A / 10.0	C / 25.7	C / 25.7
Southbound	A / 9.2	A / 9.2	C / 20.9	C / 20.9
Overall	B / 12.2	B / 12.2	B / 13.4	B / 13.4
12. West Market Street & Southern Boulevard (Signal Removed)				
Eastbound	B / 12.1	[A / 7.6]	B / 11.5	[A / 8.3]
Westbound	B / 11.9	--	B / 13.6	--
Southbound (Stop)	B / 11.4	B / 10.8	B / 14.1	B / 12.9
Overall	B / 11.9	A / 1.9	B / 13.0	A / 2.7

Table 3: Weekday AM and PM Peak Hour Traffic Analysis Results (Intersections 13-18)				
Movement	Existing 2019 AM Peak Hour LOS/Delay	Proposed 2019 AM Peak Hour LOS/Delay	Existing 2019 PM Peak Hour LOS/Delay	Proposed 2019 PM Peak Hour LOS/Delay
13. West Market Street & Nevada Avenue (Signal Removed)				
Eastbound	B / 18.5	[A / 7.6]	B / 19.2	[A / 8.1]
Westbound	B / 12.6	[A / 7.8]	B / 12.9	[A / 8.2]
Northbound (Stop)	C / 23.8	B / 10.2	C / 30.1	B / 12.8
Southbound (Stop)	C / 21.0	B / 11.3	C / 23.7	C / 15.8
Overall	B / 16.6	A / 1.3	B / 17.3	A / 2.0
14. West Market Street & Austin Avenue (Signal Retained)				
Eastbound	B / 17.3	B / 17.3	B / 16.3	B / 16.3
Westbound	B / 10.7	B / 10.7	A / 9.7	A / 9.7
Northbound	B / 12.6	B / 12.6	B / 16.8	B / 16.8
Southbound	B / 12.1	B / 12.1	B / 15.7	B / 15.7
Overall	B / 14.4	B / 14.4	B / 13.1	B / 13.1
15. West Market Street & Parkman Road (Signal Retained)				
Eastbound	A / 5.3	A / 5.3	A / 2.8	A / 2.8
Westbound	B / 13.4	B / 13.4	B / 13.4	B / 13.4
Northbound	B / 10.8	B / 10.8	B / 14.6	B / 14.6
Southbound	B / 11.2	B / 11.2	B / 14.9	B / 14.9
Overall	A / 9.6	A / 9.6	B / 10.7	B / 10.7
16. West Market Street & Tod Avenue (Signal Retained)				
Eastbound	C / 23.7	C / 23.7	C / 20.5	C / 20.5
Westbound	B / 12.7	B / 12.7	B / 14.8	B / 14.8
Northbound	C / 23.8	C / 23.8	C / 28.8	C / 28.8
Southbound	C / 21.0	C / 21.0	C / 26.8	C / 26.8
Overall	B / 19.8	B / 19.8	C / 20.9	C / 20.9
17. West Market Street & West Market Street / Highland Avenue (Signal Retained)				
Eastbound	B / 12.9	B / 12.9	B / 13.5	B / 13.5
Westbound	C / 20.1	C / 20.1	C / 20.7	C / 20.7
Northbound	B / 18.9	B / 18.9	C / 24.3	C / 24.3
Southbound	C / 22.7	C / 22.7	D / 47.7	D / 47.7
Overall	B / 16.5	B / 16.5	C / 22.5	C / 22.5
18. South Street & Main Avenue (Signal Retained)				
Eastbound	C / 25.0	C / 25.0	C / 24.6	C / 24.6
Westbound	B / 19.2	B / 19.2	B / 19.9	B / 19.9
Northbound	B / 19.7	B / 19.7	C / 22.8	C / 22.8
Southbound	B / 19.3	B / 19.3	C / 23.5	C / 23.5
Overall	C / 21.5	C / 21.5	C / 22.4	C / 22.4

Table 4: Weekday AM and PM Peak Hour Traffic Analysis Results (Intersections 19-24)				
Movement	Existing 2019 AM Peak Hour LOS/Delay	Proposed 2019 AM Peak Hour LOS/Delay	Existing 2019 PM Peak Hour LOS/Delay	Proposed 2019 PM Peak Hour LOS/Delay
19. South Street & Park Avenue (Signal Removed)				
Eastbound	C / 22.3	[A / 8.3]	C / 22.2	[A / 9.2]
Westbound	C / 22.1	[A / 8.4]	A / 26.4	[A / 8.8]
Northbound (Stop)	B / 19.6	C / 19.9	C / 21.4	D / 27.6
Southbound (Stop)	C / 20.2	C / 16.9	C / 22.8	D / 33.6
Overall	C / 22.1	A / 1.5	B / 14.3	A / 3.2
20. South Street & Pine Avenue (Signal Retained)				
Eastbound	C / 25.4	C / 25.4	A / 7.4	A / 7.4
Westbound	C / 25.2	C / 25.2	C / 25.2	C / 25.2
Northbound	B / 13.4	B / 13.4	B / 18.1	B / 18.1
Southbound	B / 16.3	B / 16.3	C / 21.1	C / 21.1
Overall	C / 23.9	C / 23.9	B / 17.3	B / 17.3
21. South Street & Elm Road (Signal Retained)				
Eastbound	A / 0.7	A / 0.7	A / 1.3	A / 1.3
Westbound	A / 6.6	A / 6.6	A / 6.8	A / 6.8
Southbound	C / 20.8	C / 20.8	C / 26.9	C / 26.9
Overall	A / 5.9	A / 5.9	A / 7.6	A / 7.6
22. South Street & Chestnut Avenue / Niles Road (Signal Retained)				
Eastbound	C / 27.8	C / 27.8	B / 18.6	B / 18.6
Westbound	B / 18.4	B / 18.4	B / 15.4	B / 15.4
Northbound	C / 23.0	C / 23.0	D / 54.3	D / 54.3
Southbound	C / 23.9	C / 23.9	C / 27.7	C / 27.7
Overall	C / 24.1	C / 24.1	C / 25.3	C / 25.3
23. Youngstown Road & Laird Avenue (Signal Retained)				
Eastbound	B / 17.3	B / 17.3	C / 21.0	C / 21.0
Westbound	C / 25.7	C / 25.7	C / 23.2	C / 23.2
Northbound	B / 18.0	B / 18.0	C / 25.1	C / 25.1
Southbound	B / 17.8	B / 17.8	C / 23.6	C / 23.6
Overall	B / 18.6	B / 18.6	C / 24.1.	C / 24.1.
24. Youngstown Road & Central Parkway (Signal Retained)				
Eastbound	C / 20.3	C / 20.3	B / 19.8	B / 19.8
Westbound	C / 21.2	C / 21.2	B / 19.9	B / 19.9
Northbound	C / 20.4	C / 20.4	C / 23.6	C / 23.6
Southbound	C / 20.9	C / 20.9	C / 24.7	C / 24.7
Overall	C / 20.8	C / 20.8	C / 20.8	C / 20.8

Table 5: Weekday AM and PM Peak Hour Traffic Analysis Results (Intersections 25-30)				
Movement	Existing 2019 AM Peak Hour LOS/Delay	Proposed 2019 AM Peak Hour LOS/Delay	Existing 2019 PM Peak Hour LOS/Delay	Proposed 2019 PM Peak Hour LOS/Delay
25. Youngstown Road & Ridge Avenue (Signal Retained)				
Eastbound	B / 19.4	B / 19.4	C / 21.0	C / 21.0
Westbound	B / 12.5	B / 12.5	B / 11.1	B / 11.1
Northbound	B / 11.7	B / 11.7	B / 15.8	B / 15.8
Overall	B / 16.0	B / 16.0	B / 16.8	B / 16.8
26. West Market Street & Main Avenue / Mahoning Avenue (Signal Retained)				
Eastbound	A / 6.8	A / 6.8	A / 7.1	A / 7.1
Westbound	A / 6.7	A / 6.7	A / 7.2	A / 7.2
Northbound	C / 20.5	C / 20.5	C / 27.3	C / 27.3
Southbound	B / 19.4	B / 19.4	C / 24.4	C / 24.4
Overall	B / 12.0	B / 12.0	B / 14.9	B / 14.9
27. West Market Street & S Park Avenue / N Park Avenue (Signal Retained)				
Eastbound	B / 18.5	B / 18.5	C / 21.7	C / 21.7
Westbound	B / 13.1	B / 13.1	B / 15.1	B / 15.1
Northbound	A / 9.8	A / 9.8	B / 10.5	B / 10.5
Southbound	B / 10.0	B / 10.0	B / 10.7	B / 10.7
Overall	B / 14.5	B / 14.5	B / 16.5	B / 16.5
28. East Market Street & Pine Avenue (Signal Retained)				
Eastbound	A / 4.3	A / 4.3	A / 3.4	A / 3.4
Westbound	B / 12.2	B / 12.2	B / 11.9	B / 11.9
Northbound	B / 11.0	B / 11.0	B / 13.3	B / 13.3
Southbound	B / 10.9	B / 10.9	B / 12.8	B / 12.8
Overall	A / 8.7	A / 8.7	A / 8.3	A / 8.3
29. East Market Street & Elm Road (Signal Retained)				
Eastbound	B / 10.6	B / 10.6	A / 1.3	A / 1.3
Westbound	A / 9.9	A / 9.9	A / 8.9	A / 8.9
Northbound	B / 13.3	B / 13.3	B / 19.5	B / 19.5
Southbound	B / 13.8	B / 13.8	B / 17.7	B / 17.7
Overall	B / 12.5	B / 12.5	B / 13.2	B / 13.2
30. East Market Street & Chestnut Avenue (Signal Retained)				
Eastbound	C / 27.1	C / 27.1	C / 33.5	C / 33.5
Westbound	C / 33.1	C / 33.1	C / 34.0	C / 34.0
Northbound	C / 25.1	C / 25.1	C / 30.7	C / 30.7
Southbound	C / 20.4	C / 20.4	C / 24.1	C / 24.1
Overall	C / 28.6	C / 28.6	C / 31.6	C / 31.6

Table 6: Weekday AM and PM Peak Hour Traffic Analysis Results (Intersections 31-36)				
Movement	Existing 2019 AM Peak Hour LOS/Delay	Proposed 2019 AM Peak Hour LOS/Delay	Existing 2019 PM Peak Hour LOS/Delay	Proposed 2019 PM Peak Hour LOS/Delay
31. East Market Street & Laird Avenue (Signal Retained)				
Eastbound	B / 14.3	B / 14.3	C / 20.3	C / 20.3
Westbound	B / 10.8	B / 10.8	B / 11.9	B / 11.9
Northbound	B / 14.8	B / 14.8	B / 14.9	B / 14.9
Southbound	B / 15.0	B / 15.0	B / 15.4	B / 15.4
Overall	B / 12.6	B / 12.6	B / 16.3	B / 16.3
32. East Market Street & Genesee Avenue (Signal Retained)				
Eastbound	B / 16.2	B / 16.2	C / 21.9	C / 21.9
Westbound	B / 12.0	B / 12.0	C / 10.3	C / 10.3
Southbound	B / 17.0	B / 17.0	C / 21.0	C / 21.0
Overall	B / 14.0	B / 14.0	B / 17.8	B / 17.8
33. East Market Street & Belvedere Avenue (Signal Removed)				
Eastbound	A / 7.4	[A / 9.7]	A / 8.3	[A / 8.8]
Westbound	B / 19.4	[A / 8.7]	B / 14.1	[B / 10.4]
Northbound (stop)	C / 20.4	C / 22.0	C / 22.8	D / 31.2
Southbound (stop)	C / 21.3	D / 32.8	C / 23.1	D / 27.1
Overall	B / 14.7	A / 1.1	B / 10.7	A / 0.8
34. East Market Street & Perkinswood Boulevard (Signal Retained)				
Eastbound	A / 1.3	A / 1.3	A / 3.0	A / 3.0
Westbound	B / 11.2	B / 11.2	B / 10.8	B / 10.8
Northbound	B / 15.5	B / 15.5	B / 15.7	B / 15.7
Southbound	B / 15.9	B / 15.9	B / 16.0	B / 16.0
Overall	A / 8.4	A / 8.4	A / 7.3	A / 7.3
35. East Market Street & Eastland Avenue (Signal Retained)				
Eastbound	A / 0.9	A / 0.9	A / 3.4	A / 3.4
Westbound	B / 10.1	B / 10.1	B / 13.1	B / 13.1
Northbound	C / 20.9	C / 20.9	B / 18.4	B / 18.4
Overall	A / 7.4	A / 7.4	A / 8.7	A / 8.7
36. East Market Street & Country Club Drive (Signal Removed)				
Eastbound	A / 8.9	[B / 10.3]	A / 7.2	[A / 9.5]
Westbound	B / 10.7	[A / 9.2]	A / 9.3	[B / 11.2]
Northbound	B / 15.6	C / 22.1	B / 17.3	D / 27.8
Southbound	B / 15.7	E / 36.1	B / 17.2	E / 40.0
Overall	B / 10.1	A / 0.9	A / 8.2	A / 0.9

Table 7: Weekday AM and PM Peak Hour Traffic Analysis Results (Intersections 37-42)				
Movement	Existing 2019 AM Peak Hour LOS/Delay	Proposed 2019 AM Peak Hour LOS/Delay	Existing 2019 PM Peak Hour LOS/Delay	Proposed 2019 PM Peak Hour LOS/Delay
37. East Market Street & North Road (Signal Retained)				
Eastbound	B / 14.0	C / 33.4	C / 22.0	D / 38.7
Westbound	D / 49.7	C / 31.3	D / 48.8	C / 27.9
Northbound	F / 88.8	D / 39.7	E / 55.4	D / 43.3
Southbound	D / 54.3	D / 40.9	E / 65.4	D / 42.3
Overall	D / 50.2	C / 34.7	D / 43.9	D / 36.5
38. High Street & Mahoning Avenue (Signal Retained)				
Westbound	B / 14.5	B / 14.5	B / 17.9	B / 17.9
Northbound	C / 21.1	C / 21.1	C / 23.0	C / 23.0
Southbound	A / 7.0	A / 7.0	A / 6.7	A / 6.7
Overall	B / 12.3	B / 12.3	B / 14.5	B / 14.5
39. High Street & Mid-Block Pedestrian Crossing (Signal Retained)				
Eastbound	A / 7.6	A / 7.6	A / 7.0	A / 7.0
Westbound	A / 7.6	A / 7.6	A / 7.1	A / 7.1
Overall	A / 7.6	A / 7.6	A / 7.0	A / 7.0
40. High Street & N Park Avenue (Signal Retained)				
Eastbound	B / 18.3	B / 18.3	B / 17.4	B / 17.4
Westbound	B / 18.1	B / 18.1	B / 18.2	B / 18.2
Northbound	B / 15.1	B / 15.1	B / 16.2	B / 16.2
Southbound	A / 6.1	A / 6.1	A / 2.2	A / 2.2
Overall	B / 14.0	B / 14.0	B / 12.8	B / 12.8
41. High Street & Elm Road (Signal Retained)				
Eastbound	A / 8.7	A / 8.7	B / 12.9	B / 12.9
Westbound	A / 8.5	A / 8.5	B / 11.6	B / 11.6
Northbound	B / 15.2	B / 15.2	B / 14.0	B / 14.0
Southbound	C / 20.4	C / 20.4	B / 15.0	B / 15.0
Overall	B / 15.8	B / 15.8	B / 13.9	B / 13.9
42. N Park Avenue & Washington Street (Signal Removed)				
Eastbound (Stop)	B / 11.0	B / 12.1	B / 11.4	C / 15.6
Westbound (Stop)	B / 11.6	B / 11.9	B / 12.2	B / 13.6
Northbound	A / 9.7	[A / 7.6]	B / 10.4	[A / 7.7]
Southbound	A / 10.0	[A / 7.6]	B / 10.2	[A / 7.9]
Overall	B / 10.5	A / 5.3	B / 10.9	A / 5.5

Table 8: Weekday AM and PM Peak Hour Traffic Analysis Results (Intersections 43-48)				
Movement	Existing 2019 AM Peak Hour LOS/Delay	Proposed 2019 AM Peak Hour LOS/Delay	Existing 2019 PM Peak Hour LOS/Delay	Proposed 2019 PM Peak Hour LOS/Delay
43. N Park Avenue & Atlantic Street (Signal Removed)				
Eastbound (Stop)	B / 10.9	C / 17.6	B / 12.0	D / 33.4
Westbound (Stop)	B / 11.1	C / 16.4	B / 12.0	D / 30.7
Northbound	B / 11.1	[A / 7.7]	B / 12.1	[A / 7.8]
Southbound	B / 11.8	[A / 7.6]	B / 12.1	[A / 7.9]
Overall	B / 11.3	A / 9.1	B / 12.1	B / 16.3
44. N Park Avenue & Dana Street (Signal Removed)				
Westbound (Stop)	B / 16.0	B / 10.0	B / 16.6	B / 13.2
Northbound	C / 22.0	--	C / 26.2	--
Southbound	A / 6.3	[A / 7.6]	A / 6.6	[A / 8.0]
Overall	B / 12.7	A / 0.2	B / 16.7	A / 0.7
45. Woodland Street & Elm Road (Signal Retained)				
Eastbound	C / 21.4	C / 21.4	C / 22.7	C / 22.7
Westbound	C / 21.1	C / 21.1	C / 24.9	C / 24.9
Northbound	B / 19.4	B / 19.4	B / 19.5	B / 19.5
Southbound	C / 20.5	C / 20.5	B / 18.5	B / 18.5
Overall	C / 20.4	C / 20.4	C / 20.3	C / 20.3
46. Woodland Street & Laird Avenue (Signal Removed)				
Eastbound	B / 10.5	[A / 7.5]	B / 12.4	[A / 7.4]
Westbound	B / 11.8	[A / 7.4]	B / 11.6	[A / 7.5]
Northbound (Stop)	B / 12.5	B / 13.4	B / 12.8	B / 12.9
Southbound (Stop)	B / 13.2	B / 14.5	B / 12.7	B / 13.2
Overall	B / 12.4	A / 9.2	B / 12.5	A / 8.0
47. Woodland Street & Genesee Avenue (Signal Removed)				
Eastbound (Stop)	B / 10.2	B / 12.2	B / 10.4	C / 17.8
Westbound (Stop)	B / 10.0	B / 12.0	B / 10.1	B / 13.8
Northbound	B / 12.6	[A / 7.7]	B / 15.2	[A / 7.9]
Southbound	B / 13.9	[A / 7.5]	B / 17.3	[A / 7.6]
Overall	B / 12.3	A / 4.4	B / 14.3	A / 5.9
48. Atlantic Street & Paige Avenue (Signal Removed)				
Eastbound	A / 9.7	[A / 7.7]	A / 8.6	[A / 7.8]
Westbound	A / 1.4	[A / 7.8]	B / 16.3	[A / 8.0]
Northbound (Stop)	B / 13.4	B / 12.3	B / 18.3	B / 13.5
Southbound (Stop)	B / 13.6	B / 12.7	B / 18.4	B / 14.1
Overall	A / 6.7	A / 1.6	B / 12.9	A / 1.7

Table 9: Weekday AM and PM Peak Hour Traffic Analysis Results (Intersections 49-54)				
Movement	Existing 2019 AM Peak Hour LOS/Delay	Proposed 2019 AM Peak Hour LOS/Delay	Existing 2019 PM Peak Hour LOS/Delay	Proposed 2019 PM Peak Hour LOS/Delay
49. Atlantic Street & Elm Road (Signal Retained)				
Eastbound	B / 19.2	B / 19.2	A / 4.8	A / 4.8
Westbound	B / 14.9	B / 14.9	B / 14.5	B / 14.5
Northbound	B / 18.2	B / 18.2	B / 14.4	B / 14.4
Southbound	B / 10.8	B / 10.8	A / 4.6	A / 4.6
Overall	B / 16.2	B / 16.2	B / 10.1	B / 10.1
50. Atlantic Street & Laird Avenue (Signal Removed)				
Eastbound	A / 2.9	[A / 7.7]	B / 18.8	[A / 7.5]
Westbound	B / 10.8	[A / 7.7]	B / 11.4	[A / 7.6]
Northbound (Stop)	B / 12.7	B / 14.4	B / 14.7	B / 13.4
Southbound (Stop)	B / 13.0	B / 14.6	B / 14.0	B / 12.8
Overall	A / 8.5	A / 4.2	B / 15.1	A / 5.4
51. Atlantic Street & Genesee Avenue (Signal Retained)				
Eastbound	B / 18.9	B / 18.9	B / 11.8	B / 11.8
Westbound	B / 14.5	B / 14.5	B / 13.5	B / 13.5
Northbound	B / 16.9	B / 16.9	C / 23.0	C / 23.0
Southbound	B / 12.4	B / 12.4	B / 18.4	B / 18.4
Overall	B / 15.4	B / 15.4	B / 17.2	B / 17.2
52. Atlantic Street & North Road (Signal Retained)				
Eastbound	B / 13.1	B / 13.1	B / 14.4	B / 14.4
Northbound	B / 15.7	B / 15.7	B / 17.2	B / 17.2
Southbound	B / 14.1	B / 14.1	B / 15.3	B / 15.3
Overall	B / 14.7	B / 14.7	B / 16.1	B / 16.1
53. Elm Road & Dana Street / Edgewood Street (Signal Removed)				
Eastbound (Stop)	B / 12.9	C / 17.0	B / 14.5	D / 29.7
Westbound (Stop)	B / 12.7	C / 15.4	B / 13.9	D / 29.3
Northbound	B / 14.9	[A / 8.6]	A / 9.3	[A / 8.7]
Southbound	B / 10.7	[A / 7.8]	B / 12.5	[A / 8.9]
Overall	B / 12.2	A / 1.2	B / 11.1	A / 2.4
54. Elm Road & Larchmont Avenue (Signal Retained)				
Eastbound	D / 38.5	D / 38.5	D / 38.9	D / 38.9
Northbound	A / 1.9	A / 1.9	A / 1.6	A / 1.6
Southbound	C / 32.9	C / 32.9	B / 17.9	B / 17.9
Overall	C / 22.5	C / 22.5	B / 12.9	B / 12.9

Table 10: Weekday AM and PM Peak Hour Traffic Analysis Results (Intersections 55-61)				
Movement	Existing 2019 AM Peak Hour LOS/Delay	Proposed 2019 AM Peak Hour LOS/Delay	Existing 2019 PM Peak Hour LOS/Delay	Proposed 2019 PM Peak Hour LOS/Delay
55. Elm Road & Gretchen Drive (Signal Retained)				
Westbound	B / 10.1	B / 10.1	B / 11.9	B / 11.9
Northbound	A / 9.7	A / 9.7	B / 13.3	B / 13.3
Southbound	B / 11.3	B / 11.3	A / 9.6	A / 9.6
Overall	B / 10.7	B / 10.7	B / 11.7	B / 11.7
56. Reeves Road & North Road (Signal Retained)				
Eastbound	B / 17.3	B / 17.3	B / 17.3	B / 17.3
Westbound	B / 13.0	B / 13.0	B / 13.0	B / 13.0
Northbound	B / 13.3	B / 13.3	B / 13.3	B / 13.3
Southbound	B / 10.7	B / 10.7	B / 10.7	B / 10.7
Overall	B / 13.1	B / 13.1	B / 13.1	B / 13.1
57. Tod Avenue & Palmyra Road (Signal Removed)				
Eastbound (Stop)	B / 13.0	B / 12.1	B / 15.9	C / 19.3
Northbound	B / 11.6	[A / 7.9]	B / 12.5	[A / 8.5]
Southbound	B / 11.8	--	B / 12.8	--
Overall	B / 11.9	A / 2.5	B / 13.2	A / 3.5
58. Tod Avenue & 5th Street (Signal Retained)				
Eastbound	B / 11.9	B / 11.9	B / 14.4	B / 14.4
Westbound	B / 12.5	B / 12.5	B / 14.8	B / 14.8
Northbound	B / 11.8	B / 11.8	B / 11.4	B / 11.4
Southbound	B / 12.1	B / 12.1	B / 11.8	B / 11.8
Overall	B / 12.0	B / 12.0	B / 12.1	B / 12.1
59. Main Avenue & Fulton Street (Signal Removed)				
Westbound (Stop)	B / 12.6	B / 10.4	B / 12.9	B / 12.8
Northbound	B / 11.1	--	B / 12.9	--
Southbound	B / 10.7	[A / 8.0]	B / 13.0	[A / 8.0]
Overall	B / 11.2	A / 2.6	B / 12.9	A / 3.8
60. Pine Avenue & Industrial Park Driveway (Signal Removed)				
Eastbound (Stop)	B / 13.3	A / 9.1	B / 16.3	A / 9.9
Northbound	A / 9.1	[A / 7.5]	A / 8.1	[A / 7.7]
Southbound	A / 9.0	--	A / 8.2	--
Overall	A / 9.1	A / 0.1	A / 8.2	A / 0.0
61. Youngstown Road & Willard Avenue (Signal Retained)				
Eastbound	A / 9.1	A / 9.1	B / 11.1	B / 11.1
Westbound	A / 9.0	A / 9.0	B / 11.1	B / 11.1
Northbound	B / 15.1	B / 15.1	B / 16.5	B / 16.5
Southbound	B / 15.6	B / 15.6	B / 15.7	B / 15.7
Overall	A / 9.7	A / 9.7	B / 11.7	B / 11.7

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South Street Lane-Use Analysis

Based on discussion with the City, the left-turn phasing was evaluated at the intersections of South Street & Main Avenue, South Street & Park Avenue, and South Street & Pine Avenue (Intersections 18, 19, and 20). Currently, these signals have protected-only phasing on South Street because of the offset left-turns. In order to allow protected-permitted phasing, two pavement marking options were developed.

Option 1:

The pavement is currently striped to allow long left-turn lanes in the eastbound and westbound directions. Option 1 shortens the left-turn lanes and shifts the eastbound left-turn lanes into the existing painted medians as shown in the image below.



The distance from stop bar to stop bar between Main Avenue and Park Avenue is approximately 475 feet, and between Park Avenue and Pine Avenue is approximately 350 feet. The South Street left-turn queuing was evaluated to determine if the current storages can be shortened.

To evaluate the queuing, the intersection was analyzed in Synchro/SimTraffic. The following assumptions/methodologies were used:

- SimTraffic was run three times with different number seeds
- Interval parameters from Figure 401-14c of the ODOT L&D Manual, Volume 1 were used
- Queues reported from SimTraffic are the 95th percentile queues

The required storage length for the southbound left-turn lane was also calculated according to the procedures described in Section 400 of the ODOT *Location and Design Manual, Volume 1*. The calculations are summarized in **Table 11**. Also, *SimTraffic* shows that the existing queue lengths are less than the existing storage. Output from SimTraffic is provided in **Appendix E**.

Queueing analysis indicates that the storage lanes can be shorted to the proposed lengths shown in **Table 11** and will fit within the respective 475 and 350 feet of available space.

Table 11: Storage Length Calculations (Option 1)								
Intersection/ Turn Lane	AM Peak	PM Peak	Calculated Turn Lane Length	Calculated Turn Lane Length	SimTraffic Queue	SimTraffic Queue	Existing Turn Lane Length (including taper)	Proposed Turn Lane Length (including 50' taper)
	Left Turn		(AM)	(PM)	(AM)	(PM)		
Intersection 18: South St & Main Ave	60 Second Cycle							
WBL (Condition A) (25 mph)	58	73	100'	150'	59'	67'	450'	375'
Intersection 19: South St & S Park Ave	Unsignalized							
EBL (Condition A) (25 mph)	16	7	100'	100'	28'	15'	440'	440'
WBL (Condition A) (25 mph)	8	19	100'	100'	15'	30'	325'	275'
Intersection 20: South St & Pine Ave	60 Second Cycle							
EBL (Condition A) (25 mph)	12	15	100'	100'	29'	40'	320'	320'

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Option 2:

Alternatively, the westbound left-turn movement at the intersection of South Street & Park Avenue could be prohibited and redirected to Main Avenue. This option would require less pavement marking modification because the existing pavement markings between Main Avenue and Park Avenue would be retained as shown in the image below. During the hours in which traffic count data was collected at this intersection, an average of ten vehicles per hour completed the westbound left-turn movement from South Street to Main Avenue.



The South Street left-turn queuing was evaluated for this option to determine if the existing westbound left-turn storage can accommodate the additional volume from Park Avenue.

Queueing analysis indicates that the existing storage lengths can accommodate the additional volume and this pavement marking plan allows the existing storage lengths to be retained as shown in **Table 12**. Output from SimTraffic is provided in **Appendix E**.

Table 12: Storage Length Calculations (Option 2)

Intersection/ Turn Lane	AM Peak	PM Peak	Calculated Turn Lane Length	Calculated Turn Lane Length	SimTraffic Queue	SimTraffic Queue	Existing Turn Lane Length (including taper)	Proposed Turn Lane Length (including 50' taper)
	Left Turn		(AM)	(PM)	(AM)	(PM)		
Intersection 18: South St & Main Ave	60 Second Cycle							
WBL (Condition A) (25 mph)	66	92	100'	150'	71'	71'	450'	450'
Intersection 19: South St & S Park Ave	Unsignalized							
EBL (Condition A) (25 mph)	16	7	100'	100'	26'	17'	440'	440'
Intersection 20: South St & Pine Ave	60 Second Cycle							
EBL (Condition A) (25 mph)	12	15	100'	100'	34'	35'	320'	320'

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Capacity Analysis:

Capacity analysis for both options was conducted using permitted-protected left-turn phasing along South Street. Option 1 was further analyzed to with permitted phasing to evaluate the impacts of removing the protected left-turn signal phases. A comparison of Option 1 with protected left-turn phases, Option 2 with protected left-turn phases and Option 1 without protected left-turn phases is shown in **Table 13**. Output from Synchro is provided in **Appendix E**.

Table 13: Capacity Analysis Comparison						
Movement	Option 1	Option 2	Permitted Phasing	Option 1	Option 2	Permitted Phasing
	AM Peak Hr LOS/Delay	AM Peak Hr LOS/Delay	AM Peak Hr LOS/Delay	PM Peak Hr LOS/Delay	PM Peak Hr LOS/Delay	PM Peak Hr LOS/Delay
18. South Street & Main Avenue (Signal Retained)						
Eastbound	C / 24.4	C / 24.4	B / 17.6	C / 23.9	C / 23.9	A / 3.2
Westbound	C / 21.5	C / 21.3	B / 17.5	A / 9.1	A / 9.2	B / 16.7
Northbound	B / 19.7	B / 19.7	B / 13.9	C / 22.8	C / 22.8	B / 14.9
Southbound	B / 19.3	B / 19.3	B / 13.7	C / 23.5	C / 23.5	B / 15.2
Overall	C / 22.0	C / 22.0	B / 16.4	B / 18.2	B / 18.1	B / 12.1
19. South Street & Park Avenue (Signal Removed)						
Eastbound	[A / 8.3]	[A / 8.4]	[A / 8.3]	[A / 9.2]	[A / 9.3]	[A / 9.2]
Westbound	[A / 8.4]	--	[A / 8.4]	[A / 8.8]	--	[A / 8.8]
Northbound (Stop)	C / 19.9	C / 19.5	C / 19.9	D / 27.6	D / 26.3	D / 27.6
Southbound (Stop)	C / 16.9	C / 16.6	C / 16.9	D / 33.6	D / 31.4	D / 33.6
Overall	A / 1.5	A / 1.4	A / 1.5	A / 3.2	A / 2.9	A / 3.2
20. South Street & Pine Avenue (Signal Retained)						
Eastbound	C / 25.0	C / 25.0	B / 13.7	C / 23.5	C / 23.5	A / 6.9
Westbound	C / 24.3	C / 24.3	A / 1.9	C / 24.1	C / 24.1	A / 1.1
Northbound	B / 13.4	B / 13.4	B / 14.2	B / 18.1	B / 18.1	B / 17.1
Southbound	B / 16.3	B / 16.3	B / 13.6	C / 21.1	C / 21.1	B / 16.4
Overall	C / 23.3	C / 23.3	A / 8.5	C / 23.2	C / 23.2	A / 5.6

As shown in the table above, both options would operate acceptably and will allow for protected-permitted phasing once the left-turn offsets are mitigated. Option 2 allows for the longest storage lengths, the least amount of restriping, and capacity analysis shows that the westbound left-turn lane has enough excess capacity to absorb the westbound left-turns from Park Avenue.

5. Multi-Way Stop Analysis

Methodology

Multi-way stop control can be useful as a safety measure at intersections if certain traffic conditions exist. In general, the decision to install multi-way stop control should be based on an engineering study following the criteria outlined in Section 2B.07 of the *Ohio Manual of Uniform Traffic Control Devices* (OMUTCD). The criteria for consideration include the following:

- A. Where traffic control signals are justified, the multi-way stop is an interim measure that can be installed quickly to control traffic while arrangements are being made for the installation of the traffic control signal.
- B. A location with five or more reported crashes in a 12-month period that are susceptible to correction by a multi-way stop installation. Such crashes include right-turn and left-turn collisions as well as right-angle collisions.
- C. Minimum Volumes:
 - a. The vehicular volume entering the intersection from the major street approach (total of both approaches) averages as least 300 vehicles per hour for any eight hours of an average day, and
 - b. The combined vehicular, pedestrian and bicycle volume entering the intersection from the minor street approaches (total of both approaches) averages at least 200 units per hour for the same eight hours, with an average vehicle delay to minor-street traffic of at least 30 seconds per vehicle during the highest hours, but
 - c. If the 85th-percentile approach speed on the major-street traffic exceeds 40 mph, the minimum volume warrants are 70 percent of the values listed above.
- D. Other criteria that may be considered in the study include: the need to control left-turn conflicts; the need to control vehicle/pedestrian conflicts near locations that generate high pedestrian volumes; locations where road users, after stopping, cannot see conflicting traffic and are not able to negotiate the intersection unless conflicting cross traffic is also required to stop; and an intersection of two residential collector (through) street of similar design and operating characteristics where multi-way stop control would improve traffic operational characteristics of the intersection.

The analysis contained in this report evaluates the City's multi-way stop-controlled intersections against the Minimum Volume criteria. We were provided with a map showing a total of 65 multi-way stop-controlled intersections throughout the City, which we used to conduct a preliminary review of each intersection. During this initial site visit we noted that intersection #6 had been converted from a multi-way stop-controlled to two-way stop-controlled. In addition, seven multi-way stop-controlled intersections not on the map were located. This brings the total of multi-way stop-controlled intersections in the City to 71. The analysis will determine which intersections are not warranted based on traffic volumes.

Based on a site visit to each intersection, a list of intersections where road users, after stopping, cannot see conflicting traffic and are not able to negotiate the intersection unless conflicting cross traffic is also required to stop, will be generated.

Volume Analysis

To begin the volume analysis, the upper confidence AADT values were calculated by increasing the StreetLight AADT values by the upper confidence range value provided by the StreetLight analysis. This method provides an AADT value at the upper range of the prediction interval. Using the upper range value provides a conservative approach when performing analyses to show that a multi-way stop is not warranted. Conversely, using the lower range values would provide a conservative approach if the analyses were being completed to show that a multi-way stop is warranted.

The upper range AADT values were converted to hourly volumes using ODOT's *Hourly Percent by Vehicle Type* tables for urban local roadways. This table shows that the eight highest hours of traffic volumes occur between 11 AM to 7 PM. The hourly volumes during these hours vary from 6.2 to 9.0 percent of the AADT volumes. The average hourly volume for these eight hours is 7.4 percent of the AADT volume. A table listing the eighth highest hour volume using the 6.2 percent value and the average hourly volume for the highest eight hours of the day using the 7.4 percent value is contained in **Appendix E**. The hourly values calculated using the 7.4 percent factor will be used as it provides a conservative approach when performing analyses to show that a multi-way stop is not warranted.

Minimum Volume Warrant

The average of the eight highest hourly volumes were compared to the 300 vehicle per hour and 200 vehicle per hour thresholds outlined in the OMUTCD. This comparison found that 64 of the City's 71 multi-way stop-controlled intersections do not meet the minimum vehicular volume warrant. The volumes at three additional intersections are close to the threshold values and were recommended for further study. At the City's request, the Trumbull County Engineer's Office conducted 24-hour traffic counts at these intersections. The traffic counts are contained in **Appendix B**. A review of the additional count information confirms that the traffic volumes at each of these intersections are below the multi-way stop warrant threshold volumes and that stop signs should be removed from the major street approaches. Tabled summarizing the results can be found on the following pages.

Hourly Percent By Vehicle Type
Urban Minor Collector

Hour	Hour of Day	P&A (Cars)	% P&A (Cars)	B&C (Trucks)	% B&C (Trucks)	Total	% Total
0	12-1am	1,059	0.2%	115	0.4%	1,174	0.2%
1	1-2am	520	0.1%	77	0.3%	597	0.1%
2	2-3am	298	0.1%	65	0.2%	363	0.1%
3	3-4am	301	0.1%	62	0.2%	363	0.1%
4	4-5am	1,133	0.3%	133	0.5%	1,266	0.3%
5	5-6am	5,278	1.2%	473	1.6%	5,751	1.2%
6	6-7am	16,379	3.7%	1,207	4.1%	17,586	3.7%
7	7-8am	29,781	6.7%	1,946	6.6%	31,727	6.7%
8	8-9am	25,459	5.8%	2,101	7.1%	27,560	5.8%
9	9-10am	20,904	4.7%	1,784	6.0%	22,688	4.8%
10	10-11am	21,029	4.8%	1,861	6.3%	22,890	4.9%
11	11-12am	24,340	5.5%	1,981	6.7%	26,321	5.6%
12	12-1pm	27,207	6.2%	2,136	7.2%	29,343	6.2%
13	1-2pm	26,606	6.0%	2,036	6.9%	28,642	6.1%
14	2-3pm	30,127	6.8%	2,389	8.1%	32,516	6.9%
15	3-4pm	35,947	8.1%	2,432	8.2%	38,379	8.1%
16	4-5pm	41,147	9.3%	2,347	8.0%	43,494	9.2%
17	5-6pm	42,956	9.7%	2,012	6.8%	44,968	9.5%
18	6-7pm	30,362	6.9%	1,388	4.7%	31,750	6.7%
19	7-8pm	22,737	5.1%	1,116	3.8%	23,853	5.1%
20	8-9pm	18,203	4.1%	784	2.7%	18,987	4.0%
21	9-10pm	11,563	2.6%	549	1.9%	12,112	2.6%
22	10-11pm	5,701	1.3%	347	1.2%	6,048	1.3%
23	11-12pm	2,745	0.6%	179	0.6%	2,924	0.6%
	Total	441,782	100%	29,520	100%	471,302	100%



Sight Distance and Intersection Geometric Review

A field review of each intersection not meeting the minimum vehicular volume warrant was conducted. Based on this field review, the multi-way stop control at eight of the 71 intersections should be retained as a result of sight distance, geometric limitations and other influencing factors such as schools and multi-use trails. The following tables include a column noting the intersections that should remain under multi-way stop control based on the field review.

Intersection Number	Major Street		Minor Street		Volume Thresholds, StreetLight Data			Result of Additional Study	Retain Due to Field Conditions
	Street Name	Average of 8 Highest Hours (7.4% of AADT)	Street Name	Average of 8 Highest Hours (7.4% of AADT)	Below Threshold, REMOVE	Below Threshold, Recommend for Additional Study	Retain Due to Volumes		
1	Delaware Avenue SW	59	Hamilton Street SW	107					Retain
		162							
2	Nevada Avenue SW	197	Union Street SW	46	Remove				
		198		58					
3	Nevada Avenue SW	198	Hamilton Street SW	106	Remove				
		197		59					
4	Nevada Avenue SW	190	Oak Street SW	189	Remove				
		189		154					
5	Palmyra Road SW	365	Risher Road	106	Remove				
		334							
6	Front Street SW	58	Penn Avenue SW	59	Currently two-way stop controlled				
		106		58					
7	Hamilton Street SW	59	York Avenue SW	59	Remove				
		95		59					
8	Jefferson Street SW	66	York Avenue SW	59	Remove				
		189		58					
9	Oak Street SW	154	York Avenue SW	58	Remove				
		191		80					
10	Palmyra Road SW	392	Austin Avenue SW	118	Remove				
		390		45					
11	Lane Drive SW	59	Valley Ave SW	107	Remove				
		138		54					
12	Beal Street NW	197	Midwae Drive NW	186	Remove				
		198							
13	Southern Boulevard NW	266	Solar Street NW	69	Remove				
		265							
14	Northwest Boulevard NW	185	Commerce Avenue NW	50	Remove				
		196		107					

Intersection Number	Major Street		Minor Street		Volume Thresholds, StreetLight Data			Result of Additional Study	Retain Due to Field Conditions
	Street Name	Average of 8 Highest Hours (7.4% of AADT)	Street Name	Average of 8 Highest Hours (7.4% of AADT)	Below Threshold, REMOVE	Below Threshold, Recommend for Additional Study	Retain Due to Volumes		
15	Southern Boulevard NW	219	Linda Drive NW	187		Additional Study		Remove	
		265		266					
16	Beal Street NW / Dunstan Drive NW	197	Montgomery Avenue NW	120			Retain		
		297		198					
17	Northfield Avenue NW	108	Norwood Street NW	48	Remove				
		185		108					
18	Oakdale Drive NW	108	Drexel Avenue NW	132	Remove				
		59		189					
19	Norwood Street NW	189	Drexel Avenue NW	190	Remove				
		189		189					
20	Drexel Avenue NW	189	Moncrest Drive NW	184					Retain, School
		197		192					
21	Westwood Drive NW	84	Monticello Avenue NW	59					Retain
		197		189					
22	Moncrest Drive NW	192	Monticello Avenue NW	189					Retain
		184							
23	Riverview Street NW	106	Niblock Avenue NW	45	Remove				
		106		59					
24	Ohio Avenue NW	189	Ward Street NW	59	Remove				
		189		59					
25	Dickey Avenue NW	58	Taylor Street NW	48	Remove				
		59		59					
26	Dickey Avenue NW	59	Ward Street NW	59	Remove				
		59		59					
27	Comstock Street NW	266	Vernon Avenue NW	107	Remove				
		336		58					
28	Federal Street NW	94	Arlington Avenue NW	192	Remove				
		78		189					
29	Porter Street NE	189	Vine Avenue NE	185	Remove				
		190		197					
30	Laird Avenue NE	335	Edgewood Street NE	190			Retain		
		334		106					
31	Edgewood Street NE	106	Bonnie Brae Avenue NE	73	Remove				
		106		185					
32	Hollywood Street NE	108	Kenilworth Avenue NE	162	Remove				
		119		190					
33	Edgewood Street NE	106	Kenilworth Avenue NE	190	Remove				
		103		189					
34	Charles Avenue NE	189	High Street NE	55					Retain, Trail
		190		55					
35	Willard Avenue NE	189	Montclair Street NE	55	Remove				
		190		190					
36	Perkinswood Boulevard NE	198	Woodland Street NE	185	Remove				
		196		161					
37	Butler Road NE	184	Foster Drive NE	82					Retain
		185		116					
38	Butler Road NE	190	Woodland Street NE / Overlook Drive NE	108	Remove				
		189		108					
39	Fairway Drive NE	191	Butler Road NE						Retain
		108		190					
40	Homewood Avenue SE	261	South Street SE	198		Additional Study		Remove	
		197		189					
41	Kenilworth Avenue SE	184	South Street SE	189	Remove				
		95		116					
42	Woodbine Avenue SE	162	South Street SE	116	Remove				
		162		106					
43	Oak Knoll Avenue SE	169	Belle Street SE	55	Remove				
		151		43					

Intersection Number	Major Street		Minor Street		Volume Thresholds, StreetLight Data			Result of Additional Study	Retain Due to Field Conditions
	Street Name	Average of 8 Highest Hours (7.4% of AADT)	Street Name	Average of 8 Highest Hours (7.4% of AADT)	Below Threshold, REMOVE	Below Threshold, Recommend for Additional Study	Retain Due to Volumes		
44	Adelaide Avenue SE	189	Belle Street SE	43	Remove				
		184		53					
45	Belvedere Avenue SE	187	Grandview Street SE	59	Remove				
		162		59					
46	Kenmore Avenue SE	184	South Street SE	120	Remove				
		185		107					
47	Trumbull Avenue SE	198	Catalpa Street SE	58	Remove				
		196		59					
48	Meadowbrook Avenue SE	189	Catalpa Street SE	59	Remove				
		197		106					
49	Eastland Avenue SE	515	Catalpa Street SE	106	Remove				
		336							
50	Homewood Avenue SE	103	Clarence Street SE	69	Remove				
		106							
51	Kenilworth Avenue SE	190	Clarence Street SE	69	Remove				
		162		59					
52	Francis Avenue SE	94	Sussex Street SE	189	Remove				
		225							
53	Kenmore Avenue SE	184	Sussex Street SE	189	Remove				
		190		184					
54	Perkinswood Boulevard SE	265	Sussex Street SE	185		Additional Study	Remove		
		265		106					
55	Hazelwood Avenue SE	190	Colonial Street SE	72	Remove				
		189		82					
56	Milton Street SE	189	Hazelwood Avenue SE	190	Remove				
		185		162					
57	Wallace Street SE	48	Duke Avenue SE	59	Remove				
		48		59					
58	Brier Street SE	48	Duke Avenue SE	81	Remove				
		59		59					
59	Brier Street SE	69	Willard Avenue SE	118	Remove				
		94		95					
60	Burton Street SE	189	Willard Avenue SE	185	Remove				
		190		118					
61	Milton Street SE	189	Willard Avenue SE	184				Retain, School	
		162		185					
62	Meadowbrook Avenue SE	184	Surrey Road SE	106	Remove				
		189		187					
63	Eastland Avenue SE	266	Surrey Road SE	187			Retain		
		335		185					
64	Central Parkway Avenue SE	106	Perkinswood Boulevard SE / Trumbull Avenue SE	197			Retain		
		295		197					
65	Martha Street NE	55	Mazda Avenue NE	58	Remove				
		58		81					
66	Jackson Street SW	187	Nevada Avenue SW	162	Remove				
		80							
67	Wick Street SE	42	Duke Avenue SE	59	Remove				
		42		59					
68	Willard Street SE	198	Sussex Street SE	184	Remove				
		197		189					
69	Meadowbrook Avenue SE	198	Sussex Street SE	73	Remove				
		189		185					
70	Eastland Avenue SE	335	Sussex Street SE	93	Remove				
		335							
71	Brighton Avenue NE	45	Martha Street NE	55	Remove				
		59		45					
72	Glenwood Street NE	50	Mazda Avenue NE	5	Remove				
		95		6					

The major street and minor street designations in the previous tables are based on a combination of traffic volumes and roadway profiles.

Overhead flashing beacons are currently installed at Intersection 2, Nevada Avenue and Union Street; Intersection 5, Palmyra Road and Risher Road; and at Intersection 10, Palmyra Road and Austin Avenue. With the proposed removal of the multi-way stop control at these three intersections, the all-red flashing beacons should be removed or retrofitted with a yellow lens on the uncontrolled approaches.

When converting multi-way stop-controlled intersections to two-way stop-controlled intersections any placards indicating "ALL WAY" stop should be removed from beneath the stop signs that are to remain. Furthermore, consideration should be given to installing "CROSS TRAFFIC DOES NOT STOP" signs beneath stop signs that are to remain. This should avoid confusion to motorists who may have become accustomed to the multi-way stop traffic control that had previously been in place at the intersection.

Overhead flashing beacons are typically used where the traffic volumes or physical conditions do not justify a conventional traffic signal, but crash rates indicate the possibility of a special need. There is no specific warrant for the installation of a flashing beacon; the *Manual of Uniform Traffic Control Devices* describes a beacon as a supplement to the regulatory signing at a stop-controlled intersection.

The FHWA's Safety Evaluation of Flashing Beacons at Stop-Controlled Intersections report published in 2008 concluded that flashing beacons at unsignalized intersections can be a cost-effective safety improvement. The report indicates a potential reduction of 4 percent in angle crashes and a 1 percent reduction of injury and fatal crashes when flashing beacons are installed.