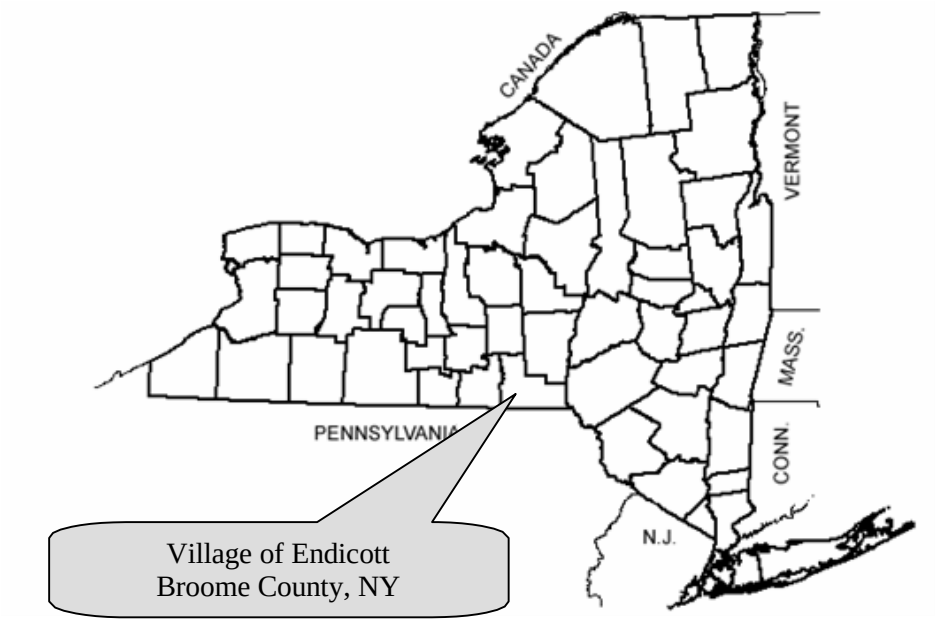
UNWARRANTED TRAFFIC SIGNAL STUDY

VILLAGE OF ENDICOTT
BROOME COUNTY, NY

June 2017



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13901

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This study was funded by the Federal Highway Administration (FHWA) Metropolitan Planning Program. The views expressed herein are solely those of the Binghamton Metropolitan Transportation Study, and do not represent an official position of the FHWA

BMTS
BINGHAMTON METROPOLITAN TRANSPORTATION STUDY
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BINGHAMTON METROPOLITAN TRANSPORTATION STUDY
POLICY COMMITTEE
RESOLUTION 2017-18

Resolution accepting the Unwarranted Traffic Signal Study for the Village of Endicott as Complete

WHEREAS the Binghamton Metropolitan Transportation Study Policy Committee has been designated by the Governor of the State of New York as the Metropolitan Planning Organization responsible, together with the State, for the comprehensive, continuing, and cooperative transportation planning process for the Binghamton Urban Area, and

WHEREAS Federal regulations (23 CFR Chapter 1, Part 450, Subpart C, and 49 CFR Chapter VI, Part 613, Subpart B) require that the urban transportation planning process shall include development of a Unified Planning Work Program which shall annually describe all urban transportation and transportation related planning activities anticipated within the next one or two year period, and will document the work to be performed with technical assistance provided under the Federal Highway Administration metropolitan planning (PL) program and the Federal Transit Administration Section 5303 program, and

WHEREAS the BMTS Policy Committee has created a Planning Committee of technical representatives to advise it on matters concerning the implementation of the urban transportation planning process, and

WHEREAS the approved 2016-2017 Unified Planning Work Program included an FHWA funded task to evaluate the traffic signals within the Village of Endicott to determine which signals are warranted, and

WHEREAS BMTS staff has completed the study,

NOW THEREFORE BE IT RESOLVED THAT the BMTS Policy Committee accepts the Unwarranted Traffic Signal Study for the Village of Endicott as complete.

CERTIFICATION OF RESOLUTION 2017-18

I, the undersigned, duly elected Chair of the Binghamton Metropolitan Transportation Study Policy Committee, do hereby certify that the foregoing is a true and correct copy of BMTS Policy Committee Resolution 2017-18, adopted by consensus this 8th day of June, 2017.

Michael Marinaccio

Michael Marinaccio, Chair
BMTS Policy Committee

6-8-17

Date

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APPENDICES

INTRODUCTION

At the request of the Village of Endicott the Binghamton Metropolitan Transportation Study (BMTS) completed a Traffic Operation Study in 2003 that analyzed eighteen intersections within the Village for operational improvements and to determine if they were warranted. The Village of Endicott has eliminated four signals since that study was completed. Due to the changing demographics, the closure of businesses and changes in traffic patterns, BMTS has analyzed the current inventory of Village traffic signals for improvements, upgrades and possible removal. Traffic signal maintenance represents a significant cost, and as such BMTS performed a study to determine signal locations that no longer meet federal warrants. The goal of this study is to identify traffic signals within the Village for removal based on a variety of criteria in an effort to improve traffic operation, increase safety, and reduce maintenance costs.

In March 2016, BMTS adopted the Unified Planning Work Program (UPWP). The UPWP identifies the transportation planning activities that are to be undertaken in the BMTS metropolitan planning area for the State Fiscal Years 2016-2017. The Village of Endicott Traffic Signal Study was one of the tasks included in this plan.

ANALYSIS CRITERIA

The Federal Highway Administration (FHWA) publishes the Manual on Uniform Traffic Control Devices (MUTCD). This publication defines the standards for traffic control devices on all public streets in the United States. It is published under 23 Code of Federal Regulations (CFR), Part 655, Subpart F. For the purposes of this study the MUTCD 2009 Edition, will be used as the basis for all analysis pertaining to traffic signal use and removal in accordance with federal regulation.

TRAFFIC CONTROL SIGNAL ROLE AND FUNCTION

A traffic control signal's primary role is to assign the right-of-way to the various traffic movements at a given intersection. When properly used, traffic control signals are valuable devices for the control of vehicular and pedestrian traffic. The MUTCD describes the advantages and disadvantages of signals as follows:

"A. They provide for the orderly movement of traffic.
B. They increase the traffic-handling capacity of the intersection if:
1. Proper physical layouts and control measures are used, and
2. The signal operational parameters are reviewed and updated (if needed) on a regular basis (as engineering judgment determines that significant traffic flow and/or land use changes have occurred) to maximize the ability of the traffic control signal to satisfy current traffic demands.
C. They reduce the frequency and severity of certain types of crashes, especially right-angle collisions.
D. They are coordinated to provide for continuous or nearly continuous movement of traffic at a definite speed along a given route under favorable conditions.
E. They are used to interrupt heavy traffic at intervals to permit other traffic, vehicular or pedestrian, to cross."

In addition to these functions, traffic control signals provide emphasis at hazardous locations, control some types of railroad-highway grade crossings, control travel lane use, and supplement certain signs. With the wide variety of functions and roles that traffic control signals perform, the MUTCD has necessarily provided strong and direct guidance for their justification and use.

TRAFFIC CONTROL SIGNAL WARRANTS

The MUTCD states that the selection and use of traffic control signals shall be based on an engineering study. The MUTCD identifies minimum situational warrants that must exist at a given location before a traffic control signal can be considered. The MUTCD further states that even in situations where minimum warrants are met, an engineering study should still be performed to confirm that the installation of a signal would improve overall safety or operation of the intersection. The nine warrants for traffic signal installation identified by the MUTCD are as follows:

Warrant 1, Eight-Hour Vehicular Volume

Warrant 2, Four-Hour Vehicular Volume

Warrant 3, Peak Hour

Warrant 4, Pedestrian Volume

Warrant 5, School Crossing

Warrant 6, Coordinated Signal System

Warrant 7, Crash Experience

Warrant 8, Roadway Network

Warrant 9, Intersection near a Grade Crossing

Refer to the MUTCD 2009 Edition, Chapter 4C for further explanation of these warrants and how they are applied. Traffic control signals that do not meet at least one of these warrants often have a variety of operational and safety related shortcomings that should be addressed.

UNWARRANTED TRAFFIC SIGNALS

The MUTCD addresses unnecessary traffic control signals as follows:

“Traffic control signals are often considered a panacea for all traffic problems at intersections. This belief has led to traffic control signals being installed at many locations where they are not needed, adversely affecting the safety and efficiency of vehicular, bicycle, and pedestrian traffic. Traffic control signals, even when justified by traffic and roadway conditions, can be ill-designed, ineffectively placed, improperly operated, or poorly maintained. Improper or unjustified traffic control signals can result in one or more of the following disadvantages:

A. Excessive delay,
B. Excessive disobedience of the signal indications, i.e. running red lights
C. Increased use of less adequate routes as road users attempt to avoid the traffic control signals,
D. Significant increases in the frequency of collisions (especially rear-end collisions).”

Traffic control signals that have been in place for many years may not meet the warrants outlined by the current edition of the MUTCD. This may be due to demographic change in the area, land use changes, altered traffic patterns, or updated warrants that are based on a more modern understanding of traffic operation. Locations where signals no longer meet warrants may represent safety hazards to the traveling public, may be causing undue delay for motorists and require ever scarcer maintenance funds to ensure their proper operation. Due to the many factors that decide if a signal is warranted, and beneficial, it is necessary to study each signal location using the most up to date methodology and understanding of traffic analysis.

TRAFFIC SIGNAL STUDY METHODOLOGY

The Village of Endicott maintains 20 traffic signals. BMTS performed a preliminary analysis on these signals to determine which intersections merited further investigation for removal. Refer to table 1.1 for a complete list of the intersections studied. After a finalized list of traffic control signals was developed, BMTS staff compiled additional intersection data for warrant analysis.

BMTS conducts traffic counts for all signalized intersections within its metropolitan planning area on a three-year reoccurring cycle. The counts are conducted by BMTS staff during the morning (AM) and evening (PM) peak hour period. These time periods typically represent the highest hourly traffic volumes for a given intersection. The peak periods are therefore a pertinent analysis tool when determining if the intersection meets signal warrants and is operating properly. At the intersections targeted for removal, the traffic counts were analyzed using multiple traffic analysis software packages. SYNCHRO 9, with its plugin module Warrants 9 and HCS (Highway Capacity Software) were used to analyze the operation and warrants at all thirty Village of Endicott traffic signals included in this study. These software packages are based on traffic analysis methods from the 2010 Highway Capacity Manual (HCM), developed by the Transportation Research Board. The HCM is the accepted reference for analyzing traffic operations in the United States.

Vehicular and pedestrian traffic volumes are just four of the nine warrants for signal installation. The remaining five warrants are based on intersection location, classification, accident history, and the proximity of certain trip generators, e.g. schools. BMTS staff evaluated each intersection in the study to determine if it met the criteria for any of the remaining signal warrants. Site visits were conducted at key intersections to observe intersection traffic operation. The New York State Accident Information Location System (ALIS) was used to examine accident history over a three -year period (2013-2015) for each intersection included in the study.

TRAFFIC SIGNAL REMOVAL RECOMMENDATIONS

Table 1.1 contains BMTS recommendations for signal removal based on the analysis described in this document. Seven signals have been recommended for removal. These signals do not meet traffic control signal warrants previously described. Refer to Appendix C for a map of recommended signal removals.

Table 1.1 Traffic Signal Removal Recommendations

Description	Intersection Layout	Warrants 2009	Recommendation
Madison Ave/Broad St	Four way	YES	Retain due to school
Vestal Ave/North St	T	NO	Retain due to accident history
Robble Ave/Watson Blvd	Four way	NO	Signal removal Two way stop control
Madison Ave/Monroe St	Four way	NO	Signal removal Four-way stop
Hayes Ave/Watson Blvd	Four way	NO	Retain due to accident history
Lincoln Ave/Monroe St	Four way	NO	Signal removal Four-way stop
Lincoln Ave/Broad St	Four way	NO	Signal Removal Two way stop control
Washington Ave//Monroe St	Four way	NO	Signal removal with Pedestrian upgrades
Washington Ave/Broad St	Four way	NO	Signal removal with Pedestrian upgrades
McKinley Ave/Monroe St	Four way	YES	Retain
Oak Hill Ave/Pine St	Four way	NO	Removal
Oak Hill Ave/Witherill St	T	YES	Retain
Oak Hill Ave/Watson Blvd	Four way	NO	Retain with upgrades
Oak Hill Ave/Clark St	Four way	YES	Retain
McKinley Ave/Watson Blvd	Four way	YES	Retain
Oak Hill Ave/North/Madison Ave	Four way	YES	Retain
Lincoln Ave/North St	T	NO	Retain due to Price Chopper
Washington Ave/North St/ Huron Parking Lot	Four way	YES	Retain
McKinley Ave/North St	Four way	YES	Retain

TRAFFIC SIGNAL REMOVAL PROCEDURE

Per the MUTCD, traffic signal removal should be accomplished using the following steps:

A. Determine the appropriate traffic control to be used after removal of the signal.
B. Remove any sight-distance restrictions as necessary.
C. Inform the public of the removal study.
D. Flash or cover the signal heads for a minimum of 90 days, and install the appropriate stop control or other traffic control devices.
E. Remove the signal if the engineering data collected during the removal study period confirms that the signal is no longer needed.

STOP CONTROL RECOMMENDATIONS

If traffic signals are removed per recommendation, the intersections in question will become stop controlled through signage. The preferred stop condition for the majority of intersections is known as Two Way Stop Control (TWSC). This configuration allows traffic on the higher volume, or major, road to flow uncontrolled while traffic on the intersecting minor street is controlled by stop sign. Where there is a T-intersection, a One Way Stop Control (OWSC) is preferred and will also allow traffic on the higher volume road to flow uncontrolled. In some cases, it is necessary to provide stop control measures on all legs of an intersection. This condition is known as All Way Stop Control (AWSC). The MUTCD indicates that an engineering study should be used to justify an AWSC. The following items are considered when determining suitability of an AWSC intersection:

- Traffic Volumes
- Accident History
- Pedestrian Volume
- Sight distance
- Intersection Operation

Table 1.2 contains recommendations for appropriate traffic control devices for intersections undergoing signal removal. These recommendations are based on the AWSC criteria shown above.

Table 1.2 Intersection Traffic Control Recommendations

Description	Major Street	Layout	Recommended Stop Condition	Accident History	Traffic Volume Warrant
Robble Ave/Watson Blvd	Watson Blvd	Four Way	Two way stop on Watson Blvd.	Not met	Not met
Madison Ave/Monroe St	Monroe St	Four Way	Four-way stop	Not met	Not met
Lincoln Ave/Monroe St	Monroe St	Four Way	Four-way stop	Not met	Not met
Lincoln Ave/Broad St	Lincoln Ave	Four Way	Two way stop on Broad St.	Not met	Not met
Washington Ave/Monroe St	Washington Ave	Four Way	Two way stop on Monroe St.	Not met	Not met
Washington Ave/Broad St	Washington Ave	Four Way	Two way stop on Broad St.	Not met	Not met
Oak Hill Ave/Pine St	Pine St	Four Way	Two way on Oak Hill Ave.	Not met	Not met

Robble Ave./Watson Blvd
The signal warrants at this intersection are not met. Traffic volumes are low and there were no accidents that were correctable by having a traffic signal. A two way stop controlled intersection with stop signs on Watson Blvd. is recommended. This signal was previously recommended for removal in the BMTS November 2003 Village of Endicott Traffic Operations Study.

Madison Ave./ Monroe St.
The signal warrants at this intersection are not met. Traffic volumes are low and fairly equal on all four approaches of the intersection. A four-way stop is recommended at the intersection. This signal was previously recommended for removal in the BMTS November 2003 Village of Endicott Traffic Operations Study.

Lincoln Ave./Monroe St.
The signal warrants at this intersection are not met. The traffic volumes are low and fairly equal on all four approaches of the intersection. A four-way stop is recommended. This signal was previously recommended for removal in the BMTS November 2003 Village of Endicott Traffic Operations Study.

Lincoln Ave./Broad St.
The signal warrants at this intersection are not met. There was a pedestrian accident at the intersection during the time period studies. Signal removal is recommended with a two way stop with stop signs on Broad St. and improved pavement markings. This signal was previously recommended for removal in the BMTS November 2003 Village of Endicott Traffic Operations Study.

Washington Ave./Monroe St.
The signal warrants at this intersection are not met. A two way stop with stop signs on Monroe St. are recommended. Since Washington Ave. is the main commercial street of "downtown" Endicott, pedestrian improvements should be made in conjunction with the signal removal. Upgraded crosswalks with signing and the placement of yield to pedestrian signs in the crosswalk are recommended. If this signal is not removed, the signal at the intersection should be replaced with updated pedestrian signals.

Washington Ave./Broad St.
The signal warrants at this intersection are not met. A two way stop with stop signs on Broad St. is recommended. Pedestrian and crosswalk improvements should be made the same as were recommended for Washington Ave./Monroe St. If the signal is not removed, it also needs to be upgraded with pedestrian signals included.

Oak Hill Ave./Pine St.
The signal warrants at this intersection are not met. A two-way stop is recommended with stop signs om Oak Hill Ave. The operation of the intersection would also be improved by better delineation of the driveways near the intersection.

Broome County, the Village of Endicott, and the Town of Union are currently working with Bergman Associates to complete The Endicott Revitalization Plan. A component of this study is Washington Avenue. The BMTS recommendation to remove the two unwarranted traffic signals at Monroe Street and Broad Street provides the Village with an opportunity to improve pedestrian accessibility along Washington Avenue. By providing curb extensions, improved crosswalk markings, signage and incorporating Complete Street principles the area becomes a more inviting safe place for pedestrians.

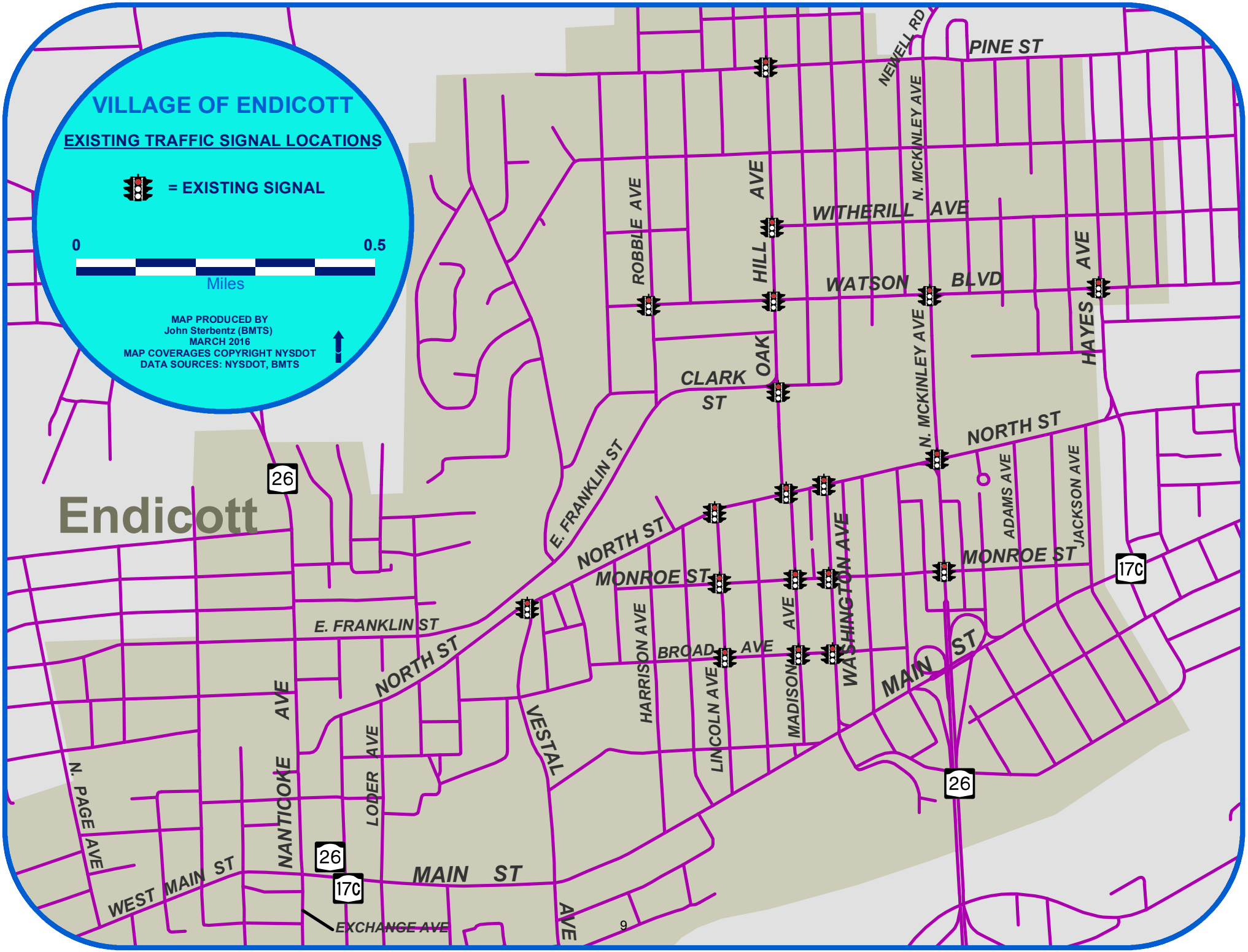
STUDY CONCLUSION

The Transportation Research Board lists the estimated service life of various components of a traffic control signal as between 1.4 and 24.6 years. These components include bulbs, signs, signal heads, controller cabinets, detector loops etc. It is costly to continue to maintain traffic control signals, particularly those that are unwarranted and inefficient. The Village has been routinely upgrading traffic signals by using Federal funds provided through the Binghamton Metropolitan Transportation Study Transportation Improvement Program. But, funds are limited and the Village of Endicott still has many older traffic signals that need upgrades or replacement. The Village has the justification based on this engineering study to remove the recommended signals and in the process make more efficient use of public funds and provide safer and more efficient intersections within the Village of Endicott.

Traffic control signals require maintenance, electrical power, and have a limited service life. The 2012 Traffic Signal Maintenance Consolidation Study conducted by BMTS lists the annual maintenance requirement for each signal as approximately 50 hours. The removal of the recommended traffic control signals would save Village personnel approximately 350 hours per year of preventive and responsive maintenance labor. This would allow Village staff to direct preventive maintenance efforts to the remaining warranted traffic control signals. Removing the recommended 7 signals would also save electrical operating costs as well as costs to drivers in operating costs and delay.

Appendix A

Traffic Signals in the Village of Endicott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EXISTING TRAFFIC SIGNAL LOCATIONS
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0.5
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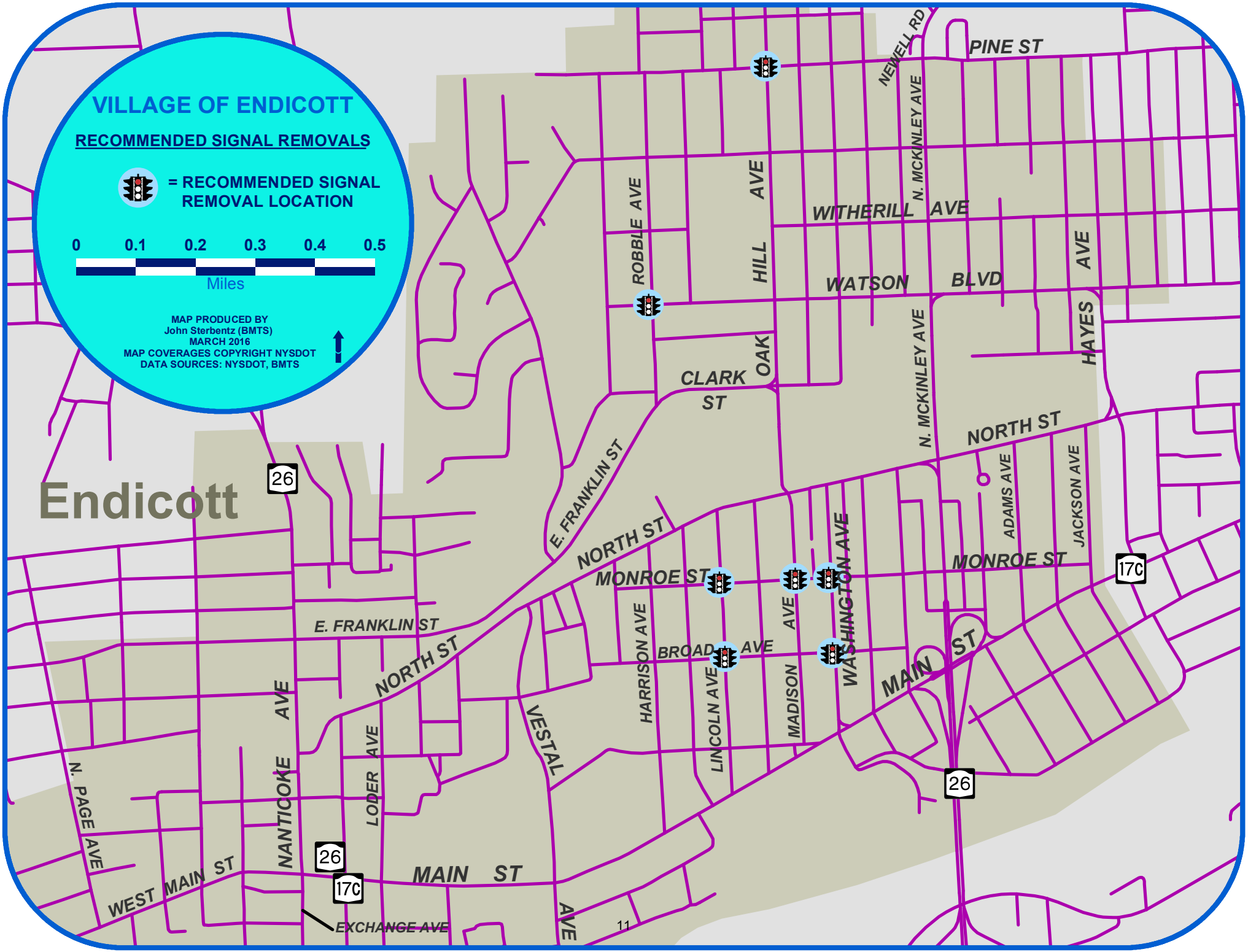
MAP PRODUCED BY
John Sterbentz (BMTS)
MARCH 2016
MAP COVERAGES COPYRIGHT NYSDOT
DATA SOURCES: NYSDOT, BMTS
Endicott
NEWELL RD
PINE ST
ROBBLE AVE
HILL AVE
N. MCKINLEY AVE
WITHERILL AVE
WATSON BLVD
HAYES AVE
OAK
CLARK ST
E. FRANKLIN ST
NORTH ST
ADAMS AVE
JACKSON AVE
MONROE ST
HARRISON AVE
BROAD AVE
LINCOLN AVE
MADISON AVE
WASHINGTON AVE
MAIN ST
VESTAL
LODER AVE
NANTICOKE AVE
N. PAGE AVE
WEST MAIN ST
EXCHANGE AVE
26
17C
9

Appendix B

Traffic Signal Removal Recommendations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MAP PRODUCED BY
John Sterbentz (BMTS)
MARCH 2016
MAP COVERAGES COPYRIGHT NYSDOT
DATA SOURCES: NYSDOT, BMTS
Endicott
NEWELL RD
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VESTAL AVE
NANTICOKE AVE
LODER AVE
N. PAGE AVE
WEST MAIN ST
EXCHANGE AVE
26
17C
11

Appendix C

Traffic Signal Removal Process

Traffic Signal Transition - Closure Procedure

The evaluation and removal of Village Traffic Signals will follow and conform to ITE Guidelines approval This procedure will include:

1. Public Notification - Newspaper notification to the public will be issued in addition to a direct outreach to businesses, institutions and residents within a two block proximity to the intersection under evaluation.
2. Advance Notification Signs - Signal under Study signs will be installed at the evaluation intersection and will remain in place for at least a 30 day period. During this period a survey of the intersection will be performed to determine appropriate traffic control signs to be used after signal removal. The survey will also identify any changes necessary affecting line of sight or any sight distance restriction. Implementation of those changes will occur prior to the covering of the signal lights.

3. Covered Signal Evaluation - Following the installation of required traffic control signs and road markings, an evaluation period of 90 days or longer will be utilized to assess impact on traffic flow. An alternative procedure for the 90 day period may include a flashing period for part or all of the 90 day evaluation. The flashing configuration will reflect either a four way or two way stop.

   Stop signs will be installed prior to the start of the 90 day evaluation period. This will include “STOP AHEAD” signs some distance before the intersection. Signal Under Study notification signs will be removed at the time stop sign installation.

   At the time of stop sign installation, a temporary secondary sign “CROSS STREET DOES NOT STOP” sign will be added and mounted under the intersection stop sign. This sign will remain for a period no less than one month.

4. 90 Day Observation Period - Data collection during this period will include intersection observation and solicitation of general traffic flow performance from public input. Periodic observations will be made at various times during a 24 hour cycle with a focus on peak demand hours. The Village web site will be utilized to allow public feedback of intersection traffic flow or any observations by Village residents. Businesses and residents living in near proximity to the intersection will be requested to provide concerns, opinions and observations.

   At 30 days prior to the removal of the signal, temporary signs “SIGNAL TO BE REMOVE On (date)” will be posted.

5. Signal Removal – The removal of the traffic signal will be based on acceptable results from the observation period. Signal poles and related wiring will remain in place for a minimum of one year.

Appendix D

FHWA MUTCD
Signal Warrants

CHAPTER 4C. TRAFFIC CONTROL SIGNAL NEEDS STUDIES

Section 4C.01 Studies and Factors for Justifying Traffic Control Signals

Standard:

01 **An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.**

02 **The investigation of the need for a traffic control signal shall include an analysis of factors related to the existing operation and safety at the study location and the potential to improve these conditions, and the applicable factors contained in the following traffic signal warrants:**

Warrant 1, Eight-Hour Vehicular Volume Warrant 2, Four-Hour Vehicular Volume Warrant 3, Peak Hour
Warrant 4, Pedestrian Volume
Warrant 5, School Crossing
Warrant 6, Coordinated Signal System Warrant 7, Crash Experience
Warrant 8, Roadway Network
Warrant 9, Intersection Near a Grade Crossing

03 **The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal.**

Support:

04 Sections 8C.09 and 8C.10 contain information regarding the use of traffic control signals instead of gates and/ or flashing-light signals at highway-rail grade crossings and highway-light rail transit grade crossings, respectively.

Guidance:

05 *A traffic control signal should not be installed unless one or more of the factors described in this Chapter are met.*

06 *A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection.*

07 *A traffic control signal should not be installed if it will seriously disrupt progressive traffic flow.*

08 *The study should consider the effects of the right-turn vehicles from the minor-street approaches. Engineering judgment should be used to determine what, if any, portion of the right-turn traffic is subtracted from the minor-street traffic count when evaluating the count against the signal warrants listed in Paragraph 2.*

09 *Engineering judgment should also be used in applying various traffic signal warrants to cases where approaches consist of one lane plus one left-turn or right-turn lane. The site-specific traffic characteristics should dictate whether an approach is considered as one lane or two lanes. For example, for an approach with one lane for through and right-turning traffic plus a left-turn lane, if engineering judgment indicates that it should be considered a one-lane approach because the traffic using the left-turn lane is minor, the total traffic volume approaching the intersection should be applied against the signal warrants as a one-lane approach.*
The approach should be considered two lanes if approximately half of the traffic on the approach turns left and the left-turn lane is of sufficient length to accommodate all left-turn vehicles.

10 *Similar engineering judgment and rationale should be applied to a street approach with one through/left-turn lane plus a right-turn lane. In this case, the degree of conflict of minor-street right-turn traffic with traffic on the major street should be considered. Thus, right-turn traffic should not be included in the minor-street volume if the movement enters the major street with minimal conflict. The approach should be evaluated as a one-lane approach with only the traffic volume in the through/left-turn lane considered.*

11 *At a location that is under development or construction and where it is not possible to obtain a traffic count that would represent future traffic conditions, hourly volumes should be estimated as part of an engineering study for comparison with traffic signal warrants. Except for locations where the engineering study uses the satisfaction of Warrant 8 to justify a signal, a traffic control signal installed under projected conditions should have an engineering study done within 1 year of putting the signal into stop-and-go operation to determine if the signal is justified. If not justified, the signal should be taken out of stop-and-go operation or removed.*

12 *For signal warrant analysis, a location with a wide median, even if the median width is greater than 30 feet, should be considered as one intersection.*

Option:

13 At an intersection with a high volume of left-turn traffic from the major street, the signal warrant analysis may be performed in a manner that considers the higher of the major-street left-turn volumes as the "minor-street" volume and the corresponding single direction of opposing traffic on the major street as the "major-street" volume.

14 For signal warrants requiring conditions to be present for a certain number of hours in order to be satisfied, any four sequential 15-minute periods may be considered as 1 hour if the separate 1-hour periods used in the warrant analysis do not overlap each other and both the major-street volume and the minor-street volume are for the same specific one-hour periods.

15 For signal warrant analysis, bicyclists may be counted as either vehicles or pedestrians.

Support:

16 When performing a signal warrant analysis, bicyclists riding in the street with other vehicular traffic are usually counted as vehicles and bicyclists who are clearly using pedestrian facilities are usually counted as pedestrians.

Option:

17 Engineering study data may include the following:

A. The number of vehicles entering the intersection in each hour from each approach during 12 hours of an average day. It is desirable that the hours selected contain the greatest percentage of the 24-hour traffic volume.
B. Vehicular volumes for each traffic movement from each approach, classified by vehicle type (heavy trucks, passenger cars and light trucks, public-transit vehicles, and, in some locations, bicycles), during each
15-minute period of the 2 hours in the morning and 2 hours in the afternoon during which total traffic entering the intersection is greatest.
C. Pedestrian volume counts on each crosswalk during the same periods as the vehicular counts in Item B and during hours of highest pedestrian volume. Where young, elderly, and/or persons with physical or visual disabilities need special consideration, the pedestrians and their crossing times may be classified by general observation.
D. Information about nearby facilities and activity centers that serve the young, elderly, and/or persons with disabilities, including requests from persons with disabilities for accessible crossing improvements at the location under study. These persons might not be adequately reflected in the pedestrian volume count if the absence of a signal restrains their mobility.
E. The posted or statutory speed limit or the 85th-percentile speed on the uncontrolled approaches to the location.
F. A condition diagram showing details of the physical layout, including such features as intersection geometrics, channelization, grades, sight-distance restrictions, transit stops and routes, parking conditions, pavement markings, roadway lighting, driveways, nearby railroad crossings, distance to nearest traffic control signals, utility poles and fixtures, and adjacent land use.
G. A collision diagram showing crash experience by type, location, direction of movement, severity, weather, time of day, date, and day of week for at least 1 year.

18 The following data, which are desirable for a more precise understanding of the operation of the intersection, may be obtained during the periods described in Item B of Paragraph 17:

A. Vehicle-hours of stopped time delay determined separately for each approach.
B. The number and distribution of acceptable gaps in vehicular traffic on the major street for entrance from the minor street.
C. The posted or statutory speed limit or the 85th-percentile speed on controlled approaches at a point near to
the intersection but unaffected by the control.
D. Pedestrian delay time for at least two 30-minute peak pedestrian delay periods of an average weekday or
like periods of a Saturday or Sunday.
E. Queue length on stop-controlled approaches.

Section 4C.02 Warrant 1, Eight-Hour Vehicular Volume

Support:

01 The Minimum Vehicular Volume, Condition A, is intended for application at locations where a large volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

02 The Interruption of Continuous Traffic, Condition B, is intended for application at locations where Condition A is not satisfied and 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.

03 It is intended that Warrant 1 be treated as a single warrant. If Condition A is satisfied, then Warrant 1 is satisfied and analyses of Condition B and the combination of Conditions A and B are not needed. Similarly, if Condition B is satisfied, then Warrant 1 is satisfied and an analysis of the combination of Conditions A and B is not needed.

Standard:

04 **The need for a traffic control signal shall be considered if an engineering study finds that one of the following conditions exist for each of any 8 hours of an average day:**

A. The vehicles per hour given in both of the 100 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; or

B. The vehicles per hour given in both of the 100 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.

In applying each condition the major-street and minor-street volumes shall be for the same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of these 8 hours.

Option:

05 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 70 percent columns in Table 4C-1 may be used in place of the 100 percent columns.

Guidance:

06 *The combination of Conditions A and B is intended for application at locations where Condition A is not satisfied and Condition B is not satisfied and should be applied only after an adequate trial of other alternatives that could cause less delay and inconvenience to traffic has failed to solve the traffic problems.*

Standard:

07 **The need for a traffic control signal shall be considered if an engineering study finds that both of the following conditions exist for each of any 8 hours of an average day:**

A. The vehicles per hour given in both of the 80 percent columns of Condition A in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection; and

B. The vehicles per hour given in both of the 80 percent columns of Condition B in Table 4C-1 exist on the major-street and the higher-volume minor-street approaches, respectively, to the intersection.

These major-street and minor-street volumes shall be for the same 8 hours for each condition; however, the 8 hours satisfied in Condition A shall not be required to be the same 8 hours satisfied in Condition B. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.

Table 4C-1. Warrant 1, Eight-Hour Vehicular Volume

Condition A—Minimum Vehicular Volume

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	500	400	350	280	150	120	105	84
2 or more	1	600	480	420	336	150	120	105	84
2 or more	2 or more	600	480	420	336	200	160	140	112
1	2 or more	500	400	350	280	200	160	140	112

Condition B—Interruption of Continuous Traffic

Number of lanes for moving traffic on each approach		Vehicles per hour on major street (total of both approaches)				Vehicles per hour on higher-volume minor-street approach (one direction only)			
Major Street	Minor Street	100%[a]	80%[b]	70%[c]	56%[d]	100%[a]	80%[b]	70%[c]	56%[d]
1	1	750	600	525	420	75	60	53	42
2 or more	1	900	720	630	504	75	60	53	42
2 or more	2 or more	900	720	630	504	100	80	70	56
1	2 or more	750	600	525	420	100	80	70	56

[a] Basic minimum hourly volume

[b] Used for combination of Conditions A and B after adequate trial of other remedial measures

[c] May be used when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

[d] May be used for combination of Conditions A and B after adequate trial of other remedial measures when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

Option:

08 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

Section 4C.03 Warrant 2, Four-Hour Vehicular Volume

Support:

01 The Four-Hour Vehicular Volume signal warrant conditions are intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic control signal.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that, for each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) all fall above the applicable curve in Figure 4C-1 for the existing combination of approach lanes. On the minor street, the higher volume shall not be required to be on the same approach during each of these 4 hours.**

Option:

03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000,
Figure 4C-2 may be used in place of Figure 4C-1.

Section 4C.04 Warrant 3, Peak Hour

Support:

01 The Peak Hour signal warrant is intended for use at a location where traffic conditions are such that for a minimum of 1 hour of an average day, the minor-street traffic suffers undue delay when entering or crossing the major street.

Standard:

02 **This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities that attract or discharge large numbers of vehicles over a short time.**

03 **The need for a traffic control signal shall be considered if an engineering study finds that the criteria in either of the following two categories are met:**

A. If all three of the following conditions exist for the same 1 hour (any four consecutive 15-minute periods) of an average day:

1. The total stopped time delay experienced by the traffic on one minor-street approach (one direction only) controlled by a STOP sign equals or exceeds: 4 vehicle-hours for a one-lane approach or 5 vehicle-hours for a two-lane approach; and

2. The volume on the same minor-street approach (one direction only) equals or exceeds 100 vehicles per hour for one moving lane of traffic or 150 vehicles per hour for two moving lanes; and

3. The total entering volume serviced during the hour equals or exceeds 650 vehicles per hour for intersections with three approaches or 800 vehicles per hour for intersections with four or more approaches.

B. The plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the higher-volume minor-street approach (one direction only) for 1 hour (any four consecutive 15-minute periods) of an average day falls above the applicable curve in Figure 4C-3 for the existing combination of approach lanes.

Option:

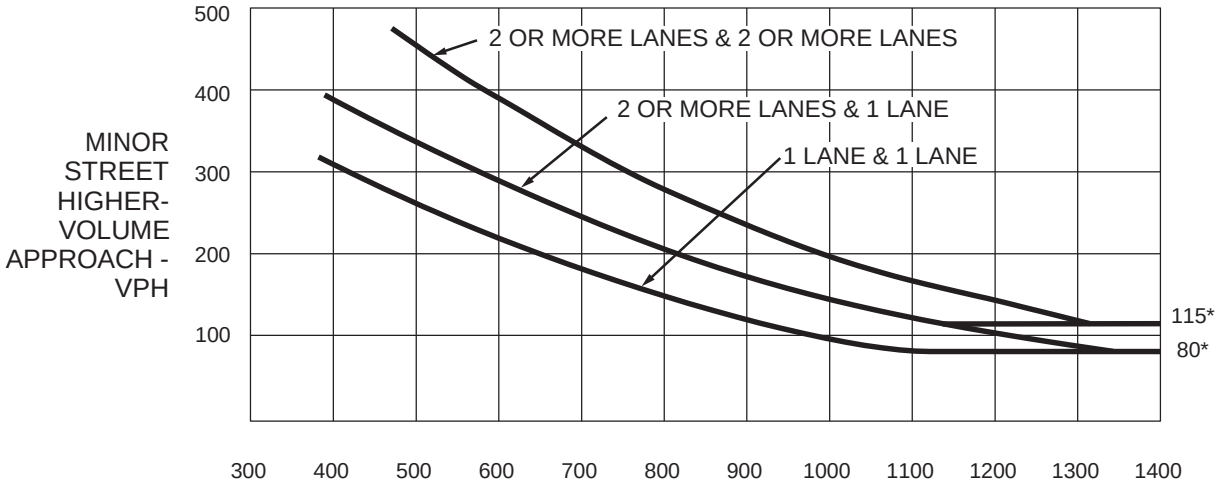
04 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, Figure 4C-4 may be used in place of Figure 4C-3 to evaluate the criteria in the second category of the Standard.

05 If this warrant is the only warrant met and a traffic control signal is justified by an engineering study, the traffic control signal may be operated in the flashing mode during the hours that the volume criteria of this warrant are not met.

Guidance:

06 *If this warrant is the only warrant met and a traffic control signal is justified by an engineering study, the traffic control signal should be traffic-actuated.*

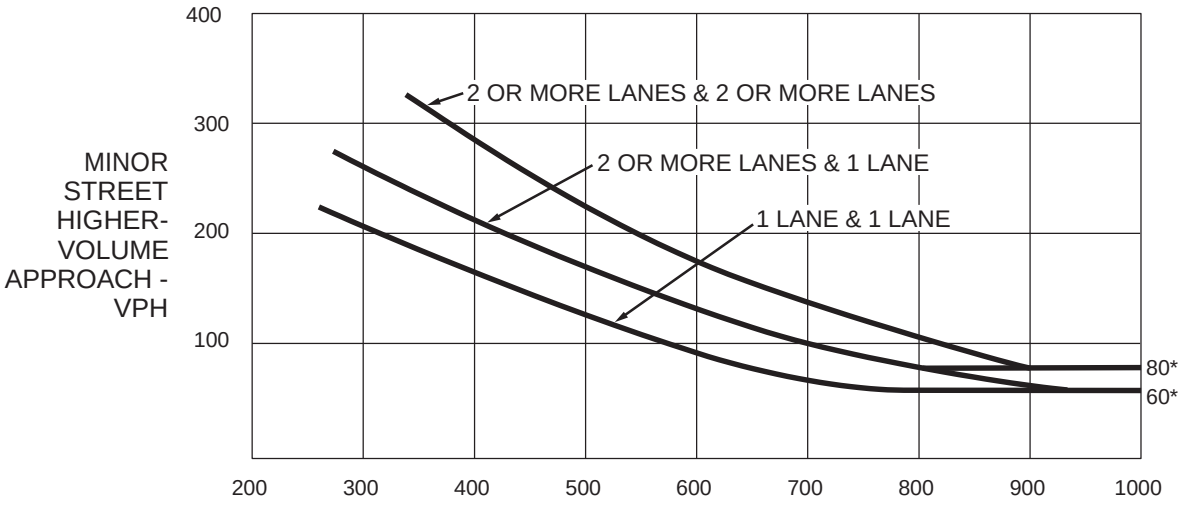
Figure 4C-1. Warrant 2, Four-Hour Vehicular Volume



*Note: 115 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 80 vph applies as the lower threshold volume for a minor-street approach with one lane.

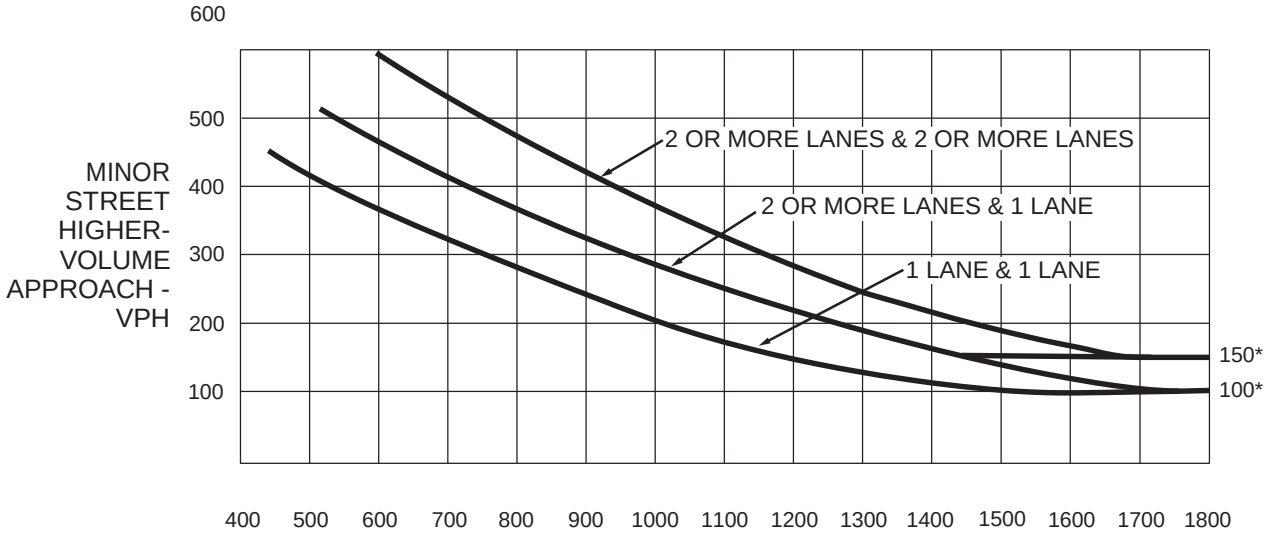
Figure 4C-2. Warrant 2, Four-Hour Vehicular Volume (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)



*Note: 80 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 60 vph applies as the lower threshold volume for a minor-street approach with one lane.

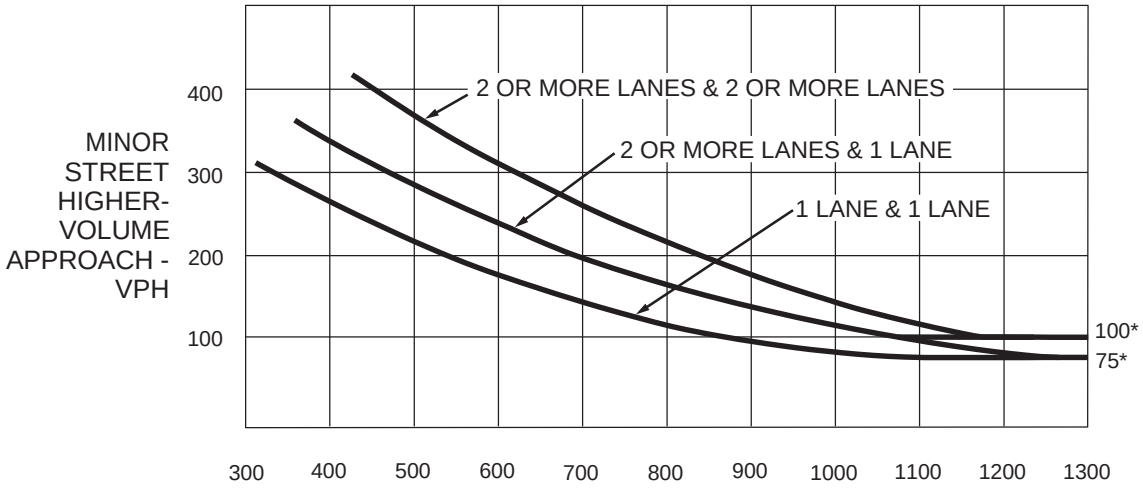
Figure 4C-3. Warrant 3, Peak Hour



*Note: 150 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 100 vph applies as the lower threshold volume for a minor-street approach with one lane.

Figure 4C-4. Warrant 3, Peak Hour (70% Factor)

(COMMUNITY LESS THAN 10,000 POPULATION OR ABOVE 40 MPH ON MAJOR STREET)



*Note: 100 vph applies as the lower threshold volume for a minor-street approach with two or more lanes and 75 vph applies as the lower threshold volume for a minor-street approach with one lane.

Section 4C.05 Warrant 4, Pedestrian Volume

Support:

01 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.

Standard:

02 **The need for a traffic control signal at an intersection or midblock crossing shall be considered if an engineering study finds that one of the following criteria is met:**

- **A. For each of any 4 hours of an average day, the plotted points representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) all fall above the curve in Figure 4C-5; or**
- **B. For 1 hour (any four consecutive 15-minute periods) of an average day, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding pedestrians per hour crossing the major street (total of all crossings) falls above the curve in Figure 4C-7.**

Option:

03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 35 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000,
Figure 4C-6 may be used in place of Figure 4C-5 to evaluate Criterion A in Paragraph 2, and Figure 4C-8 may be
used in place of Figure 4C-7 to evaluate Criterion B in Paragraph 2.

Standard:

04 **The Pedestrian Volume signal warrant shall not be applied at locations where the distance to the nearest traffic control signal or STOP sign controlling the street that pedestrians desire to cross is less**
than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.

05 **If this warrant is met and a traffic control signal is justified by an engineering study, the traffic control signal shall be equipped with pedestrian signal heads complying with the provisions set forth in Chapter 4E.** *Guidance:*

06 *If this warrant is met and a traffic control signal is justified by an engineering study, then:*

- *A. If it is installed at an intersection or major driveway location, the traffic control signal should also control the minor-street or driveway traffic, should be traffic-actuated, and should include pedestrian detection.*
- *B. If it is installed at a non-intersection crossing, the traffic control signal should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs, and should be*
  pedestrian-actuated. If the traffic control signal is installed at a non-intersection crossing, at least one of the signal faces should be over the traveled way for each approach, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the crosswalk or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance, and the installation should include suitable standard signs and pavement markings.
- *C. Furthermore, if it is installed within a signal system, the traffic control signal should be coordinated.*

Option:

07 The criterion for the pedestrian volume crossing the major street may be reduced as much as 50 percent if the 15th-percentile crossing speed of pedestrians is less than 3.5 feet per second.

08 A traffic control signal may not be needed at the study location if adjacent coordinated traffic control signals consistently provide gaps of adequate length for pedestrians to cross the street.

Section 4C.06 Warrant 5, School Crossing

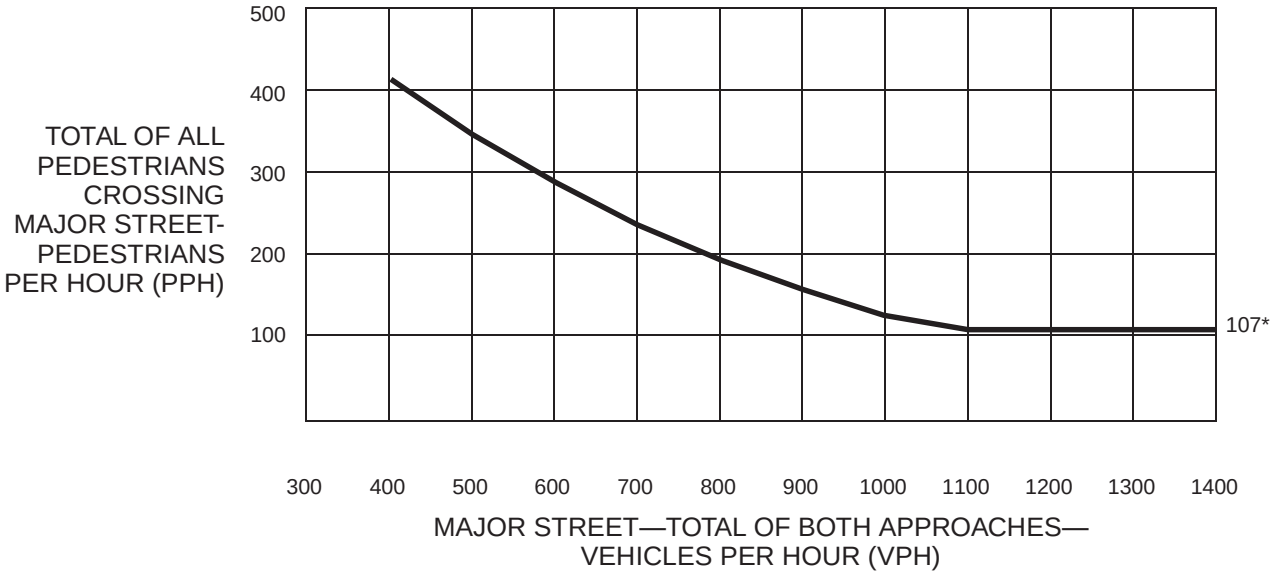
Support:

01 The School Crossing signal warrant is intended for application where the fact that schoolchildren cross the major street is the principal reason to consider installing a traffic control signal. For the purposes of this warrant, the word “schoolchildren” includes elementary through high school students.

Standard:

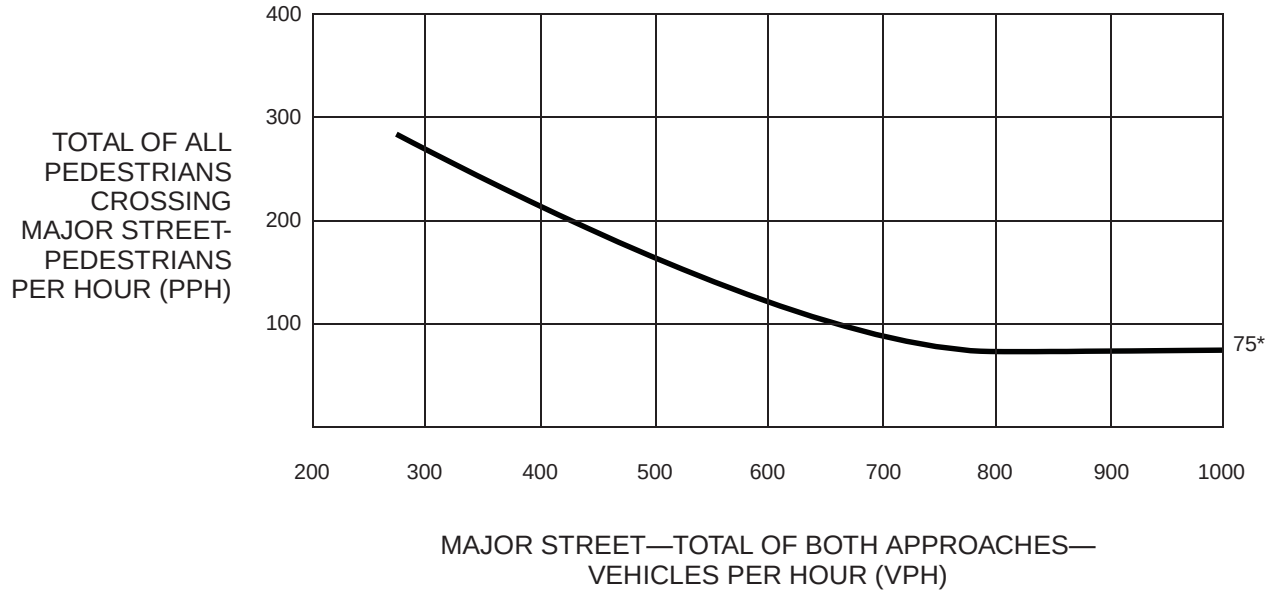
02 **The need for a traffic control signal shall be considered when an engineering study of the frequency and adequacy of gaps in the vehicular traffic stream as related to the number and size of groups of schoolchildren at an established school crossing across the major street shows that the number of adequate gaps in the traffic stream during the period when the schoolchildren are using the crossing is less than the number of minutes in the same period (see Section 7A.03) and there are a minimum of 20 schoolchildren during the highest crossing hour.**

Figure 4C-5. Warrant 4, Pedestrian Four-Hour Volume



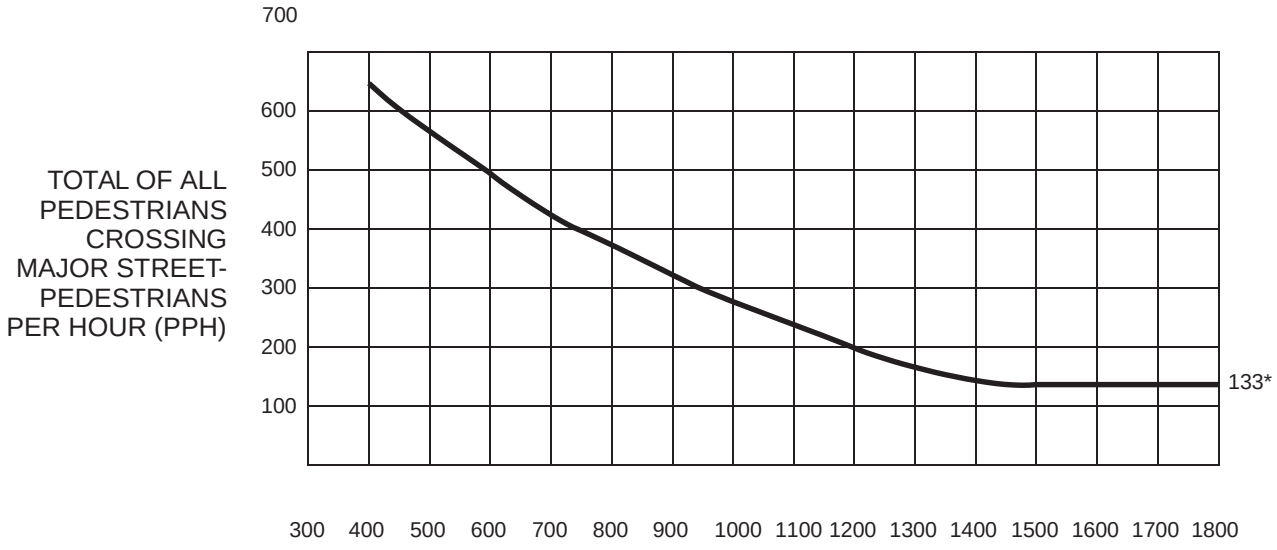
*Note: 107 pph applies as the lower threshold volume.

Figure 4C-6. Warrant 4, Pedestrian Four-Hour Volume (70% Factor)



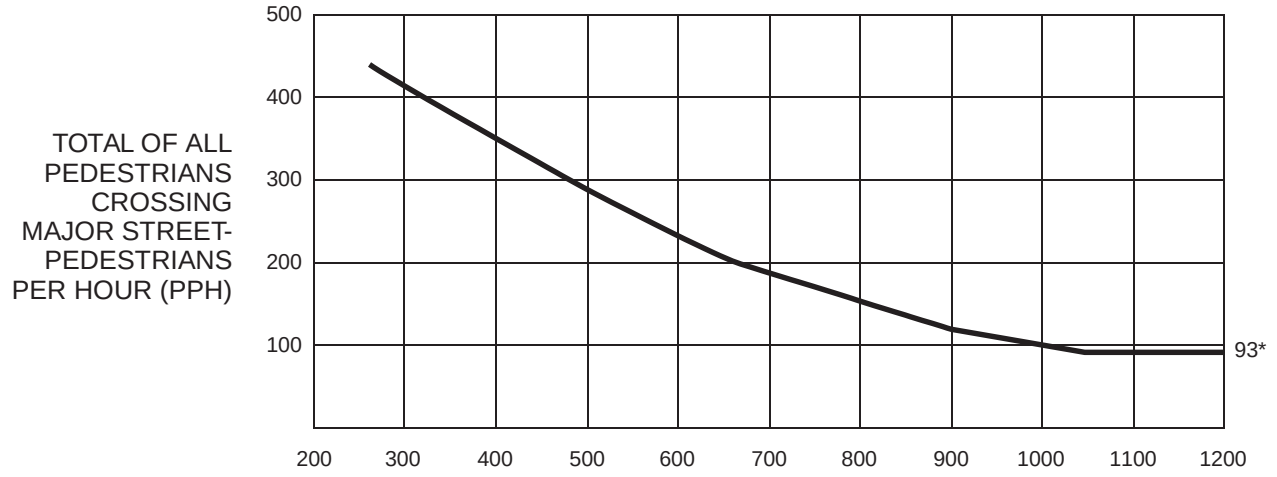
*Note: 75 pph applies as the lower threshold volume.

Figure 4C-7. Warrant 4, Pedestrian Peak Hour



*Note: 133 pph applies as the lower threshold volume.

Figure 4C-8. Warrant 4, Pedestrian Peak Hour (70% Factor)



*Note: 93 pph applies as the lower threshold volume.

03 **Before a decision is made to install a traffic control signal, consideration shall be given to the implementation of other remedial measures, such as warning signs and flashers, school speed zones, school crossing guards, or a grade-separated crossing.**

04 **The School Crossing signal warrant shall not be applied at locations where the distance to the nearest traffic control signal along the major street is less than 300 feet, unless the proposed traffic control signal will not restrict the progressive movement of traffic.**

Guidance:

05 *If this warrant is met and a traffic control signal is justified by an engineering study, then:*

A. If it is installed at an intersection or major driveway location, the traffic control signal should also control the minor-street or driveway traffic, should be traffic-actuated, and should include pedestrian detection.

B. If it is installed at a non-intersection crossing, the traffic control signal should be installed at least 100 feet from side streets or driveways that are controlled by STOP or YIELD signs, and should be pedestrian-actuated. If the traffic control signal is installed at a non-intersection crossing, at least one of the signal faces should be over the traveled way for each approach, parking and other sight obstructions should be prohibited for at least 100 feet in advance of and at least 20 feet beyond the crosswalk or site accommodations should be made through curb extensions or other techniques to provide adequate sight distance, and the installation should include suitable standard signs and pavement markings.

C. Furthermore, if it is installed within a signal system, the traffic control signal should be coordinated.

Section 4C.07 Warrant 6, Coordinated Signal System

Support:

01 Progressive movement in a coordinated signal system sometimes necessitates installing traffic control signals at intersections where they would not otherwise be needed in order to maintain proper platooning of vehicles.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that one of the following criteria is met:**

A. On a one-way street or a street that has traffic predominantly in one direction, the adjacent traffic control signals are so far apart that they do not provide the necessary degree of vehicular platooning.

B. On a two-way street, adjacent traffic control signals do not provide the necessary degree of platooning and the proposed and adjacent traffic control signals will collectively provide a progressive operation.

Guidance:

03 *The Coordinated Signal System signal warrant should not be applied where the resultant spacing of traffic control signals would be less than 1,000 feet.*

Section 4C.08 Warrant 7, Crash Experience

Support:

01 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.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that all of the following criteria are met:**

A. Adequate trial of alternatives with satisfactory observance and enforcement has failed to reduce the crash frequency; and

B. Five or more reported crashes, of types susceptible to correction by a traffic control signal, have occurred within a 12-month period, each crash involving personal injury or property damage apparently exceeding the applicable requirements for a reportable crash; and

C. For each of any 8 hours of an average day, the vehicles per hour (vph) given in both of the 80 percent columns of Condition A in Table 4C-1 (see Section 4C.02), or the vph in both of the 80 percent columns of Condition B in Table 4C-1 exists on the major-street and the higher-volume minor-street approach, respectively, to the intersection, or the volume of pedestrian traffic is not less than 80 percent of the requirements specified in the Pedestrian Volume warrant. These major-street and minor-street volumes shall be for the

same 8 hours. On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.

Option:

03 If the posted or statutory speed limit or the 85th-percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the traffic volumes in the 56 percent columns in Table 4C-1 may be used in place of the 80 percent columns.

Section 4C.09 Warrant 8, Roadway Network

Support:

01 Installing a traffic control signal at some intersections might be justified to encourage concentration and organization of traffic flow on a roadway network.

Standard:

02 **The need for a traffic control signal shall be considered if an engineering study finds that the common intersection of two or more major routes meets one or both of the following criteria:**

- **A. The intersection has a total existing, or immediately projected, entering volume of at least 1,000 vehicles per hour during the peak hour of a typical weekday and has 5-year projected traffic volumes, based on an engineering study, that meet one or more of Warrants 1, 2, and 3 during an average weekday; or**
- **B. The intersection has a total existing or immediately projected entering volume of at least 1,000 vehicles per hour for each of any 5 hours of a non-normal business day (Saturday or Sunday).**

03 **A major route as used in this signal warrant shall have at least one of the following characteristics:**

- **A. It is part of the street or highway system that serves as the principal roadway network for through traffic flow.**
- **B. It includes rural or suburban highways outside, entering, or traversing a city.**
- **C. It appears as a major route on an official plan, such as a major street plan in an urban area traffic and transportation study.**

Section 4C.10 Warrant 9, Intersection Near a Grade Crossing

Support:

01 The Intersection Near a Grade Crossing signal warrant is intended for use at a location where none of the conditions described in the other eight traffic signal warrants are met, but the proximity to the intersection of a grade crossing on an intersection approach controlled by a STOP or YIELD sign is the principal reason to consider installing a traffic control signal.

Guidance:

02 *This signal warrant should be applied only after adequate consideration has been given to other alternatives or after a trial of an alternative has failed to alleviate the safety concerns associated with the grade crossing. Among the alternatives that should be considered or tried are:*

- *A. Providing additional pavement that would enable vehicles to clear the track or that would provide space for an evasive maneuver, or*
- *B. Reassigning the stop controls at the intersection to make the approach across the track a non-stopping approach.*

Standard:

03 **The need for a traffic control signal shall be considered if an engineering study finds that both of the following criteria are met:**

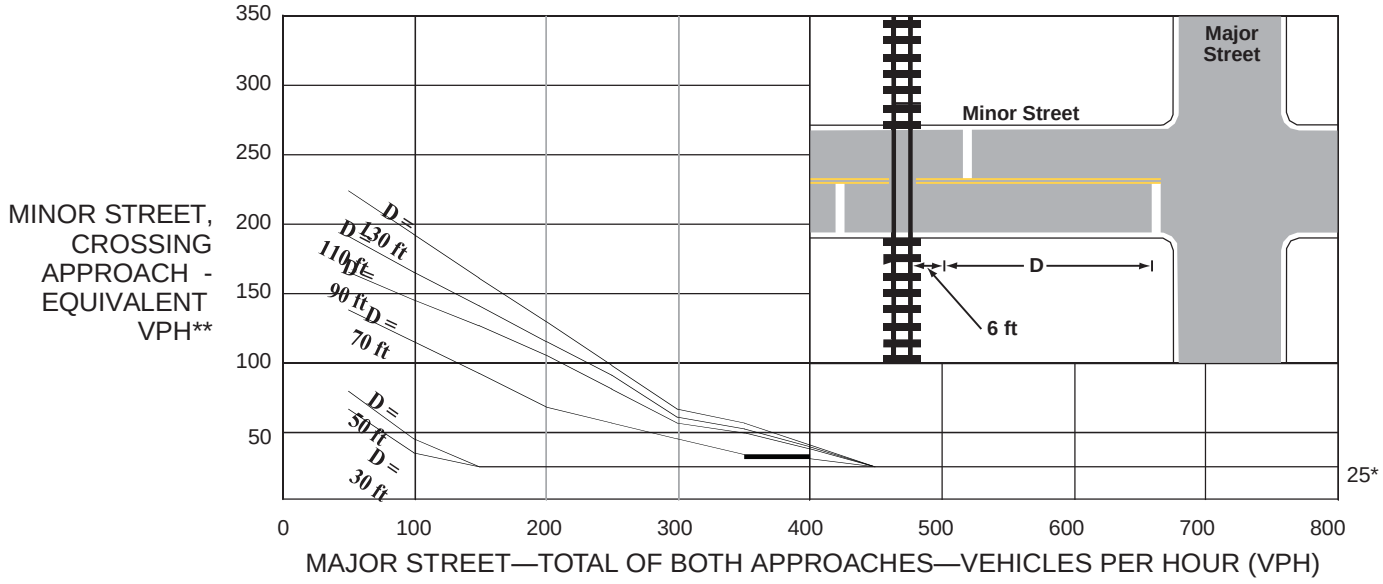
- **A. A grade crossing exists on an approach controlled by a STOP or YIELD sign and the center of the track nearest to the intersection is within 140 feet of the stop line or yield line on the approach; and**
- **B. During the highest traffic volume hour during which rail traffic uses the crossing, the plotted point representing the vehicles per hour on the major street (total of both approaches) and the corresponding vehicles per hour on the minor-street approach that crosses the track (one direction only, approaching the intersection) falls above the applicable curve in Figure 4C-9 or 4C-10 for the existing combination of approach lanes over the track and the distance D, which is the clear storage distance as defined in Section 1A.13.**

Guidance:

04 *The following considerations apply when plotting the traffic volume data on Figure 4C-9 or 4C-10:*

A. *Figure 4C-9 should be used if there is only one lane approaching the intersection at the track crossing location and Figure 4C-10 should be used if there are two or more lanes approaching the intersection at the track crossing location.*

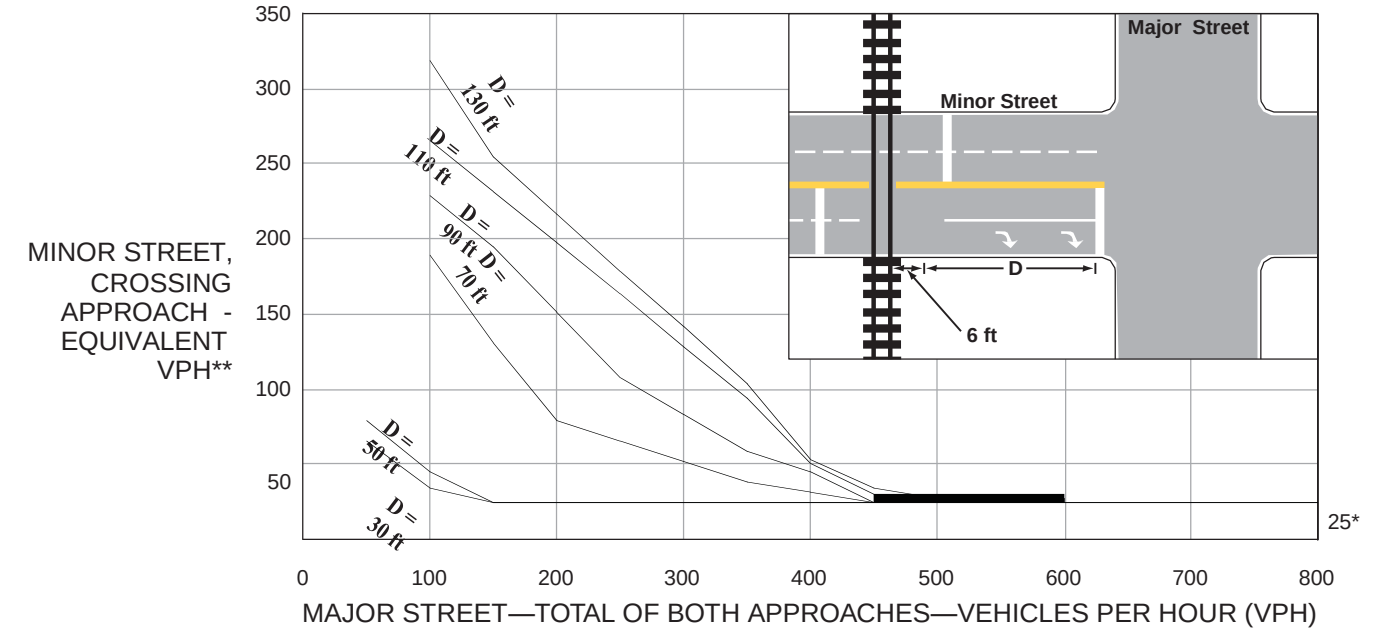
Figure 4C-9. Warrant 9, Intersection Near a Grade Crossing (One Approach Lane at the Track Crossing)



* 25 vph applies as the lower threshold volume

** VPH after applying the adjustment factors in Tables 4C-2, 4C-3, and/or 4C-4, if appropriate

Figure 4C-10. Warrant 9, Intersection Near a Grade Crossing (Two or More Approach Lanes at the Track Crossing)



* 25 vph applies as the lower threshold volume

** VPH after applying the adjustment factors in Tables 4C-2, 4C-3, and/or 4C-4, if appropriate

B. After determining the actual distance D, the curve for the distance D that is nearest to the actual distance D should be used. For example, if the actual distance D is 95 feet, the plotted point should be compared to the curve for D = 90 feet.

C. If the rail traffic arrival times are unknown, the highest traffic volume hour of the day should be used.

Option:

05 The minor-street approach volume may be multiplied by up to three adjustment factors as provided in Paragraphs 6 through 8.

06 Because the curves are based on an average of four occurrences of rail traffic per day, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-2 for the appropriate number of occurrences of rail traffic per day.

07 Because the curves are based on typical vehicle occupancy, if at least 2% of the vehicles crossing the track are buses carrying at least 20 people, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-3 for the appropriate percentage of high-occupancy buses.

08 Because the curves are based on tractor-trailer trucks comprising 10% of the vehicles crossing the track, the vehicles per hour on the minor-street approach may be multiplied by the adjustment factor shown in Table 4C-4 for the appropriate distance and percentage of tractor-trailer trucks.

Standard:

09 **If this warrant is met and a traffic control signal at the intersection is justified by an engineering study, then:**

A. The traffic control signal shall have actuation on the minor street;

B. Preemption control shall be provided in accordance with Sections 4D.27, 8C.09, and 8C.10; and

C. The grade crossing shall have flashing-light signals (see Chapter 8C).

Guidance:

10 *If this warrant is met and a traffic control signal at the intersection is justified by an engineering study, the grade crossing should have automatic gates (see Chapter 8C).*

Table 4C-2. Warrant 9, Adjustment Factor for Daily Frequency of Rail Traffic

Rail Traffic per Day	Adjustment Factor
1	0.67
2	0.91
3 to 5	1.00
6 to 8	1.18
9 to 11	1.25
12 or more	1.33

Table 4C-3. Warrant 9, Adjustment Factor for Percentage of High-Occupancy Buses

% of High-Occupancy Buses* on Minor-Street Approach	Adjustment Factor
0%	1.00
2%	1.09
4%	1.19
6% or more	1.32

* A high-occupancy bus is defined as a bus occupied by at least 20 people.

% of Tractor-Trailer Trucks on Minor-Street Approach	Adjustment Factor	
	D less than 70 feet	D of 70 feet or more
0% to 2.5%	0.50	0.50
2.6% to 7.5%	0.75	0.75
7.6% to 12.5%	1.00	1.00
12.6% to 17.5%	2.30	1.15
17.6% to 22.5%	2.70	1.35
22.6% to 27.5%	3.28	1.64
More than 27.5%	4.18	2.09