2016

Manual on Uniform Traffic Studies

Traffic Engineering & Operations Office
605 Suwannee Street, M.S. 36
Tallahassee, Florida 32399-0450

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Approved:

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Office: Traffic Engineering
Topic No.: 750-020-007-d

Department of Transportation

CHAPTER 1 MANUAL ON UNIFORM TRAFFIC STUDIES

PURPOSE:

To establish minimum standards for conducting traffic engineering studies on roads under the jurisdiction of the Florida Department of Transportation. In addition, local governmental traffic engineering agencies are recommended and encouraged to use the Manual on Uniform Traffic Studies (MUTS) as a guideline in conducting studies within their area of responsibility.

AUTHORITY:

Sections 334.044(2) and 334.044(10)(a) Florida Statutes
Rule 14-15.010, Florida Administrative Code

SCOPE:

This manual affects any office that performs traffic studies including Central Traffic Engineering Office, District Traffic Operations Offices, and Design and Planning Offices.

BACKGROUND:

Section 1A.09 of the Manual on Uniform Traffic Control Devices (MUTCD) recommends that a decision to use a particular traffic control device at a particular location should be made on the basis of either an engineering study or the application of engineering judgment.

In 1978, the Department obtained a grant from the Governor's Highway Safety Commission under the provisions of Federal Highway Safety Standard No. 13 to develop a Manual on Uniform Traffic Studies. The Manual was developed to provide a more efficient, standardized process for compiling and analyzing data collected during traffic engineering study activities. Subsequently, this Manual was completed, distributed, and has been updated periodically. Currently, it serves as a basic tool for district traffic operations studies and as a guideline for local governmental traffic engineering agencies.

This Manual shall constitute minimum guidance for use in conducting traffic engineering studies. The Manual's chapters and forms or data collection sheets are not shown in any particular order. Accordingly, sections applicable to a specific situation or problem should be considered on an individual basis.

District Traffic Operations Engineers and Design Engineers shall have studies performed by their staff or by Consultants conform, as a minimum, to the practices and techniques prescribed by the manual and shall incorporate the Manual by reference in consultant contract documents.

1.1 DISTRIBUTION

This manual is available free of charge and can be viewed and/or downloaded electronically through the Department's website under the following link:

http://www.dot.state.fl.us/trafficoperations/Operations/Studies/MUTS/MUTS.shtm

1.2 REVISIONS AND ADDITIONS

(1) The District Traffic Operations Engineers (DTOE) and the State Traffic Operations Engineer (STOE) will constitute the Manual Review Committee.

(2) All revisions will be coordinated through the Forms and Procedures Office prior to implementation.

(3) The STOE shall periodically review, amend, or revise the Manual to be compatible with current technology and state-of-the-art methods and practices.

(4) Comments or suggestions for improving the Manual may be submitted by email or in writing to the STOE, 605 Suwannee Street, Mail Station 36, Tallahassee, Florida 32399-0450, along with appropriate supporting information or data. Any time a revision is initiated by the STOE, comments will be solicited from the DTOE and any other affected offices. Their concerns, when appropriate, will be incorporated into the revision.

(5) Substantive revisions, as determined by the Manual Review Committee, will be approved by the Executive Board following the process established in the Standard Operating System.

(6) The Manual will include a section labeled "Transmittals" for retaining copies of transmittals of revisions and updates. Such transmittals will summarize changes to the Manual.

1.3 TRAINING

No training is required.

1.4 FORMS ACCESS

All forms in this Manual have been standardized and are available in the ***FDOT Forms Library***. Reproducible and electronic copies of the applicable forms are also available.

Chapter 3:

Form 750-020-01, Traffic Signal Warrant Summary

Chapter 4:

Form 750-020-02, Summary of Vehicle Movements
Form 750-020-03, Vehicle Movements Data Sheet

Chapter 5:

Form 750-020-05a, Rural Two-Lane Roadway Segment Data Collection
Form 750-020-05b, Rural Multi-Lane Roadway Segment Data Collection
Form 750-020-05c, Urban/Suburban Arterial Segment Data Collection
Form 750-020-05d, Other Roadway Segment Data Collection
Form 750-020-05e, Rural Two-Lane Roadway Intersection Data Collection
Form 750-020-05f, Rural Multi-Lane Roadway Intersection Data Collection
Form 750-020-05g, Urban/Suburban Arterial Intersection Data Collection
Form 750-020-05h, Other Intersection Data Collection
Form 750-020-05i, Collision Diagram for Segments
Form 750-020-05, Collision Diagram for Intersections
Form 750-020-06, Collision Summary

Chapter 6:

Form 750-020-04, Condition Diagram

Chapter 7:

Form 750-020-07, Intersection Delay Study

Chapter 8:

Form 750-020-08, Gap Study

Chapter 9:

Form 750-020-09, Pedestrian and Bicycle Volume Sheet
Form 750-020-10, Summary of Pedestrian and Bicycle Movements

Chapter 10:

Form 750-020-12, Advisory Speed Study

Chapter 11:

Form 750-020-13, No-Passing Zone Study

Chapter 12:

Form 750-010-03, Vehicle Spot Speed Study

Chapter 13:

Form 750-020-14, Travel Time and Delay Study Field Data Sheet
Form 750-020-19, Travel Time and Delay Study Field Summary

Chapter 14:

Form 750-020-20, Lighting Geometric and Operational Factors
Form 750-020-21-a, Present Worth Analysis for Rural-Two Lane Road
Form 750-020-21-b, Present Worth Analysis for Rural-Multilane Road
Form 750-020-21-c, Present Worth Analysis for Urban and Suburban Arterials
Form 750-020-15, Guidelines for Determining the Operational Status Mainline Sections
Form 750-020-16, Guidelines for Determining the Operational Status Interchanges
Form 750-020-17, Guidelines for Determining the Operational Status System Analysis

CHAPTER 2 TRAFFIC SIGNAL STUDY PROCEDURE

2.1 PURPOSE

(1) The purpose of this chapter is to present to the traffic engineer a guide for conducting comprehensive traffic signal studies. The information, techniques, and instructions presented herein were formulated from the ***Manual on Uniform Traffic Control Devices (MUTCD)*** and experiences of practicing traffic engineers.

(2) This manual is not all-inclusive in addressing traffic signal study situations; rather, it is a general guide for determining the installation of a new traffic signal or improvement of the operation of an existing traffic signal. This manual begins assuming the existence of an alleged problem concerning traffic control at a particular location. Subsequent chapters outline the observation of problem symptoms, establishment of areas of concern, collection and analysis of data, and preparation of a traffic signal study report.

(3) This chapter provides a logical and systematic data collection procedure for investigating traffic signal requirements. This chapter is intended to minimize the data collection effort and reduce the number of field reviews. ***Figure 2-1*** presents a flow chart of the procedure outlined in the following text. ***Figure 2-2*** is a detailed version of ***Figure 2-1*** showing the various steps of some of the major processes.

2.2 LEARNING OF THE PROBLEM

(1) This is the stage during which the traffic engineer receives notice from the public, civic organizations, businesses, etc., regarding their desire or need for a traffic signal to be installed or modified at a given site. During this stage the problem is yet to be defined.

(2) The traffic engineer is required to respond to a notice regardless of its source. The traffic engineer should first conduct an observation of the site to determine if a full scale investigation is required. This determination will be based on the observation of problem symptoms at the site, as described in the following section. Finally, the engineer should contact the reporting party about the action to be initiated.

Figure 2-1. Flow Chart of Study Procedure

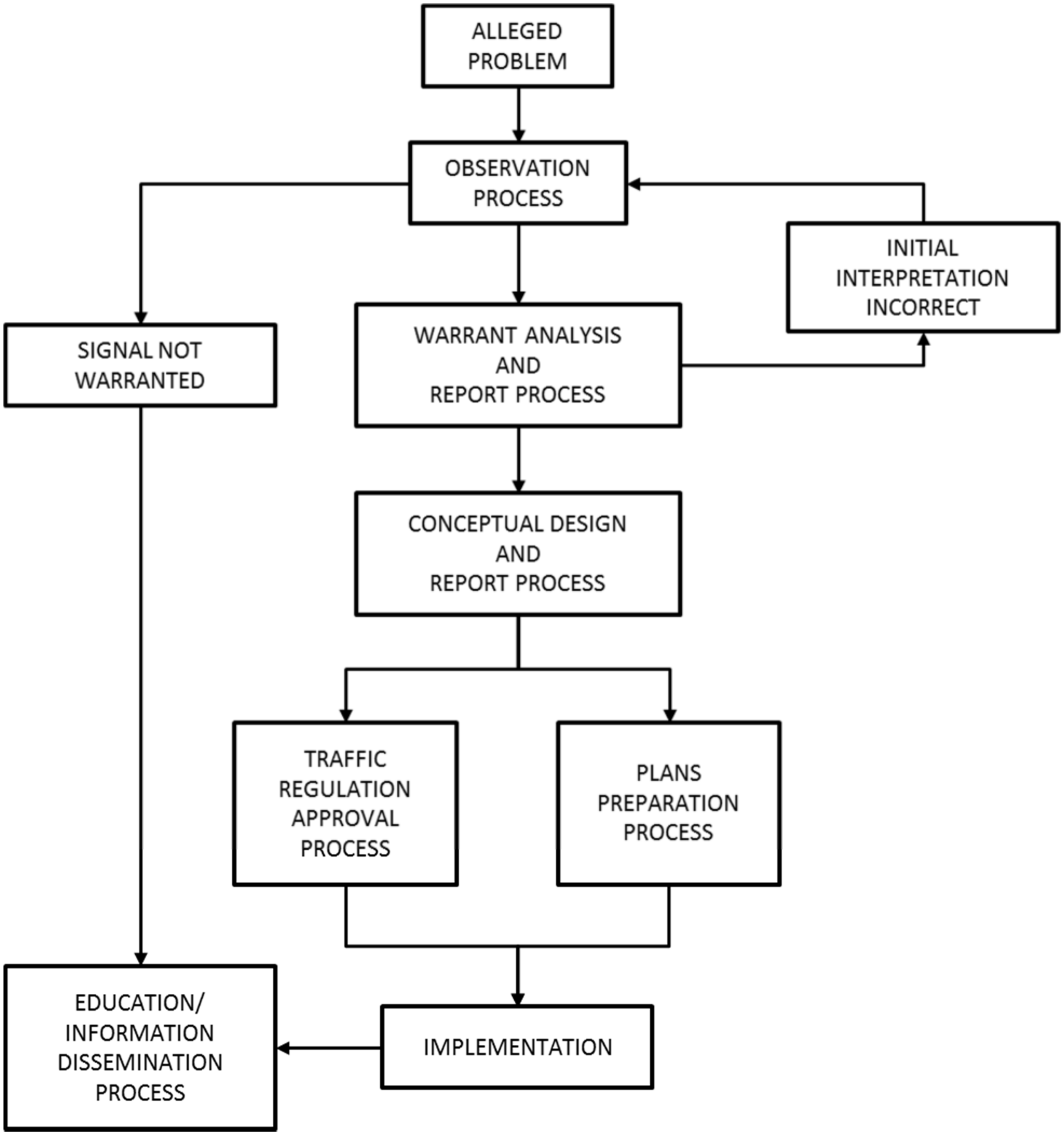
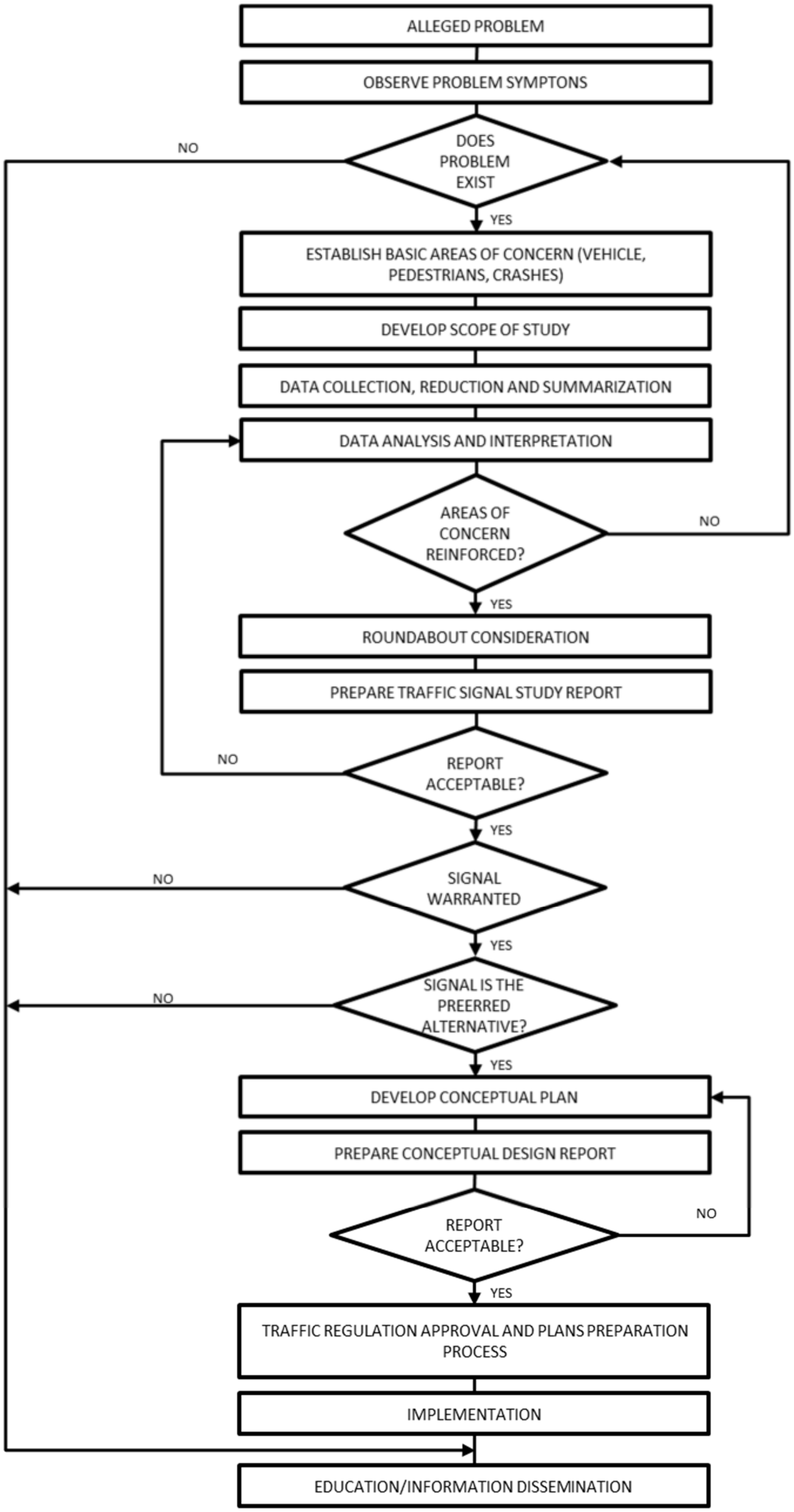


Figure 2-2. Detail of Study Procedure



2.3 OBSERVATION OF PROBLEM SYMPTOMS

(1) During the initial observation or field investigation of the site, a number of items should be noted. The preparation of a ***Condition Diagram (Chapter 6 Section 6.1)*** should be made at this time if none exists for the site. The ***Condition Diagram*** shows the location of traffic control devices, intersection geometry, and other physical features. If the engineer has an existing ***Condition Diagram***, it should be updated if necessary. Note that it is not necessary for this diagram to be drawn to scale.

(2) The engineer should observe the operational and geometric characteristics of the location and note any unusual or significant circumstances. Ideally, operations should be observed during the hours of the day when the operational problems were reported to have occurred. Color photographs of each approach and video of traffic operations and intersection geometry often save subsequent trips back to the study location.

(3) After observation of operational and geometric conditions, the engineer may determine if a real problem exists or no further investigation is warranted. Should it be determined that no problem exists, the engineer should respond either in writing or verbally to the person responsible for the initial contact regarding the site. Should it be determined that further investigation is warranted, the engineer should continue the investigation. Additionally, the engineer should notify the concerned party(ies) of the intent to investigate the site for possible signalization and provide an approximate schedule.

2.4 ESTABLISHING BASIC AREAS OF CONCERN

(1) The areas of concern can be grouped into three basic categories: **vehicle, pedestrian/bicycle,** and **crashes** and are addressed in this section. Establishing the basic area(s) of concern requires engineering judgment. Some cases are straightforward such as excessive vehicle delays, while others may be more subtle. It should be noted that the problem under consideration may be the result of more than one basic area of concern.

(2) Decisions made by the traffic engineer will provide the basis for data collection efforts to be made during the investigation. Warrants for signal installation, taken from the ***MUTCD***, are correlated with studies contained in this manual.

2.4.1 Vehicle

(1) A **vehicle** problem can normally be diagnosed during the field observation. Some of these characteristics are: excessive queue lengths, slow queue dissipation rates, and/or large traffic volumes using the intersection, etc.

(2) Typically, the data collected to determine the extent of a vehicle problem includes one or more of the following:

(a) Hourly approach volumes on an average day, as required for ***MUTCD Warrants 1, 2, 3, 8 and 9*** ***(Sections 3.6, 3.7, 3.8, 3.13, and 3.14)***. Right-turn volume reductions should be addressed per Chapter 3.

(b) Progressive Movement - distance to nearest signal greater than 1000 feet as required for **MUTCD Warrant 6** **(Section 3.11).**

(c) Travel Time and Delay Study ***(Chapter 13).***

(d) Intersection Delay Study ***(Chapter 7).***

2.4.2 Pedestrian and/or Bicycle

(1) A **pedestrian and/or bicycle** problem can also be diagnosed through field observation. However, the severity of this problem is difficult to ascertain without additional data collection.

(2) The types of data which may be needed for this problem investigation are summarized below:

(a) Pedestrian and Bicycle Volume Studies ***(Chapter 9)*** as required for ***MUTCD Warrants 4 and 5*** ***(Sections 3.9 and 3.10).***

(b) Gap Study ***(Chapter 8)*** as required for ***MUTCD Warrant 4*** ***(Section 3.9)***.

(c) Distance to nearest crosswalk, or signalized intersection is greater than 300 feet as required for ***MUTCD Warrant 4*** ***(Section 3.9).***

(d) Characteristics of pedestrians such as age, disability, average walking speed, etc.

2.4.3 Crashes

(1) The determination of an intersection's crash potential during a short field observation is difficult. Some evidence of crash occurrence may consist of damaged sign supports or tire skid marks, however, crash frequency cannot be determined from observation alone. Historical crash frequency should be determined by reviewing past crash records. The number of years that are needed for review will be determined based on the existence of any recent projects at the site. If no projects have occurred, a minimum of one year of crash data should be reviewed. Crashes may be related to demographic, operational, or geometric characteristics of an intersection.

(2) The following information can be used to further define a crash problem; note that the list provided is neither all-inclusive, nor suggested as a minimum effort:

(a) Historical records of recent projects or treatments, as well as existing or proposed projects

(b) Hourly approach volumes for the highest 8 hours as required for ***MUTCD Warrants 1, 2, 6, and 8*** ***(Sections 3.6, 3.7, 3.11 and 3.13)***

(c) Crash records/rates as required for ***MUTCD Warrant 7*** ***(Section 3.12)***

(d) Collision Diagram ***(Chapter 5)***

(e) Pedestrian Volume Count ***(Chapter 9)*** as required for ***MUTCD Warrants 4 and 5*** ***(Sections 3.9 and 3.10)***

(f) Vehicle Spot Speed Study ***(Chapter 12)***

(g) Sight distances

(h) Geometry: vertical and horizontal alignment

(i) Pavement condition for skid resistance

(j) Roadside hazards

(k) Existing guidance through signing and marking

(l) Existing roadway lighting

(m) Traffic conflict investigation and analysis

2.5 DATA COLLECTION, REDUCTION, AND SUMMARIZATION

(1) Conducting the previously mentioned studies generates a large volume of data. The study sheets and techniques available in this Manual are designed to allow for use as field collection sheets, reduction sheets, and summary sheets, thus reducing the amount of paperwork and time required to finalize field work. See the individual chapters contained herein for more information regarding data collection, reduction, and summarization.

2.6 DATA ANALYSIS AND INTERPRETATION

(1) Once the appropriate data for the warrant analysis has been collected, it is the traffic engineer's responsibility to analyze and interpret it.

(2) Application of the ***Traffic Signal Warrant Summary*** can be made in a straightforward manner and provides the traffic engineer with information concerning the minimum conditions for justifying signal installation. Instructions for use of the ***Traffic Signal Warrant Summary (Form No. 750-020-01)*** are included in ***Chapter 3*** of this Manual. Further explanation of the individual warrants can be found in ***Chapter 4C of the MUTCD.***

(3) Engineering judgment plays an important role in the decision to signalize an intersection. Situations may arise when a traffic signal is best not installed even though one of the nine warrants may be met. Such a condition may exist when minimum traffic volumes are present at a location, but signalization would severely interrupt mainline movement to serve a relatively small side street movement. Some additional considerations should be made by the engineer when minimum warrants have been met such that the installation of a signal does not create a greater problem. These considerations include, but are not limited to the following:

(a) Development of excessive queues on the major street

(b) Queue dissipation rates

(c) Spacing between adjacent signalized intersections

(d) Highway and intersection geometry (turn lanes)

(e) Location of stops/turnouts for public transportation

(f) Distance to pedestrian crossings and pedestrian crossing distance

(4) Note that even when a traffic signal is justified, i.e., it satisfies one or more warrants, it may not contribute to improved operations and safety of the roadway. Closely spaced intersections in high volume corridors would all meet volume warrants, but signals are not desirable at every cross street. Any of these conditions can negate the benefits intended by the traffic signal installation. The traffic engineer should also be increasingly aware of vehicle energy conservation when considering signal installation.

(5) A modern roundabout may be a preferred alternative to installing a new traffic signal for a wide range of circumstances. Roundabouts have been proven to significantly reduce crashes, especially those involving severe injuries and fatalities. Roundabouts typically provide reduced delay and vehicle queues compared to traffic signals, along with lower long-term maintenance costs. A roundabout should be considered as an alternative to signalization in accordance with ***Section 2.13.1 of the FDOT Plans Preparation Manual***.

2.7 PREPARATION AND APPROVAL OF TRAFFIC SIGNAL STUDY REPORT

(1) Proper documentation of all activities that have taken place from the initial allegation of a problem through the warrant analysis is required. A traffic signal study report that includes the following elements should be prepared:

(a) Cover/Title page that is signed and sealed

(b) Description and aerial image of intersection being considered

(c) Existing Conditions Diagram (sketch)

(d) Crash Analysis

(e) Discussion of Signal Warrant Analysis

(f) Discussion of Traffic Operations Analysis conducted using Highway Capacity Manual methodologies

(g) Recommendations (including sketch if applicable)

(h) Supplemental information or data to be submitted

- Completed Warrant Analysis Sheets
- Traffic counts (24 hour, 8 hour, A.M., P.M., and off-peak)
- Traffic projections if applicable
- Pedestrian counts (8 hours)
- Photos of the intersection
- Software analysis
- Pertinent supplemental information if needed outputs

(2) The traffic signal study report should conclude one of the following: (1) no problem exists and therefore no traffic signal is warranted; (2) a problem exists, but the solution is not a traffic signal; (3) a problem exists and a traffic signal will correct or reduce the problem; or (4) a problem exists and a traffic signal in conjunction with other improvements will correct or reduce the problem.

(3) In the first case, the traffic signal study should be terminated and the party initiating the request should be notified. It may also be beneficial to disseminate further information explaining the basis of the decision. In the second case, the traffic signal study should also be terminated, another study (non-signal related) should be initiated to resolve the problem, and proper notification should be given. In the third or fourth case, the study should be initiated to resolve the problem, and proper notification should be given. Additionally, the study should be handed over to the engineer responsible for conceptual design. It is again advisable at this point to notify the party initiating the request so that they are kept informed of the progress of the study.

2.8 DEVELOPMENT OF CONCEPTUAL DESIGN

(1) The conceptual design stage includes all activities that take place after justification of a new traffic signal installation or the operations modification of the existing signal is required. The activities leading up to the traffic signal design conceptual report, include the following:

- **(a)** Collect additional data
- **(b)** Develop alternatives
- **(c)** Evaluate alternatives
- **(d)** Select “best” alternative
- **(e)** Identify design improvement

(2) Collect additional data: this will generally be limited to the turning movement volume counts for 15-minute time periods required for developing the signal operating plan and controller timings. For modification of an existing signal, the data available is often dated, so it may also be necessary to collect updated volume counts. An example is an update of pedestrian and bicycle volume study. In any event, it is advisable to develop alternative concepts prior to the collection of additional data.

(3) Develop, evaluate, and select alternatives: the alternative development, evaluation, and selection steps are significant steps and are, therefore, only addressed in general terms in this manual. However, the basic approach is presented to provide the user with guidelines necessary to properly conduct the traffic signal study.

(4) Reasonable alternative concepts should be developed and then screened based on any known constraints such as funding, future programmed construction, etc. All the alternatives determined to be feasible by the engineer should then be evaluated using the optimization and simulation computer programs.

(5) The first step is an intersection analysis using Highway Capacity Manual methodologies to analyze measures of effectiveness for each alternative. If the intersection is within a coordinated system or a grid network, the intersection should be analyzed along with adjacent intersections using appropriate software that considers interaction between adjacent intersections. The Engineer of Record should be responsible for any model result.

(6) It is advisable to conduct an isolated signalized intersection analysis to examine all applicable phasing patterns and determine the optimal cycle length for an intersection regardless of whether it is isolated or part of a network. This may result in significant time savings, because isolated intersection outputs may allow a starting point for coordinated corridor or network analysis.

(7) Where complex traffic interactions exist due to atypical geometry or operations, consideration should be given to conducting a microsimulation analysis.

(8) An economic analysis should be conducted before proceeding to the implementation stage.

(9) Although local input from the maintaining agency is usually received through the traffic signal request, in all cases the conceptual design should reflect any special needs or conditions the maintaining agency requires.

2.9 PREPARATION AND APPROVAL OF TRAFFIC SIGNAL CONCEPTUAL DESIGN REPORT

(1) Upon completion of the conceptual design process, a traffic signal conceptual design report should be prepared. At a minimum, this report should include the following elements:

- **(a)** All elements of the traffic signal study report
- **(b)** Additional data collected, if any
- **(c)** Description of alternatives
- **(d)** Description of analyses (including appropriate software output)

(e) Recommendations of engineer

(f) Work to be performed

(g) Maintaining agency

(h) Enforcement agency

(i) Copies of resolutions, agreements, etc.

(j) Approval of recommended concept

(2) This report should be turned over to the engineer responsible for the preparation of the traffic signal plans. A copy should also be provided to the engineer responsible for conducting the necessary steps of the traffic regulation approval process. Ideally, these processes are conducted simultaneously, thus expediting the actual implementation of the traffic signal improvement.

2.10 IMPLEMENTATION

(1) Implementation of the improvement should take place as soon as possible after the project development and design report stages. Conditions change with time, and if too much time lapses before implementation, it may be necessary to repeat the entire traffic signal study procedure. For this reason, it is wise to plan traffic signal studies in close conjunction with the improvement program. If this is not done, the result may be an improvement that does not match the conditions at the site.

(2) Following implementation, the engineer should visit the site to determine if the traffic signal is operating as designed. At a minimum, the engineer should observe the operation during each critical time period, keeping in mind the original problem and/or any other problems identified in the Traffic Signal Study Report. Observations should be conducted both by foot and in a vehicle.

(3) In some cases, data collection may be necessary to determine if and how well the improvement is operating. Caution should be taken when assessing safety improvements as crashes tend to randomly fluctuate from year to year, and fluctuations may not be associated with improvements.

It is also advisable to couple the implementation of a traffic signal with public outreach preferably before implementation. This may result in a smoother transition process and draw attention to the benefits of the improvement.

2.11 TRAFFIC REGULATION APPROVAL PROCESS

(1) The traffic regulation approval process will not be addressed in this document. The user should refer to ***Topic Number 750-010-011-d, Traffic Regulation Approval Process***, for specific procedural requirements.

CHAPTER 3 TRAFFIC SIGNAL WARRANT SUMMARY

3.1 PURPOSE

(1) The ***Traffic Signal Warrant Summary (Form No. 750-020-01)*** provides a procedure to determine input into the decision of whether or not conditions at an intersection warrant the installation or the continued operation of a traffic signal. The form provided in this chapter summarizes data previously collected at the intersection. The data is drawn from a larger set of data, which can later be used to determine the proper design and operation, should signalization be warranted.

(a) Traffic signals should not be installed unless one or more of these nine warrants are satisfied. Because these are **minimum** requirements, satisfaction of a warrant is not necessarily justification or a mandate for a traffic signal. An engineering study must validate that the installation of a traffic control signal will improve the overall safety and/or operation of the intersection. Delay, congestion, crash experience, confusion, or other evidence of the need for right-of-way assignment must be shown. Alternatives to traffic control signals should be considered. ***Section 4B.04 of the MUTCD*** provides a list of possible alternatives.

(2) A **warrant** is a set of criteria used to define the relative need for, and appropriateness of, a particular traffic control device (e.g., STOP or YIELD sign, traffic signal, etc.). Warrants are usually expressed in the form of numerical requirements, such as the volume of vehicular or pedestrian traffic. A warrant normally carries with it a means of assigning priorities among several alternative choices. There are two fundamental concepts involved in this determination:

(a) The most effective traffic control device is the least restrictive while still accomplishing the intended purpose. For instance, geometric changes alone may negate the need for a traffic signal.

(b) Driver response to the influences of a traffic control device has been previously identified by observation, field experience, and laboratory tests under a variety of traffic and driver conditions.

(3) Warrants should be viewed as guidelines, not as absolute values. Satisfaction of a warrant is not a guarantee that the device is needed. The warrant analysis process is just one of the tools to be used in determining if a traffic signal is needed. Engineering judgment should be exercised in making the final determination.

The application of warrants is effective only when combined with knowledgeable engineering judgment considering all pertinent facts as noted in ***Section 1A.09***

of the MUTCD. In all cases, at least one or more warrants must be fully met before a traffic signal installation is considered.

3.2 THE TRAFFIC SIGNAL WARRANT SUMMARY (FORM NO. 750-020-01)

(1) There are nine traffic signal warrants available in the ***Traffic Signal Warrant Summary (Form No. 750-020-01)***. This form corresponds to the warrants for traffic signal installation presented in the ***MUTCD 2009 Edition***. The form is available electronically in a spreadsheet format.

(2) An Instructions and Input tab in the electronic form can be found at the beginning of the spreadsheet, see ***Figure 3-1*** for an example of the completed spreadsheet tab. The data completed electronically in the Input Sheet will be automatically carried over to the Warrant sheets, as applicable. Samples of each warrant are shown as ***Figure 3-2*** through ***Figure 3-11***.

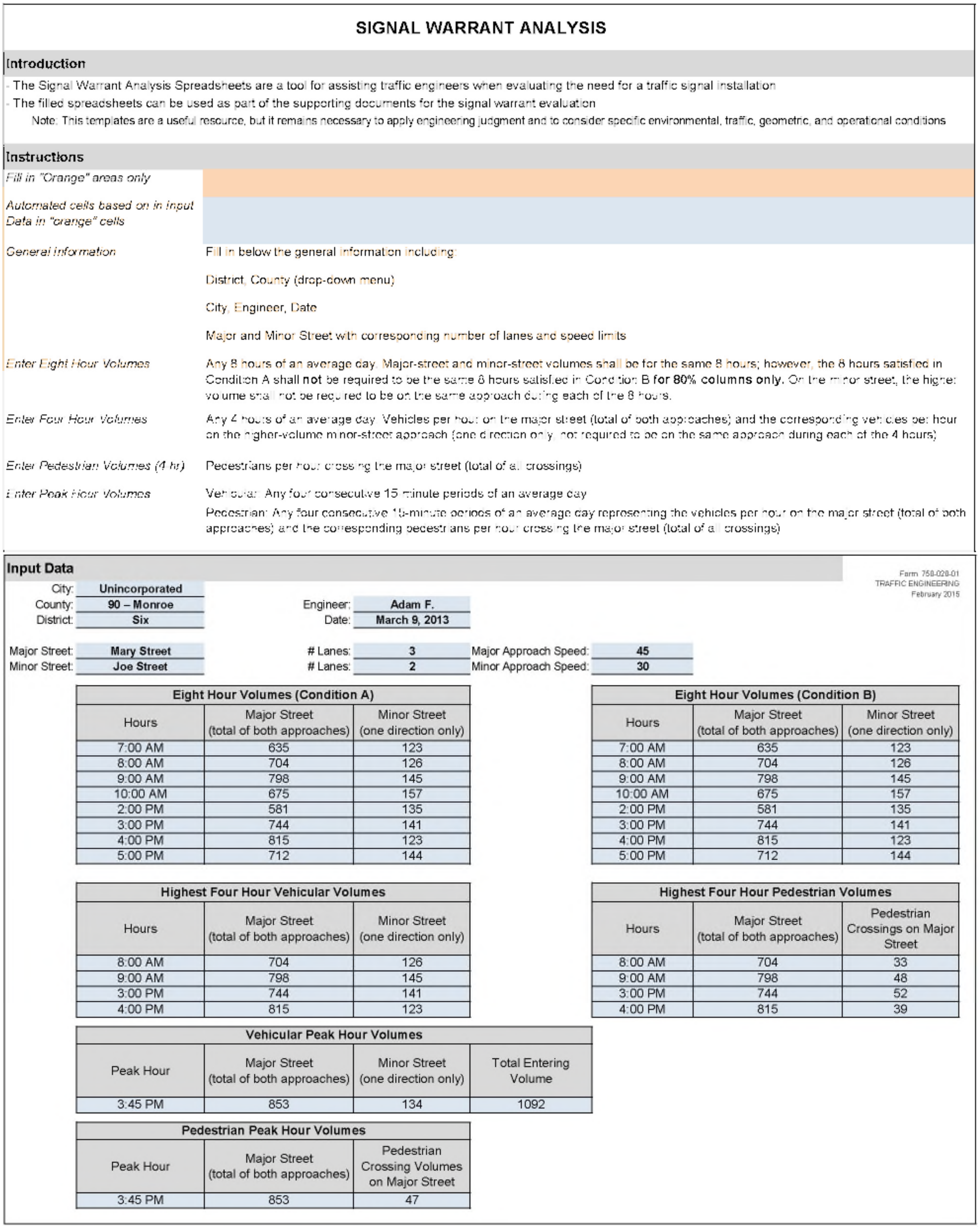
All orange highlighted cells and checkboxes shall be completed, starting with the Input sheet. The General Information completed in the Input sheet is carried over to all warrants and the summary checklist. The volumes to be completed in the Input sheet are carried over to the applicable warrants only.

(3) All nine warrants do not need to be completed if the engineer determines they are not applicable. However, the *Not Applicable* box should be checked to complete the documentation. A Warrant Summary Checklist for all warrants is provided on a separate sheet. ***Figure 3-12*** shows an example of this form completed.

(4) The investigation of the need for a traffic control signal shall include an analysis of the applicable factors contained in the following traffic signal warrants and other factors related to existing operation and safety at the study location.

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

Figure 3-1. Instructions and Input Sheets for Signal Warrant Summary



SIGNAL WARRANT ANALYSIS

Introduction

- The Signal Warrant Analysis Spreadsheets are a tool for assisting traffic engineers when evaluating the need for a traffic signal installation
- The filled spreadsheets can be used as part of the supporting documents for the signal warrant evaluation

Note: This templates are a useful resource, but it remains necessary to apply engineering judgment and to consider specific environmental, traffic, geometric, and operational conditions

Instructions

Fill in "Orange" areas only	
Automated cells based on in input Data in "orange" cells	
General information	Fill in below the general information including: District, County (drop-down menu) City, Engineer, Date Major and Minor Street with corresponding number of lanes and speed limits
Enter Eight Hour Volumes	Any 8 hours of an average day. Major-street and minor-street volumes shall be for the same 8 hours; however, the 8 hours satisfied in Condition A shall **not** be required to be the same 8 hours satisfied in Condition B **for 80% columns only.** On the minor street, the higher volume shall not be required to be on the same approach during each of the 8 hours.
Enter Four Hour Volumes	Any 4 hours of an average day. 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, not required to be on the same approach during each of the 4 hours)
Enter Pedestrian Volumes (4 hr)	Pedestrians per hour crossing the major street (total of all crossings)
Enter Peak Hour Volumes	Vehicular: Any four consecutive 15 minute periods of an average day Pedestrian: Any four consecutive 15-minute periods of an average day 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)

Input Data

Form 750-020-01
TRAFFIC ENGINEERING
February 2015

City: **Unincorporated**
County: **90 – Monroe**
District: **Six**

Engineer: **Adam F.**
Date: **March 9, 2013**

Major Street: **Mary Street** # Lanes: **3** Major Approach Speed: **45**
Minor Street: **Joe Street** # Lanes: **2** Minor Approach Speed: **30**

Eight Hour Volumes (Condition A)

Hours	Major Street (total of both approaches)	Minor Street (one direction only)
7:00 AM	635	123
8:00 AM	704	126
9:00 AM	798	145
10:00 AM	675	157
2:00 PM	581	135
3:00 PM	744	141
4:00 PM	815	123
5:00 PM	712	144

Eight Hour Volumes (Condition B)

Hours	Major Street (total of both approaches)	Minor Street (one direction only)
7:00 AM	635	123
8:00 AM	704	126
9:00 AM	798	145
10:00 AM	675	157
2:00 PM	581	135
3:00 PM	744	141
4:00 PM	815	123
5:00 PM	712	144

Highest Four Hour Vehicular Volumes

Hours	Major Street (total of both approaches)	Minor Street (one direction only)
8:00 AM	704	126
9:00 AM	798	145
3:00 PM	744	141
4:00 PM	815	123

Highest Four Hour Pedestrian Volumes

Hours	Major Street (total of both approaches)	Pedestrian Crossings on Major Street
8:00 AM	704	33
9:00 AM	798	48
3:00 PM	744	52
4:00 PM	815	39

Vehicular Peak Hour Volumes

Peak Hour	Major Street (total of both approaches)	Minor Street (one direction only)	Total Entering Volume
3:45 PM	853	134	1092

Pedestrian Peak Hour Volumes

Peak Hour	Major Street (total of both approaches)	Pedestrian Crossing Volumes on Major Street
3:45 PM	853	47

3.3 APPROACH LANES

(1) The effects of the right-turn vehicles from the minor-street approaches should be carefully considered in the study. Engineering judgment should be used to determine what, if any, portion of the right-turn traffic is deducted from the minor street traffic count when evaluating the count against the warrants presented in this chapter.

(2) The analyst should consult ***Section 4C.01 of the MUTCD***, paragraphs 08, 09, and 10 while applying engineering judgment for deducting or including right turn volumes, and determining the number of lanes and lane assignments.

(3) Intersections with approaches consisting of one lane plus one right-turn or left-turn lane should be carefully analyzed with the application of engineering judgment. Site-specific traffic characteristics will dictate whether an approach should be considered as a one lane approach or a two lane approach. For example, for a minor street approach with one through-lane plus a left-turn lane with minor traffic, engineering judgment would indicate that it should be considered as a one-lane approach. In such a case, judgment would also indicate that only the volume of traffic in the through/right turn lane should be considered against the warrants. If the left-turn lane has sufficient length to accommodate all left turn vehicles and approximately half of the traffic on the approach turns left, the approach should be considered as a two lane.

A similar rationale should be applied to a minor street approach with one shared through/left-lane plus a right-turn lane. Engineering judgment in the case of right-turn lanes must also be exercised relative to the degree of conflict of minor street right-turn traffic with traffic on the major street. If the right-turn traffic from the minor street enters the major street with minimum of conflict, the right-turn volume would not be included and only the traffic in the through/left-turn lane would be considered. Otherwise, the approach would be evaluated as a two lane approach.

(4) The following factors should be considered when applying engineering judgment to determine the portion of right turn volumes included in the minor street volume:

(a) Number of lanes on the minor street approach

(b) Presence or absence of exclusive right turn lane

(c) Presence or absence of free flow right turn

(d) Availability of gaps in major street traffic

(e) Sight distance available to right turning vehicles

(f) Percentage of minor street traffic which turns right

(g) Pedestrian and bicyclist volumes

3.4 VOLUMES

(1) The volumes of traffic should be the actual Turning Movement Counts (TMC) taken for the highest 8 to 12 hours in an average day (a weekday representing traffic volumes normally and repeatedly found at the location). Approach counts should be conducted first to determine, (1) the need for TMCs (e.g., if the volumes are too low, then 8 to 12 hours of TMCs are not needed and the warrants may be completed based on the approach counts only) and (2) the appropriate time periods for collecting TMCs. In all warrants where hourly volumes are entered, an hourly period may begin on any quarter hour (7:15, 7:30, 7:45, etc.), as long as there is no overlap among warranted hours.

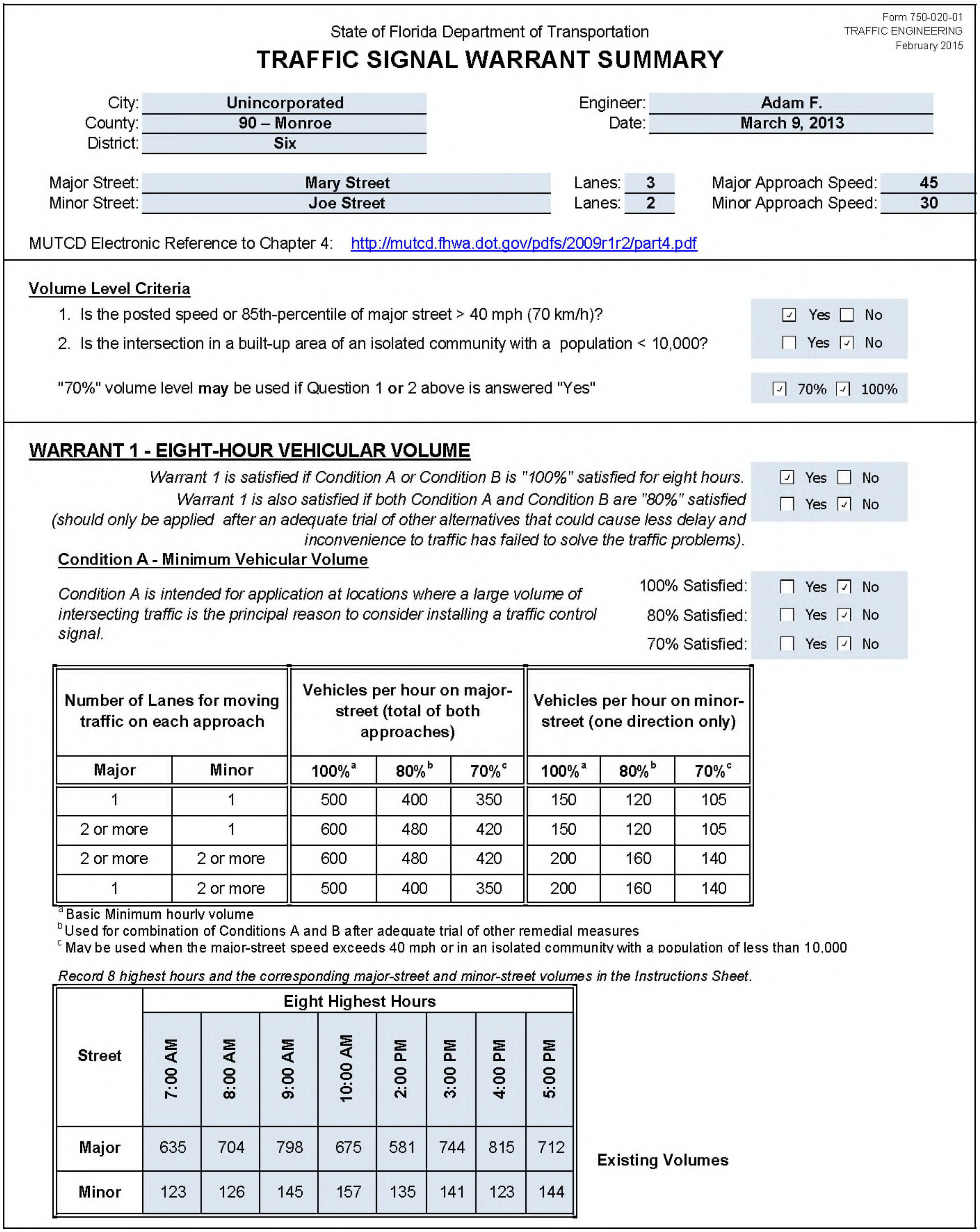
3.5 WARRANT 1: EIGHT-HOUR VEHICULAR VOLUME

(1) The Eight Hour Vehicular Volume signal warrant conditions are detailed in ***Section 4C.02 of the MUTCD***. The Minimum Vehicular Volume, Condition A is intended where a large volume of intersecting traffic is the principal reason to consider installing a traffic signal. The Interruption of Continuous Traffic, Condition B is intended where the traffic volume on a major street is so heavy that traffic on a minor intersecting street suffers excessive delay, as determined by a gap study or conflict in entering or crossing the major street. The 8 hours satisfied in Condition A are not required to be the same 8 hours satisfied in Condition B. On the minor street, the higher-volume minor-street is not required to be the same approach during each of the 8 hours.

(2) Under circumstances where Conditions A and B are not satisfied for a specific location, the combination of Conditions A and B can be applied. This combination lowers the volume threshold recommended for traffic signal installation but requires both Conditions A and B to be met. Both conditions shall be met by meeting the required vehicles per hour and higher-volume minor-street approaches for the 80% columns under both conditions. On the minor street the higher-volume minor-street is not required to be the same approach during each of the 8 hours. Under this circumstance, the major and minor street volumes shall be the same for the same 8 hours for each condition. Nonetheless, this standard should only be applied after an adequate trial of other alternatives has failed to solve the traffic problems at the particular location.

(3) **Figure 3-2 *Condition A and B*** show the portions of ***Form No. 750-020-01*** that must be completed to satisfy this warrant. This warrant should be completed based on hourly traffic volumes recorded for each approach to the intersection. The hour of the count should be noted above the appropriate columns where volumes are entered. The use of 56 percent volumes for the combination of Conditions A and B is not allowed.

**Figure 3-2. Eight Hour Vehicular Volume
Condition A**



Form 750-020-01
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: Unincorporated
County: 90 – Monroe
District: Six

Engineer: Adam F.
Date: March 9, 2013

Major Street: Mary Street — Lanes: 3 — Major Approach Speed: 45
Minor Street: Joe Street — Lanes: 2 — Minor Approach Speed: 30

MUTCD Electronic Reference to Chapter 4: http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf

Volume Level Criteria

1. Is the posted speed or 85th-percentile of major street > 40 mph (70 km/h)? ☑ Yes ☐ No
2. Is the intersection in a built-up area of an isolated community with a population < 10,000? ☐ Yes ☑ No

"70%" volume level **may** be used if Question 1 **or** 2 above is answered "Yes" ☑ 70% ☑ 100%

WARRANT 1 - EIGHT-HOUR VEHICULAR VOLUME

Warrant 1 is satisfied if Condition A or Condition B is "100%" satisfied for eight hours. ☑ Yes ☐ No

Warrant 1 is also satisfied if both Condition A and Condition B are "80%" satisfied (should only be applied after an adequate trial of other alternatives that could cause less delay and inconvenience to traffic has failed to solve the traffic problems). ☐ Yes ☑ No

Condition A - 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.

100% Satisfied: ☐ Yes ☑ No
80% Satisfied: ☐ Yes ☑ No
70% Satisfied: ☐ Yes ☑ No

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

[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

Record 8 highest hours and the corresponding major-street and minor-street volumes in the Instructions Sheet.

Street	Eight Highest Hours							
	7:00 AM	8:00 AM	9:00 AM	10:00 AM	2:00 PM	3:00 PM	4:00 PM	5:00 PM
Major	635	704	798	675	581	744	815	712
Minor	123	126	145	157	135	141	123	144

Existing Volumes

Condition B

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Condition B - Interruption of Continuous Traffic

Condition B is intended for application where Condition A is not satisfied and the traffic volume on a major street is so heavy that traffic on the minor intersecting street suffers excessive delay or conflict in entering or crossing the major street.

Applicable: ☑ Yes ☐ No
100% Satisfied: ☐ Yes ☑ No
80% Satisfied: ☐ Yes ☑ No
70% Satisfied: ☑ Yes ☐ No

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

[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

Record 8 highest hours and the corresponding major-street and minor-street volumes in the Instructions Sheet.

Eight Highest Hours								
Street	**7:00 AM**	**8:00 AM**	**9:00 AM**	**10:00 AM**	**2:00 PM**	**3:00 PM**	**4:00 PM**	**5:00 PM**
Major	635	704	798	675	581	744	815	712
Minor	123	126	145	157	135	141	123	144

Existing Volumes

3.6 WARRANT 2: FOUR-HOUR VEHICULAR VOLUME

(1) The Four-Hour Vehicular Volume signal warrant is intended to be applied where the volume of intersecting traffic is the principal reason to consider installing a traffic control signal. The warrant conditions are detailed in ***Section 4C.03 of the MUTCD***.

(2) ***Figure 3-3*** shows the portion of ***Form No. 750-020-01*** that must be completed to satisfy this warrant. The engineer should include a checkmark in the appropriate Satisfied box indicating whether the Warrant was met or not.

3.7 WARRANT 3: PEAK HOUR

(1) 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. This signal warrant shall be applied only in unusual cases, such as office complexes, manufacturing plants, industrial complexes, or high-occupancy vehicle facilities attracting or discharging large numbers of vehicles over a short time. The warrant conditions are detailed in ***Section 4C.04 of the MUTCD***.

(2) 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 the volume criteria of this warrant are not met.

(3) ***Figure 3-4*** shows the portion of ***Form No. 750-020-01*** that must be completed to satisfy this warrant.

Figure 3-3. Four-Hour Vehicular Volume

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TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **90 – Monroe**
District: **Six**

Engineer: **Adam F.**
Date: **March 9, 2013**

Major Street: **Mary Street** Lanes: **3** Major Approach Speed: **45**
Minor Street: **Joe Street** Lanes: **2** Minor Approach Speed: **30**

MUTCD Electronic Reference to Chapter 4: http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf

Volume Level Criteria

1. Is the posted speed or 85th-percentile of major street > 40 mph (70 km/h)? ☑ Yes ☐ No
2. Is the intersection in a built-up area of an isolated community with a population < 10,000? ☐ Yes ☑ No

"70%" volume level **may** be used if Question 1 **or** 2 above is answered "Yes" ☑ Yes ☐ No

WARRANT 2 - FOUR-HOUR VEHICULAR VOLUME

If all four points lie above the appropriate line, then the warrant is satisfied.

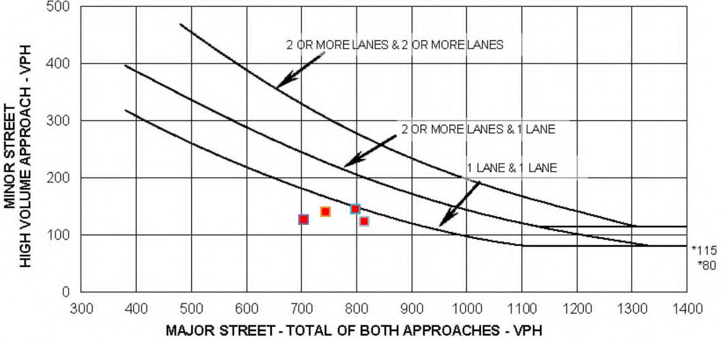
Applicable: ☑ Yes ☐ No
Satisfied: ☑ Yes ☐ No

Plot four volume combinations on the applicable figure below.

100% Volume Level

Four Highest Hours	Volumes	
	Major Street	Minor Street
8:00 AM	704	126
9:00 AM	798	145
3:00 PM	744	141
4:00 PM	815	123

FIGURE 4C-1: Criteria for "100%" Volume Level



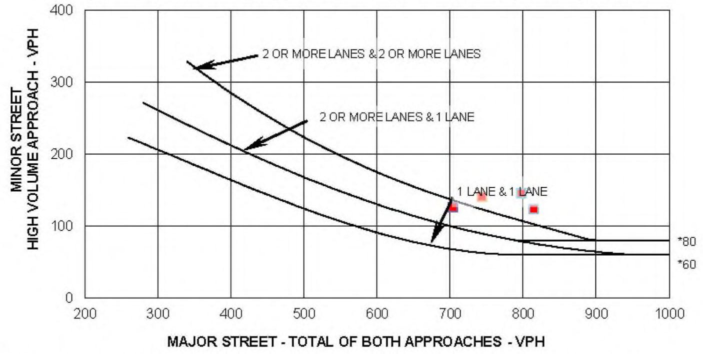
** Note: 115 vph applies as the lower threshold volume for a minor street approach with two or more lanes and 80 vph applies as the lower threshold volume threshold for a minor street approach with one lane.*

70% Volume Level

Four Highest Hours	Volumes	
	Major Street	Minor Street
8:00 AM	704	126
9:00 AM	798	145
3:00 PM	744	141
4:00 PM	815	123

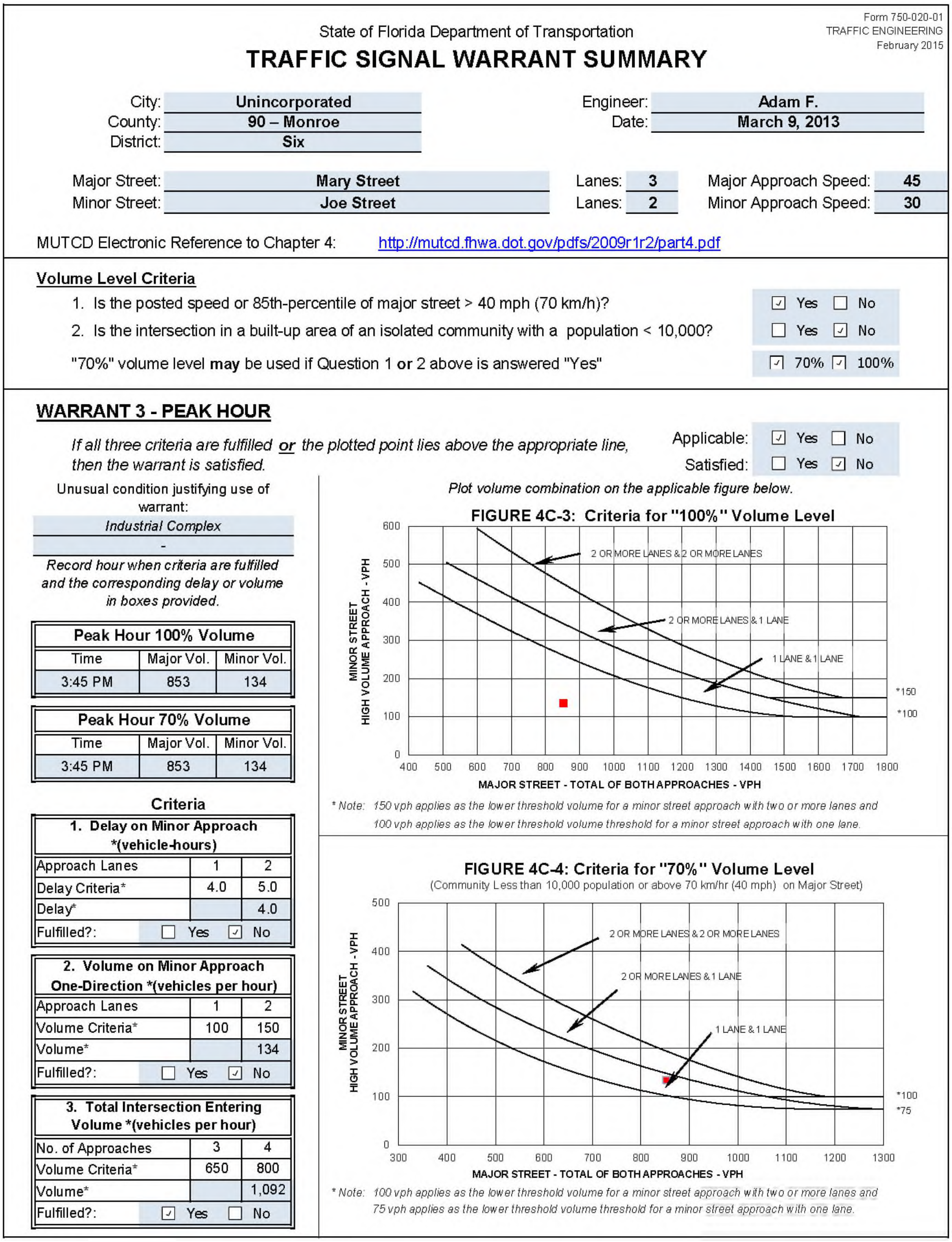
FIGURE 4C-2: Criteria for "70%" Volume Level

(Community Less than 10,000 population or above 70 km/hr (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 threshold for a minor street approach with one lane.*

Figure 3-4. Peak Hour



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TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **90 – Monroe**
District: **Six**
Engineer: **Adam F.**
Date: **March 9, 2013**

Major Street: **Mary Street** Lanes: **3** Major Approach Speed: **45**
Minor Street: **Joe Street** Lanes: **2** Minor Approach Speed: **30**

MUTCD Electronic Reference to Chapter 4: http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf

Volume Level Criteria

1. Is the posted speed or 85th-percentile of major street > 40 mph (70 km/h)? ☑ Yes ☐ No
2. Is the intersection in a built-up area of an isolated community with a population < 10,000? ☐ Yes ☑ No

"70%" volume level **may** be used if Question 1 **or** 2 above is answered "Yes" ☑ 70% ☑ 100%

WARRANT 3 - PEAK HOUR

If all three criteria are fulfilled ***or*** *the plotted point lies above the appropriate line, then the warrant is satisfied.*

Applicable: ☑ Yes ☐ No
Satisfied: ☐ Yes ☑ No

Unusual condition justifying use of warrant:
Industrial Complex
-

Record hour when criteria are fulfilled and the corresponding delay or volume in boxes provided.

Peak Hour 100% Volume		
Time	Major Vol.	Minor Vol.
3:45 PM	853	134

Peak Hour 70% Volume		
Time	Major Vol.	Minor Vol.
3:45 PM	853	134

Criteria

1. Delay on Minor Approach *(vehicle-hours)		
Approach Lanes	1	2
Delay Criteria*	4.0	5.0
Delay*		4.0
Fulfilled?:	☐ Yes	☑ No

2. Volume on Minor Approach One-Direction *(vehicles per hour)		
Approach Lanes	1	2
Volume Criteria*	100	150
Volume*		134
Fulfilled?:	☐ Yes	☑ No

3. Total Intersection Entering Volume *(vehicles per hour)		
No. of Approaches	3	4
Volume Criteria*	650	800
Volume*		1,092
Fulfilled?:	☑ Yes	☐ No

Plot volume combination on the applicable figure below.

FIGURE 4C-3: Criteria for "100%" Volume Level

** 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 threshold for a minor street approach with one lane.*

FIGURE 4C-4: Criteria for "70%" Volume Level
(Community Less than 10,000 population or above 70 km/hr (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 threshold for a minor street approach with one lane.*

3.8 WARRANT 4: PEDESTRIAN VOLUME

(1) The Pedestrian Volume signal warrant is intended where the traffic volumes on a major street are so heavy that pedestrians experience excessive delays in crossing the major street, with the determination of excessive delay being based upon a gap study. 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.

(2) A traffic signal at an intersection or midblock shall be considered using the following criteria, which should be plotted in the corresponding figures with the vehicles per hour on the major street (total of both approaches) as the x coordinates:

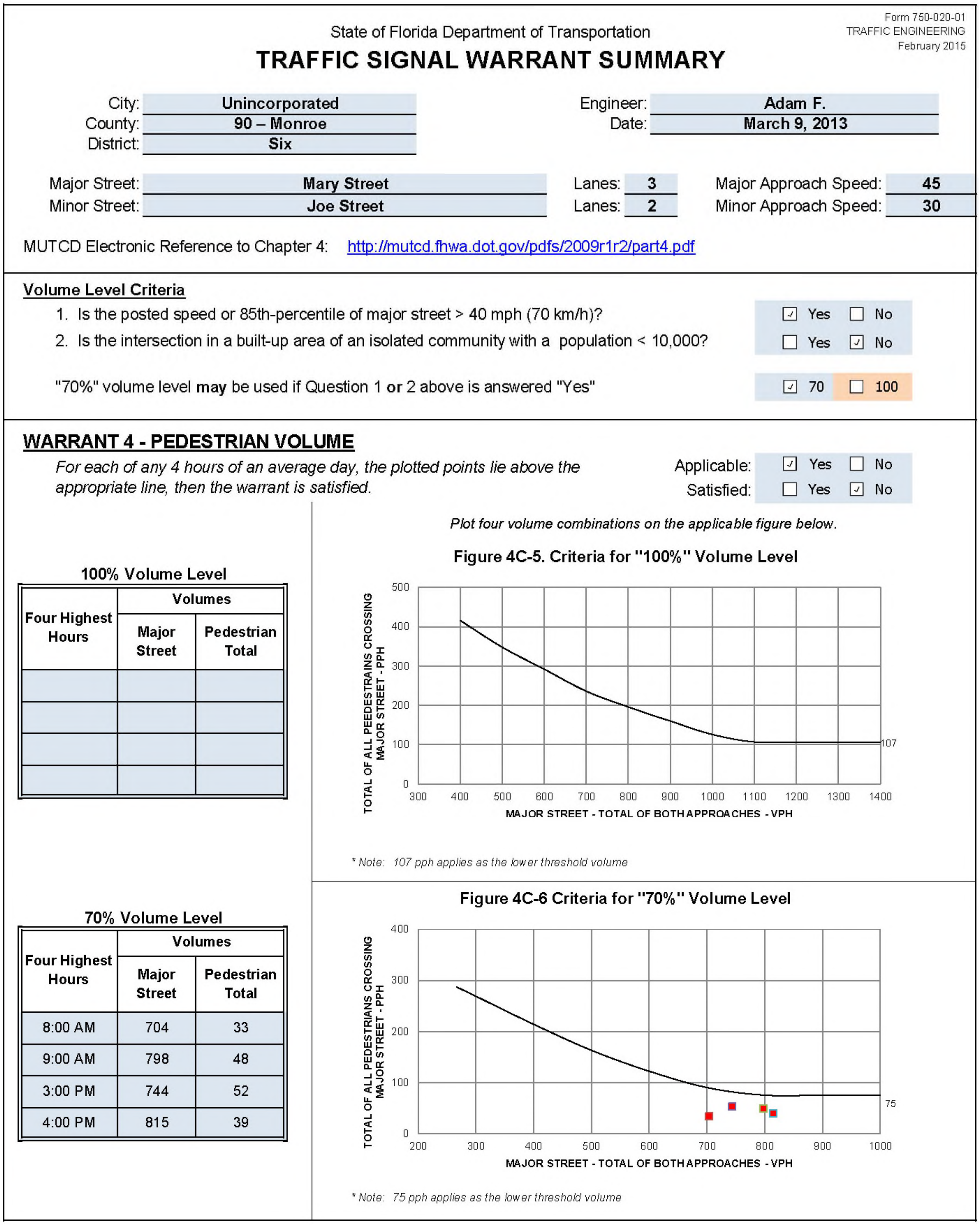
(a) Any four hours of an average day (Figures 4C-5 and 4C-6)

(b) One hour (any four consecutive 15-minute periods) of an average day (figures 4C-7 and 4-8)

(3) The total pedestrians crossing the major street along with the major street traffic volume should be plotted on Figure 4C-5 or 4C-7 from the MUTCD, depending on the criterion being evaluated. If the posted, statutory, or 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 and Figure 4C-8 may be used in place of Figure 4C-7. The warrant conditions are detailed in ***Section 4C.05 of the MUTCD***.

(4) ***Figure 3-5*** and ***Figure 3-6*** show the portions of ***Form No. 750-020-01*** that must be completed to satisfy this warrant. If a traffic control signal is justified by both this signal warrant and a traffic engineering study, the traffic control signal shall be equipped with pedestrian countdown signal heads conforming to requirements set forth in ***Chapter 4E of the MUTCD***.

Figure 3-5. Pedestrian Four-Hour Volume



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TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **90 – Monroe**
District: **Six**

Engineer: **Adam F.**
Date: **March 9, 2013**

Major Street: **Mary Street** Lanes: **3** Major Approach Speed: **45**
Minor Street: **Joe Street** Lanes: **2** Minor Approach Speed: **30**

MUTCD Electronic Reference to Chapter 4: http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf

Volume Level Criteria

1. Is the posted speed or 85th-percentile of major street > 40 mph (70 km/h)? ☑ Yes ☐ No
2. Is the intersection in a built-up area of an isolated community with a population < 10,000? ☐ Yes ☑ No

"70%" volume level **may** be used if Question 1 **or** 2 above is answered "Yes" ☑ 70 ☐ 100

WARRANT 4 - PEDESTRIAN VOLUME

For each of any 4 hours of an average day, the plotted points lie above the appropriate line, then the warrant is satisfied.

Applicable: ☑ Yes ☐ No
Satisfied: ☐ Yes ☑ No

Plot four volume combinations on the applicable figure below.

100% Volume Level

Four Highest Hours	Volumes	
	Major Street	Pedestrian Total

Figure 4C-5. Criteria for "100%" Volume Level

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

70% Volume Level

Four Highest Hours	Volumes	
	Major Street	Pedestrian Total
8:00 AM	704	33
9:00 AM	798	48
3:00 PM	744	52
4:00 PM	815	39

Figure 4C-6 Criteria for "70%" Volume Level

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

Figure 3-6. Pedestiran Peak Hour Volume

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WARRANT 4 - PEDESTRIAN VOLUME

For 1 hour (any four consecutive 15-minute periods) of an average day, the plotted point falls above the appropriate line, then the warrant is satisfied.

Applicable: ☑ Yes ☐ No
Satisfied: ☐ Yes ☑ No

Plot one volume combination on the applicable figure below.

100% Volume Level

Peak Hour	Volumes	
	Major Street	Pedestrian Total

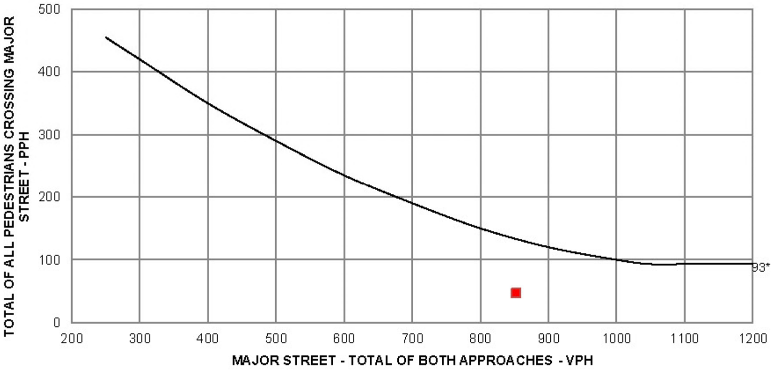
Figure 4C-7. Criteria for "100%" Volume Level - Peak Hour

* Note: 133 pph applies as the lower threshold volume

70% Volume Level

Peak Hour	Volumes	
	Major Street	Pedestrian Total
3:45 PM	853	47

Figure 4C-8 Criteria for "70%" Volume Level - Peak Hour



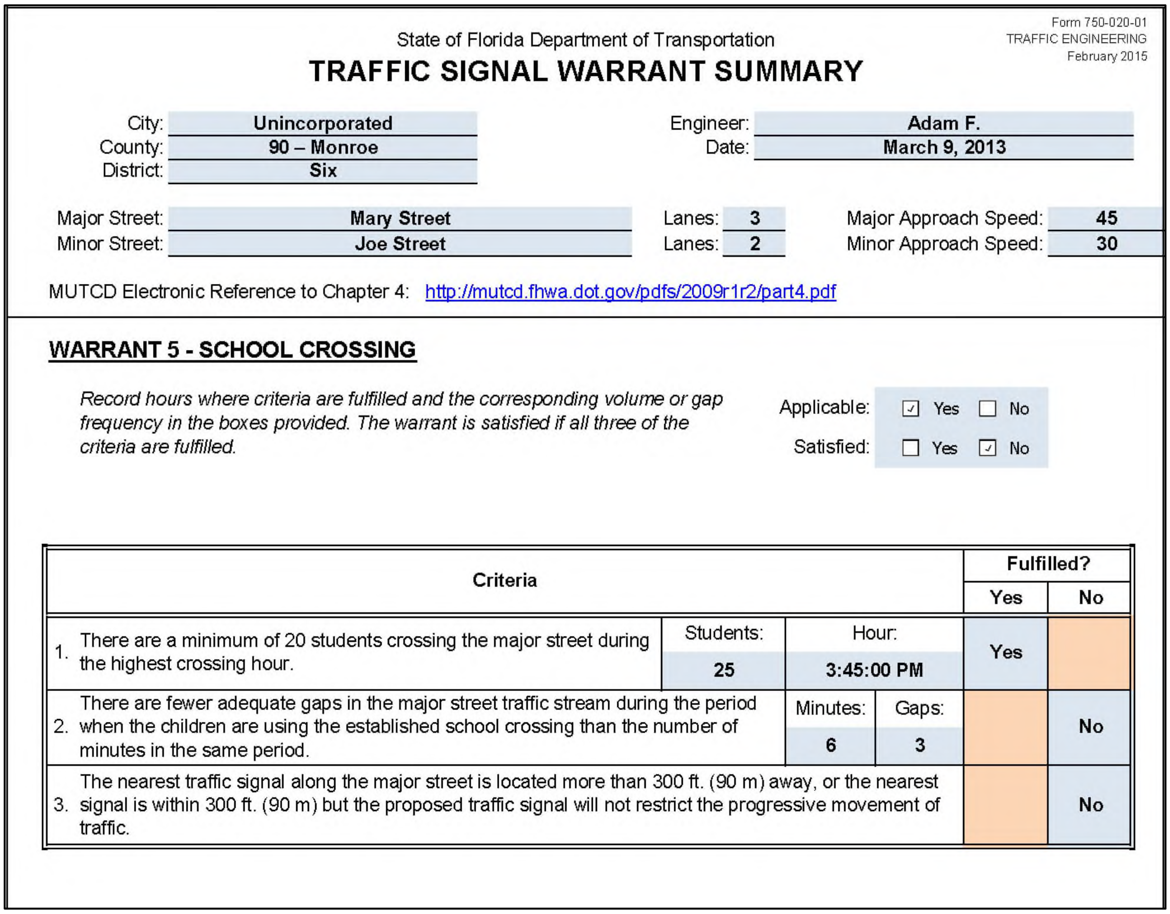
* Note: 93 pph applies as the lower threshold volume

3.9 WARRANT 5: SCHOOL CROSSING

(1) The School Crossing signal warrant is intended for application where the fact that school children cross the major street is the principal reason to consider installing a traffic control signal. The warrant conditions are detailed in ***Section 4C.06 of the MUTCD***.

(2) ***Figure 3-7*** shows the portion of ***Form No. 750-020-01*** that must be completed to satisfy this warrant.

Figure 3-7. School Crossing



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State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **90 – Monroe**
District: **Six**
Engineer: **Adam F.**
Date: **March 9, 2013**

Major Street: **Mary Street** Lanes: **3** Major Approach Speed: **45**
Minor Street: **Joe Street** Lanes: **2** Minor Approach Speed: **30**

MUTCD Electronic Reference to Chapter 4: http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf

WARRANT 5 - SCHOOL CROSSING

Record hours where criteria are fulfilled and the corresponding volume or gap frequency in the boxes provided. The warrant is satisfied if all three of the criteria are fulfilled.

Applicable: ☑ Yes ☐ No
Satisfied: ☐ Yes ☑ No

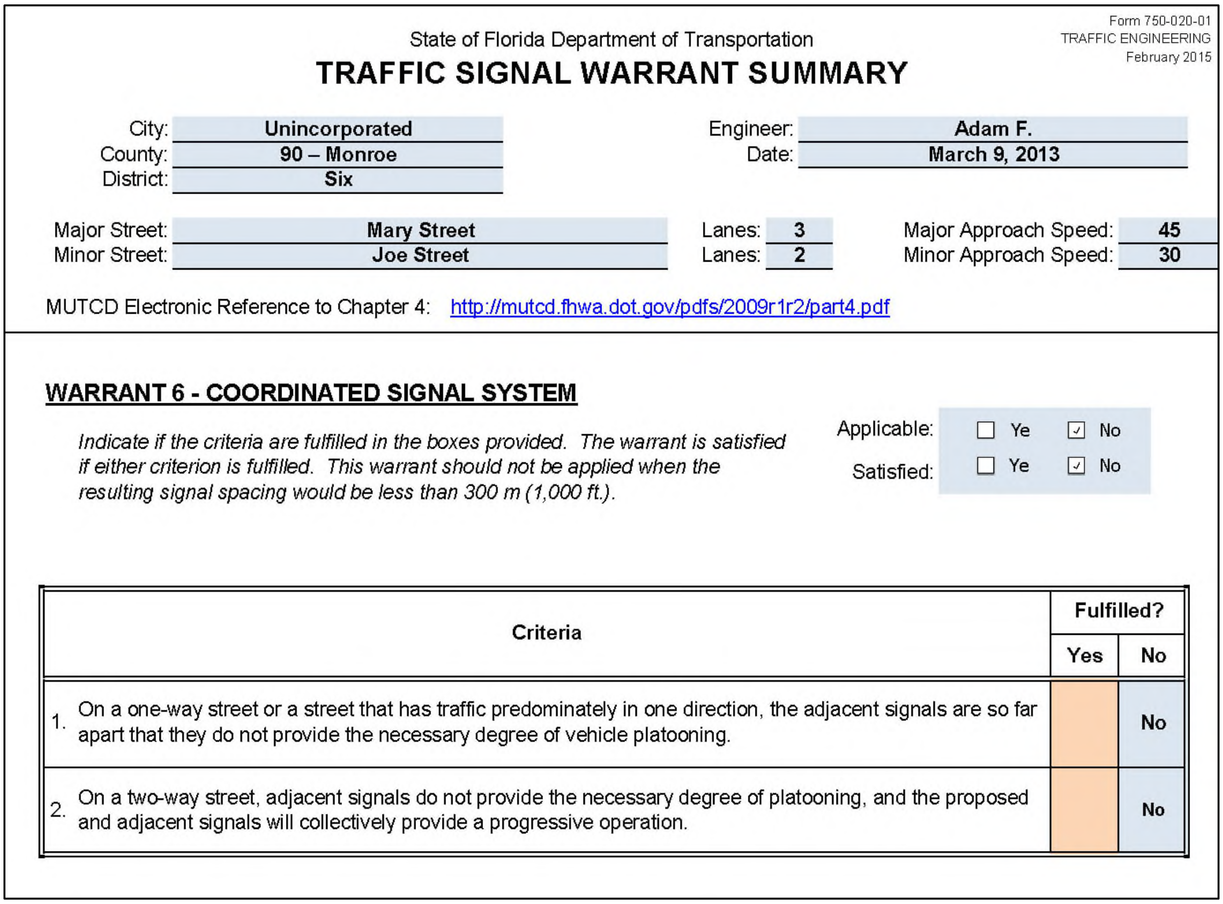
Criteria			**Fulfilled?**	
			Yes	**No**
1. There are a minimum of 20 students crossing the major street during the highest crossing hour.	Students: **25**	Hour: **3:45:00 PM**	**Yes**	
2. There are fewer adequate gaps in the major street traffic stream during the period when the children are using the established school crossing than the number of minutes in the same period.	Minutes: **6**	Gaps: **3**		**No**
3. The nearest traffic signal along the major street is located more than 300 ft. (90 m) away, or the nearest signal is within 300 ft. (90 m) but the proposed traffic signal will not restrict the progressive movement of traffic.				**No**

3.10 WARRANT 6: COORDINATED SIGNAL SYSTEM

(1) Progressive movement in a coordinated signal system sometimes necessitates installing traffic signals at intersections where they would not otherwise be needed to maintain proper platooning of vehicles. 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. The conditions for this warrant are detailed in ***Section 4C.07 of the MUTCD***.

(2) ***Figure 3-8*** shows the portion of ***Form No. 750-020-01*** that must be completed to satisfy this warrant.

Figure 3-8. Coordinated Signal System



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TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **90 – Monroe**
District: **Six**

Engineer: **Adam F.**
Date: **March 9, 2013**

Major Street: **Mary Street** Lanes: **3** Major Approach Speed: **45**
Minor Street: **Joe Street** Lanes: **2** Minor Approach Speed: **30**

MUTCD Electronic Reference to Chapter 4: http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf

WARRANT 6 - COORDINATED SIGNAL SYSTEM

Indicate if the criteria are fulfilled in the boxes provided. The warrant is satisfied if either criterion is fulfilled. This warrant should not be applied when the resulting signal spacing would be less than 300 m (1,000 ft.).

Applicable: ☐ Ye ☑ No
Satisfied: ☐ Ye ☑ No

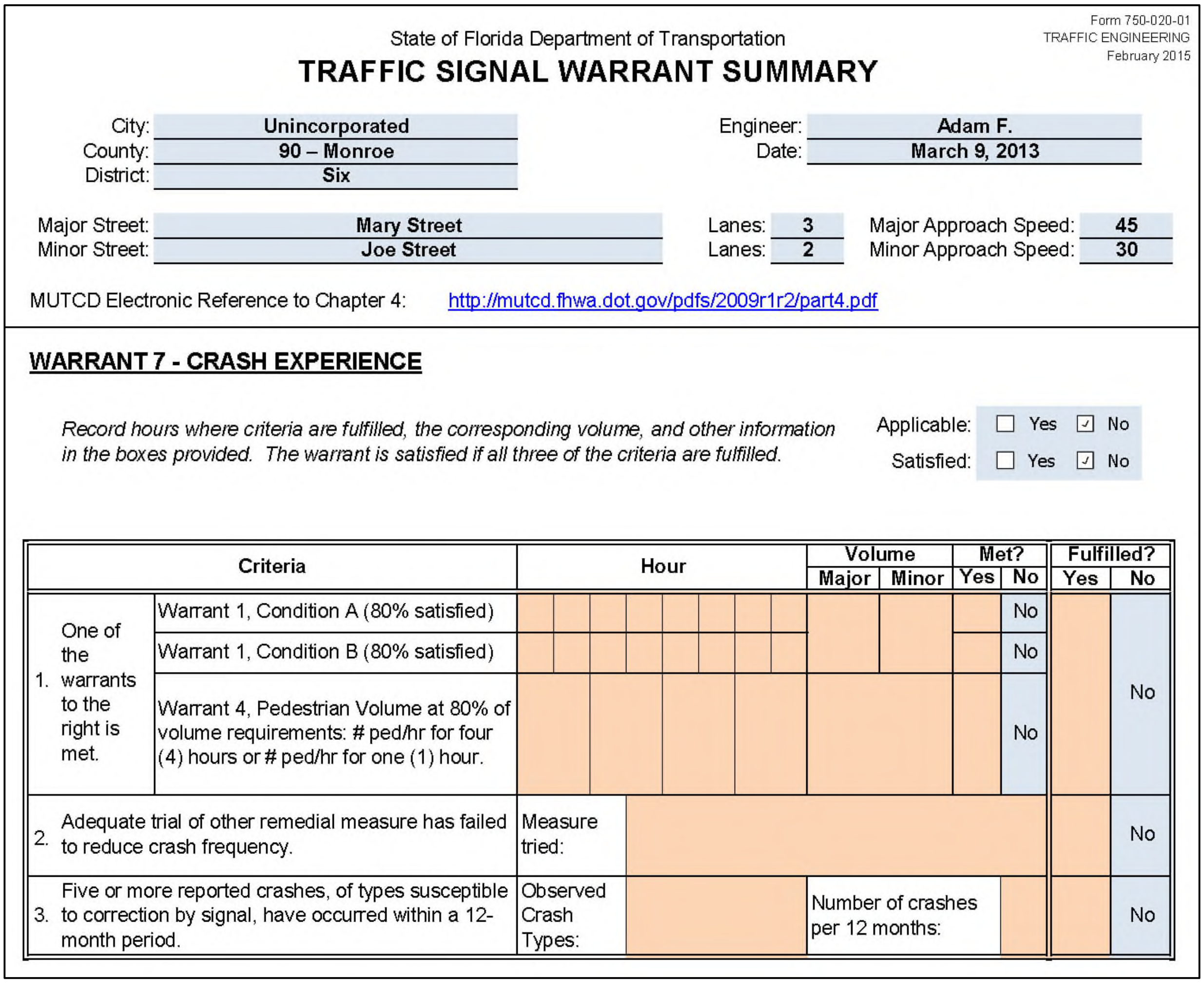
Criteria	Fulfilled?	
	Yes	**No**
1. On a one-way street or a street that has traffic predominately in one direction, the adjacent signals are so far apart that they do not provide the necessary degree of vehicle platooning.		**No**
2. On a two-way street, adjacent signals do not provide the necessary degree of platooning, and the proposed and adjacent signals will collectively provide a progressive operation.		**No**

3.11 WARRANT 7: CRASH EXPERIENCE

(1) The Crash Experience signal warrant conditions are intended for applications where the severity and frequency of crashes are the principal reasons to consider installing a traffic control signal. The conditions for this warrant are detailed in ***Section 4C.08 of the MUTCD***.

(2) ***Figure 3-9*** shows the portion of ***Form No. 750-020-01*** that must be completed to satisfy this warrant.

Figure 3-9. Crash Experience



Form 750-020-01
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation
TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **90 – Monroe**
District: **Six**
Engineer: **Adam F.**
Date: **March 9, 2013**

Major Street: **Mary Street** Lanes: **3** Major Approach Speed: **45**
Minor Street: **Joe Street** Lanes: **2** Minor Approach Speed: **30**

MUTCD Electronic Reference to Chapter 4: http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf

WARRANT 7 - CRASH EXPERIENCE

Record hours where criteria are fulfilled, the corresponding volume, and other information in the boxes provided. The warrant is satisfied if all three of the criteria are fulfilled.

Applicable: ☐ Yes ☑ No
Satisfied: ☐ Yes ☑ No

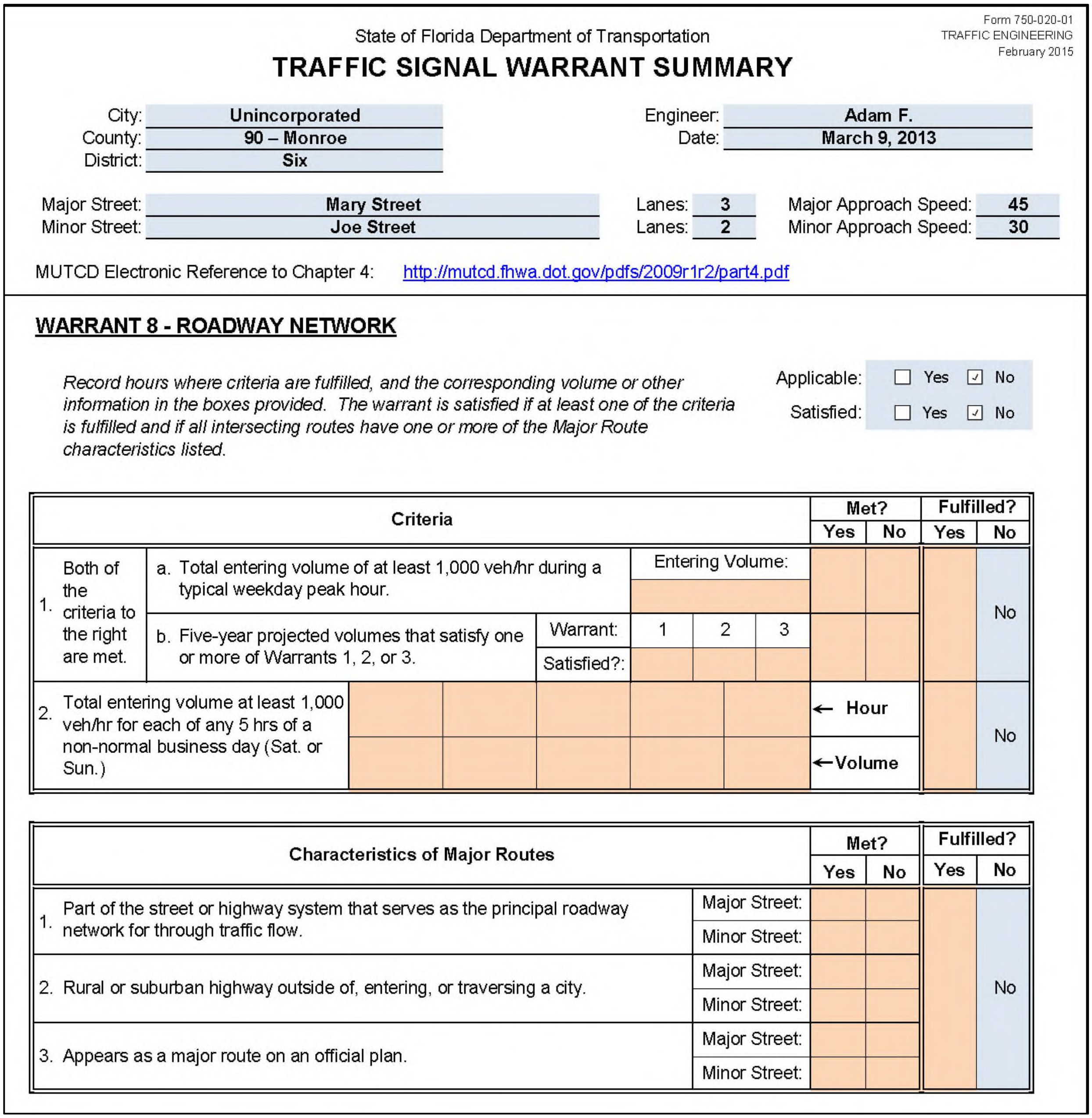
		Criteria	Hour	Volume		Met?		Fulfilled?	
				Major	Minor	Yes	No	Yes	No
1.	One of the warrants to the right is met.	Warrant 1, Condition A (80% satisfied)					No		No
		Warrant 1, Condition B (80% satisfied)					No		
		Warrant 4, Pedestrian Volume at 80% of volume requirements: # ped/hr for four (4) hours or # ped/hr for one (1) hour.					No		
2.	Adequate trial of other remedial measure has failed to reduce crash frequency.		Measure tried:						No
3.	Five or more reported crashes, of types susceptible to correction by signal, have occurred within a 12-month period.		Observed Crash Types:		Number of crashes per 12 months:				No

3.12 WARRANT 8: ROADWAY NETWORK

(1) Installing a traffic signal at some intersections may be justified to encourage concentration and organization of traffic flow on a roadway network. The conditions for this warrant are detailed in ***Section 4C.09 of the MUTCD*****.**

(2) ***Figure 3-10*** shows the portion of ***Form No. 750-020-01*** that must be completed to satisfy this warrant.

Figure 3-10. Roadway Network



Form 750-020-01
TRAFFIC ENGINEERING
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TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **90 – Monroe**
District: **Six**
Engineer: **Adam F.**
Date: **March 9, 2013**

Major Street: **Mary Street** Lanes: **3** Major Approach Speed: **45**
Minor Street: **Joe Street** Lanes: **2** Minor Approach Speed: **30**

MUTCD Electronic Reference to Chapter 4: http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf

WARRANT 8 - ROADWAY NETWORK

Record hours where criteria are fulfilled, and the corresponding volume or other information in the boxes provided. The warrant is satisfied if at least one of the criteria is fulfilled and if all intersecting routes have one or more of the Major Route characteristics listed.

Applicable: ☐ Yes ☑ No
Satisfied: ☐ Yes ☑ No

Criteria									Met?		Fulfilled?	
									Yes	No	Yes	No
1.	Both of the criteria to the right are met.	a. Total entering volume of at least 1,000 veh/hr during a typical weekday peak hour.	Entering Volume:									No
		b. Five-year projected volumes that satisfy one or more of Warrants 1, 2, or 3.	Warrant:	1	2	3						
			Satisfied?:									
2.	Total entering volume at least 1,000 veh/hr for each of any 5 hrs of a non-normal business day (Sat. or Sun.)							← Hour				No
								←Volume				

Characteristics of Major Routes		Met?		Fulfilled?	
		Yes	No	Yes	No
1. Part of the street or highway system that serves as the principal roadway network for through traffic flow.	Major Street:				No
	Minor Street:				
2. Rural or suburban highway outside of, entering, or traversing a city.	Major Street:				
	Minor Street:				
3. Appears as a major route on an official plan.	Major Street:				
	Minor Street:				

3.13 WARRANT 9: INTERSECTION NEAR A GRADE CROSSING

(1) This signal warrant is intended for intersections where a grade crossing exists on an intersection approach controlled by a STOP or YIELD sign and none of the other eight traffic signal warrants are met. This signal warrant should only be applied after evaluating other alternatives and determining that the alternatives do not address safety concerns related to the grade crossing. The conditions for this warrant are detailed in ***Section 4C.10 of the MUTCD***.

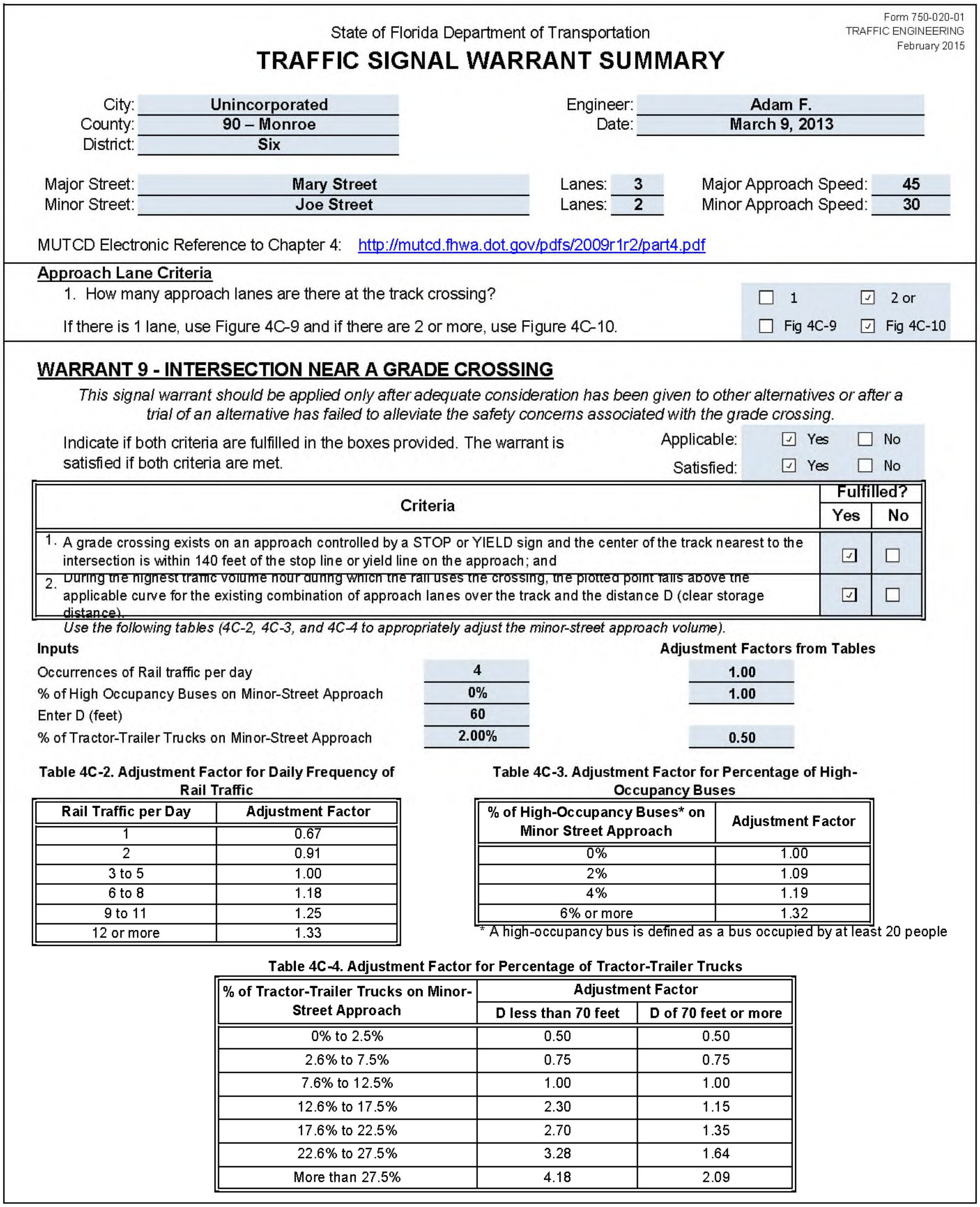
(2) ***Figure 3-11*** shows the portion of ***Form No. 750-020-01*** that must be completed to satisfy this warrant.

(3) ***Figure 3-12*** shows a summary checklist that is part of ***Form No. 750-020-01.*** This sheet can be used to provide conclusions of the analysis and to summarize the number of warrants that were satisfied or not applicable.

3.14 FORMS ACCESS

(1) A reproducible copy of the ***Traffic Signal Warrant Summary, Form No. 750-020-01*** is available in the Department's Forms Library. The electronic version of the form allow for easy data input when properly used. If the forms are to be completed electronically, the Instructions page provides guidance on the required input data, which should be input first into the Instructions form.

Figure 3-11. Intersection Near Grade Crossing



Form 750-020-01
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **90 – Monroe**
District: **Six**

Engineer: **Adam F.**
Date: **March 9, 2013**

Major Street: **Mary Street** Lanes: **3** Major Approach Speed: **45**
Minor Street: **Joe Street** Lanes: **2** Minor Approach Speed: **30**

MUTCD Electronic Reference to Chapter 4: http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf

Approach Lane Criteria

1. How many approach lanes are there at the track crossing? ☐ 1 ☑ 2 or

If there is 1 lane, use Figure 4C-9 and if there are 2 or more, use Figure 4C-10. ☐ Fig 4C-9 ☑ Fig 4C-10

WARRANT 9 - INTERSECTION NEAR A GRADE CROSSING

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.

Indicate if both criteria are fulfilled in the boxes provided. The warrant is satisfied if both criteria are met.

Applicable: ☑ Yes ☐ No
Satisfied: ☑ Yes ☐ No

Criteria	Fulfilled?	
	Yes	No
1. 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	☑	☐
2. During the highest traffic volume hour during which the rail uses the crossing, the plotted point falls above the applicable curve for the existing combination of approach lanes over the track and the distance D (clear storage distance).	☑	☐

Use the following tables (4C-2, 4C-3, and 4C-4 to appropriately adjust the minor-street approach volume).

Inputs		**Adjustment Factors from Tables**
Occurrences of Rail traffic per day	4	1.00
% of High Occupancy Buses on Minor-Street Approach	0%	1.00
Enter D (feet)	60	
% of Tractor-Trailer Trucks on Minor-Street Approach	2.00%	0.50

Table 4C-2. 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. 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

Table 4C-4. Adjustment Factor for Percentage of Tractor-Trailer Trucks

% 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

Form 750-020-01
TRAFFIC ENGINEERING
February 2015

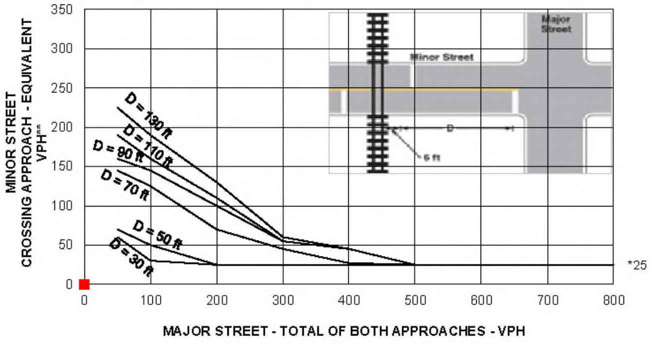
Input the major and minor street volumes before adjustment factors are applied

1 Approach Lane		
D (ft)	Major Vol.	Minor Vol.

After adjustment factors are applied

1 Approach Lane w/Factors		
D (ft)	Major Vol.	Minor Vol.

FIGURE 4C-9: Criteria for 1 Approach Lane at the Track Crossing



** Note: 25 vph applies as the lower threshold volume*

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

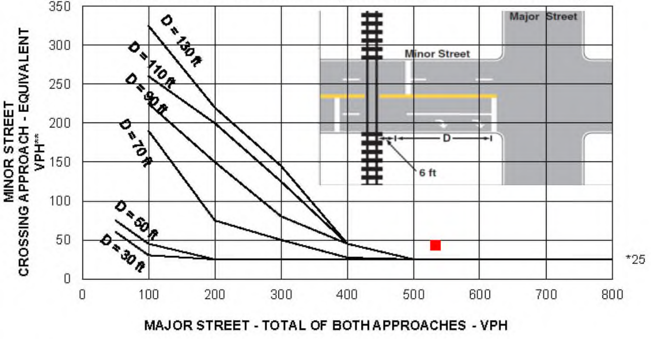
Input D and the major and minor street volumes before adjustment factors are applied

2 or more Approach Lanes		
60	533	86
D (ft)	Major Vol.	Minor Vol.

After adjustment factors are applied

2+ Approach Lane w/Factors		
60	533	43
D (ft)	Major Vol.	Minor Vol.

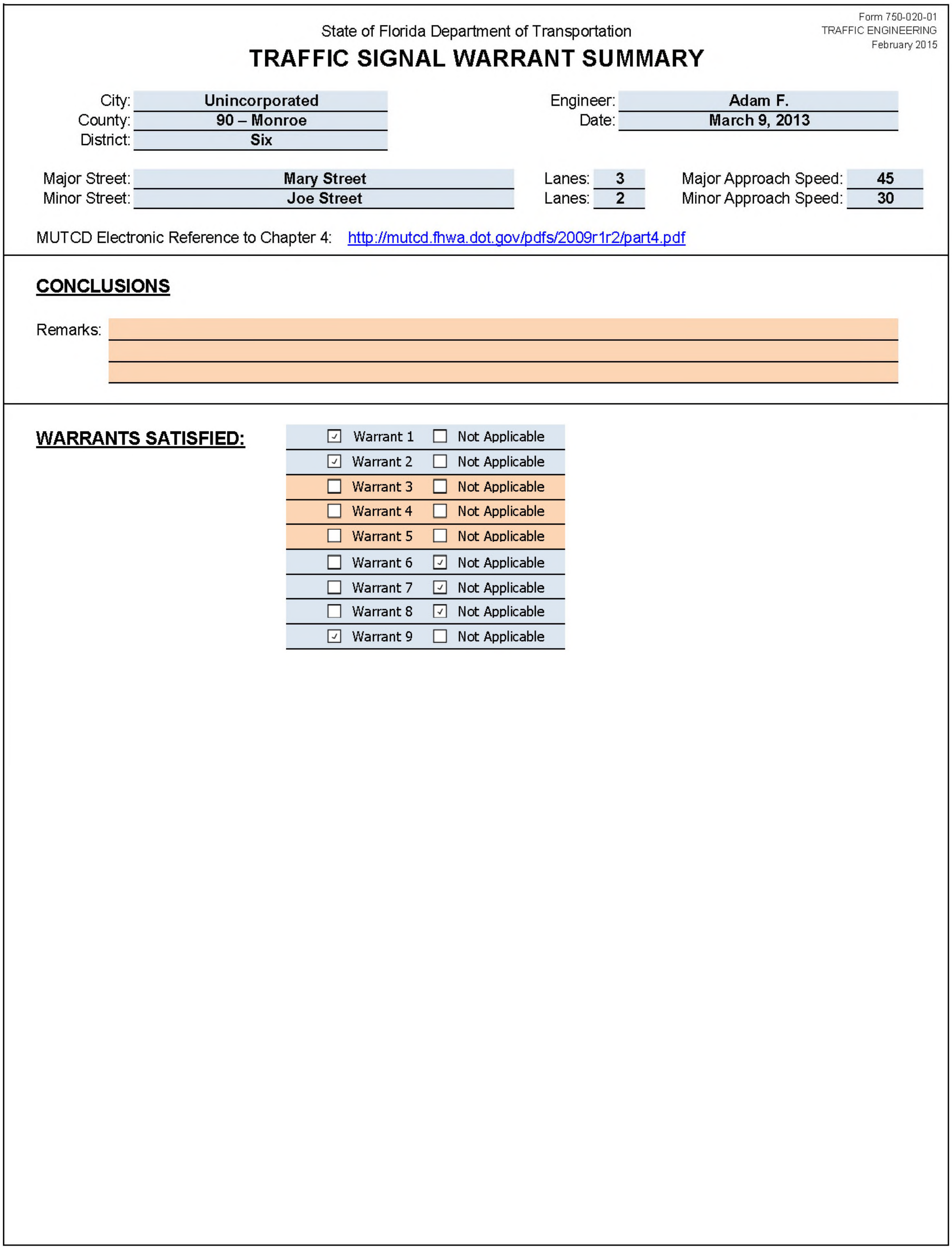
FIGURE 4C-10: Criteria for 2+ Approach Lanes at Track Crossing



** Note: 25 vph applies as the lower threshold volume*

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

Figure 3-12. Warrant Summary Checklist



Form 750-020-01
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **90 – Monroe**
District: **Six**

Engineer: **Adam F.**
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Minor Street: **Joe Street**
Lanes: **2**
Minor Approach Speed: **30**

MUTCD Electronic Reference to Chapter 4: http://mutcd.fhwa.dot.gov/pdfs/2009r1r2/part4.pdf

CONCLUSIONS

Remarks:

WARRANTS SATISFIED:

☑ Warrant 1	☐ Not Applicable
☑ Warrant 2	☐ Not Applicable
☐ Warrant 3	☐ Not Applicable
☐ Warrant 4	☐ Not Applicable
☐ Warrant 5	☐ Not Applicable
☐ Warrant 6	☑ Not Applicable
☐ Warrant 7	☑ Not Applicable
☐ Warrant 8	☑ Not Applicable
☑ Warrant 9	☐ Not Applicable

CHAPTER 4 INTERSECTION TURNING MOVEMENT COUNTS

4.1 PURPOSE

(1) The purpose of the Intersection Turning Movement Counts is to summarize the counts of vehicle movements through an intersection during certain time periods. This type of volume summary is used in making decisions regarding the geometric design of the roadway, sign and signal installation, signal timing, pavement marking, traffic circulation patterns, capacity analysis, parking and loading zones, and vehicle classification. This data is used in making decisions at a planning-level (e.g., traffic impact analyses), as well as operational analyses-level (e.g., signal installation and timing). Pedestrian and bicycle movements may be included during the intersection volume studies.

4.2 TYPES OF COUNTS

4.2.1 Vehicle Counts

(1) Counts may be conducted manually or using video technology. For manual counts, the required number of observers is dependent of the volume levels and the geometric design of the intersection. Most likely, several observers will be necessary to perform Turning Movement Counts (TMC) at signalized intersections as the majority of these studies are performed during peak flow periods. Unsignalized intersections typically require fewer observers. For video counts, the number of cameras and their placement depends on the geometry and size of the intersection.

(2) For signalized intersections, it is recommended that at least five signal cycles be captured within a specific count interval. A count interval is defined as the fraction of an hour that is used to aggregate data. The maximum cycle length should be used if the signal is actuated. Potential challenges in counting signalized intersections during actuated phasing are permissive turning movements, as they do not move consistently during their green phase, and right turns/right-turn-on-red movements, as they may be easily miscounted.

4.2.1.1 Arrival versus Departure Volumes

(1) Typically intersection volume counts are recorded as vehicles enter the intersection after crossing the stop bar. In oversaturated conditions, queues may start to develop, resulting in the need for more than one cycle to clear the intersection, and the departure counts may not always reflect the demand. In these circumstances, arrival and departure volumes should be recorded. Arrival volumes should be recorded as the vehicles approach the intersection during the analysis time and enter the queue; departures should be recorded as the vehicles cross the stop bar.

(2) Arrival volumes may extend beyond the observer's line of vision. For manual counts, a primary observer records the departure volumes and an additional observer counts arrival volumes. Video cameras can be used to capture both departure and arrival volumes.

(3) The arrival count for each interval can be calculated by adding the net change in queue length to the observed departure count. For a detailed example refer to ***Exhibit 4-1*** in the ***ITE Manual of Transportation Engineering Studies, 2nd Edition Chapter 4: Volume Studies page 45***.

4.2.2 Pedestrian and Bicycle Counts

(1) ***Chapter 9*** describes the procedures for performing pedestrian and bicycle volume counts.

4.2.3 Path-Based Counts

(1) Several modern intersection configurations combine multiple movements into shared lanes, and the traffic count is dependent of the origin and destination, commonly defined as the vehicle path. Some of these intersections include modern roundabouts, superstreets (through and left-turns replaced by a right-turn U-turn combination) and Michigan U-Turn (left-turns replaced by a right-turn U-turn combination) intersections. At these types of intersections, it is not possible to observe individual turning movements in isolation.

4.2.3.1 Modern Roundabouts

(1) At roundabouts, entering flow mixes with circulating traffic and exits at different destination points. Traditional count techniques and many automated data collection methods may record overall approach demand but may have difficulty providing turning movement counts for shared lanes. This challenge increases at multilane sites.

(2) To perform counts at roundabouts, there are three identified techniques: 1) manual counts, 2) video-image processing counts with vehicle tracking, and 3) sampling method.

(c) The manual technique can be used at low-traffic roundabouts and has great error potential as the observer has to remember the vehicle's origin when recording the exit data. Video observations can be used to improve the accuracy of this technique. Video-based roundabout counts require placement of the camera or cameras in a good vantage point and may require image calibration. The sampling method is described in ***Section 4.2.3.3***.

4.2.3.2 Michigan U-Turn and Superstreet Intersections

(1) Michigan U-turn and superstreet intersections require path-based volume counts as both restrict movements by diverging drivers to a U-turn opening on the mainline. Any of the manual or automated study methods mentioned in this chapter can be used for these intersections; however, the volume of the minor street movements will determine the required number of observers. Video observations may be used when greater volumes are present. The sampling method described in ***Section 4.2.3.3*** is also applicable.

4.2.3.3 Sampling Method for Path-Based Counts

(1) This method is applicable to all the intersections that require path-based counts. An origin-destination (O-D) matrix of turning percentages based on a sampling approach can be used to make the path-based counts more efficient. To develop such a matrix, the observer samples turning movement percentages for a short period and applies these to an approach volume. A 15 minute sample per approach and a 2 hour approach count may be sufficient for the study, depending on the traffic fluctuations. An average of multiple sampling periods can be used to improve the accuracy of the O-D matrix. Different O-D matrices should be developed for different time periods throughout the day.

(2) An alternative method is to use a license-plate matching approach in conjunction with corresponding approach volume counts. This method requires multiple observers both at the entry and exit points of a count location to record the last three digits of the vehicles license plates at the minor approaches and U-turn bays. This data is later converted to an O-D matrix. Unless very low volumes are present, this method will provide only a sample of traffic distribution as it is unlikely that all license plates will be captured during peak hours. Although this method is labor intensive, it is a reliable approach to obtain detailed distribution for path-based studies. Typically a minimum of two observers are required at the entry and two at the exit points, unless very low volumes are expected.

4.2.4 Unconventional Intersection Counts

(1) Some unconventional intersection designs include continuous flow intersections, single-point urban interchanges and diverging diamond interchanges. These unconventional designs generally do not require path-based counts and each movement can be observed in isolation. Therefore, a volume study at these unconventional intersections is done in a similar manner to a standard intersection. The observer should be familiar with the flow patterns before conducting the study. Automated data collection methods can be used where no shared lanes with other movements are present.

4.3 METHODS OF DATA COLLECTION

(1) Manual observation and automated counts are the two basic methods of obtaining traffic counts. Manual observation often refers to any method that involves a manual tally by an observer, either in the field, or from video recordings. Automated counts reduce observer workload by using automated technology to tally the counts. Either manual or automated methods can be performed in the field or during post-processing in the office.

4.3.1 Manual Observation Counts

(1) During this procedure, the observer manually records each vehicle as it proceeds through the point of interest. Manual counts minimize equipment cost and set-up time; however, they can become inefficient the longer the observer stays in the field. Most counts focus on peak-hour conditions; therefore, the set-up time and removal of automated equipment may not be justified.

4.3.1.1 Equipment

(1) ***Tally sheets:*** The traditional way to perform a manual count is to record each vehicle with a tick mark on a prepared field form as shown in ***Form No. 750-020-02***. Pedestrian and bicycle volumes may be recorded in the same form, however, if the volumes are high, they may require separate sheets. A watch or stopwatch is required to record the desired count interval and a new form shall be used at the beginning of a new interval. Once the manual counts are finished, the observer summarizes the raw counts.

(2) ***Handheld Count Boards:*** Electronic count boards contain buttons that are allocated to different movements within the intersection and the boards have an internal clock which separates the data into the chosen interval. The data can be downloaded to a computer to be summarized, processed, and displayed in the preferred presentation format. Generally, the added benefits of reduced time of manual data reduction and summary justify their expense.

Many electronic count boards are designed to aid in several types of common traffic studies (e.g., turning movement, classification, gap, stop delay, saturation flow rate, stop sign delay, spot speed, and travel-time studies). Most boards provide a shift key for special functions, such as recording particular vehicle classes. They are considered a cost-effective, labor-saving tool. A disadvantage is the restriction to aggregated data.

(3) ***Laptop Computer:*** Battery-efficient laptop computers can be used in place of electronic count boards. Available spreadsheet software can be used to record time stamps of different events and the benefit of using macro-enabled spreadsheets to collect data is the ability to customize spreadsheets to a user's specific needs. A disadvantage is the software coding and post-processing analysis required.

(4) ***Video Cameras:*** Manual counts can be conducted as a post-processing operation from video observations. It is critical to have well-chosen camera angles and adequate lighting conditions to capture all turning movements at a typical intersection with one or multiple cameras.

The observer can record their counts from a video recording with a handheld count board, tally sheets, or directly onto a computer. An added benefit of the video recording is that observations can be error-checked by a second observer or additional information such as vehicle classification, delay, or queues can be gathered.

4.3.1.2 Personnel Required

(1) Manual counts require trained observers who must be relieved periodically to avoid inefficiency. Breaks of 10 to 15 minutes are recommended at least every 2 hours, or 30 to 45 minutes every 4 hours for collection periods longer than 8 hours.

(2) The crew size to perform a manual count depends on the length of the counting period, the type of count being performed, the number of lanes or crosswalks being observed, and the volume level of traffic. A single observer can count turning movements at a low volume signalized four-way intersection with one-lane approaches if no special classifications and vehicle occupancy is needed. If additional data is required, additional observers will be needed.

4.3.1.3 Field Procedure

(1) ***Preparation:*** A preparation checklist is recommended. A sample checklist can be found in the ***ITE Manual of Transportation Engineering Studies, 2nd Edition Chapter 1: Introduction page 6, Exhibit 1-1***. To determine the type of equipment, field procedure and number of required observers for the study, the following should be reviewed:

(a) purpose and type of count to be performed,

(b) count period and time intervals, and

(c) information about the site (e.g., geometric layout, volume levels by time of day, signal timing, etc.)

(2) ***Observer Location:*** Observers should be positioned in a location with clear view of the traffic they are counting and must avoid vantage points regularly blocked by any feature. They should be located away from the edge of the travel way for safety purposes and to avoid distracting drivers.

If more than one observer is performing the study, they should maintain visual contact with one another, and be able to communicate so as to coordinate their activities. Safety vests should be worn at all times when the observer is near traffic. It is recommended that observers arrive at the site at least 15 minutes before the scheduled count start time and allow time for set-up and familiarization.

(3) ***Data Recording:*** Organization and correct labeling of the forms and files is key for successful manual counts. Each file or form should have the required information, including the count location, observer’s name, time of study, and conditions during the study.

(4) Time intervals must be maintained and coordinated accurately when two or more observers are performing the counts. Any temporary traffic event, such as collisions or maintenance activities, should be recorded as they may lead to unusual traffic counts.

(5) If the ***Summary of Turning Movement Counts Form (Form No. 750-020-02)*** is to be used follow these steps:

(a) ***Figure 4-1*** shows an example of how to fill out ***Form No. 750-020-02***. The heading of this form should be filled in completely. Identify the location of the observer by marking the appropriate checkbox in the intersection diagram. If more than one observer is used, name and number each and identify their location by number.

(b) Enter the *Street Name* of each roadway and orient the intersection by indicating north by directional arrow. Enter the letters *NB, EB, SB,* or *WB,* indicating the direction of approach in the appropriate box of the intersection diagram. In the box behind the movement indications, enter the number of lanes for each movement. Right turns can occur even if no exclusive right turn lanes are present.

(c) Briefly describe the *Weather* and include any road conditions under *Remarks* that may influence the results of the data being collected. For example, a stalled vehicle that may temporarily restrict a vehicle movement during a time period should be noted.

(d) For each time period to be counted, enter the *Begin* and *End* time. Twenty rows are provided so that a total of 4 hours can be counted in 15-minute periods and also allow the user to enter hourly totals. Other time periods of varying duration can be entered. Enter the actual counts of vehicle movements in the appropriate time period and *L, T, and R* column.

(6) In instances where the ***Vehicle Turning Movement Count Form (Form No. 750-020-03)*** is used, follow these steps:

(a) ***Figure 4-2*** shows an example of how to fill out Form No. 750-020-03, which can be used for most intersections. This figure shows the tally sheet for a 15-minute vehicle movement field count. If preferred, the total tally can be summarized and recorded on the Summary of Turning Vehicle Movement Counts Form or kept on the Vehicle Turning Movement Counts Form.

(b) In the field, each observer will enter the appropriate information and the traffic volumes for the approaches counted using the ***Vehicle Turning Movement Counts Form.***

Figure 4-1. Summary of Turning Movement Counts Form (Form No. 750-020-02)

Form 750-020-02
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

SUMMARY OF TURNING MOVEMENT COUNTS

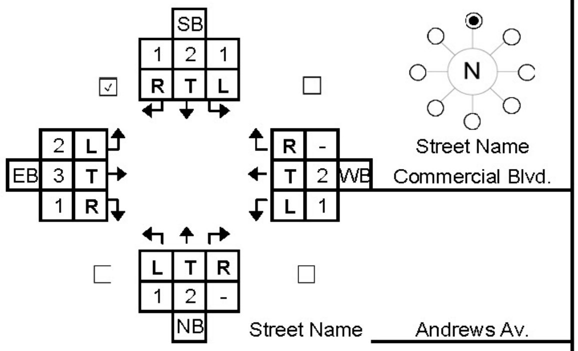
General Information

Analyst/Observer: BPP
Agency or Company: FDOT
Date Performed: Monday, March 31, 2014
Analysis Time Period: PM Peak

Site Information

City: Fort Lauderdale
County: Broward
Weather: Sunny
Remarks: Stalled vehicle on northen EB left turn lane, Dry Road Conditions

Intersection Diagram



Street Name Commercial Blvd.

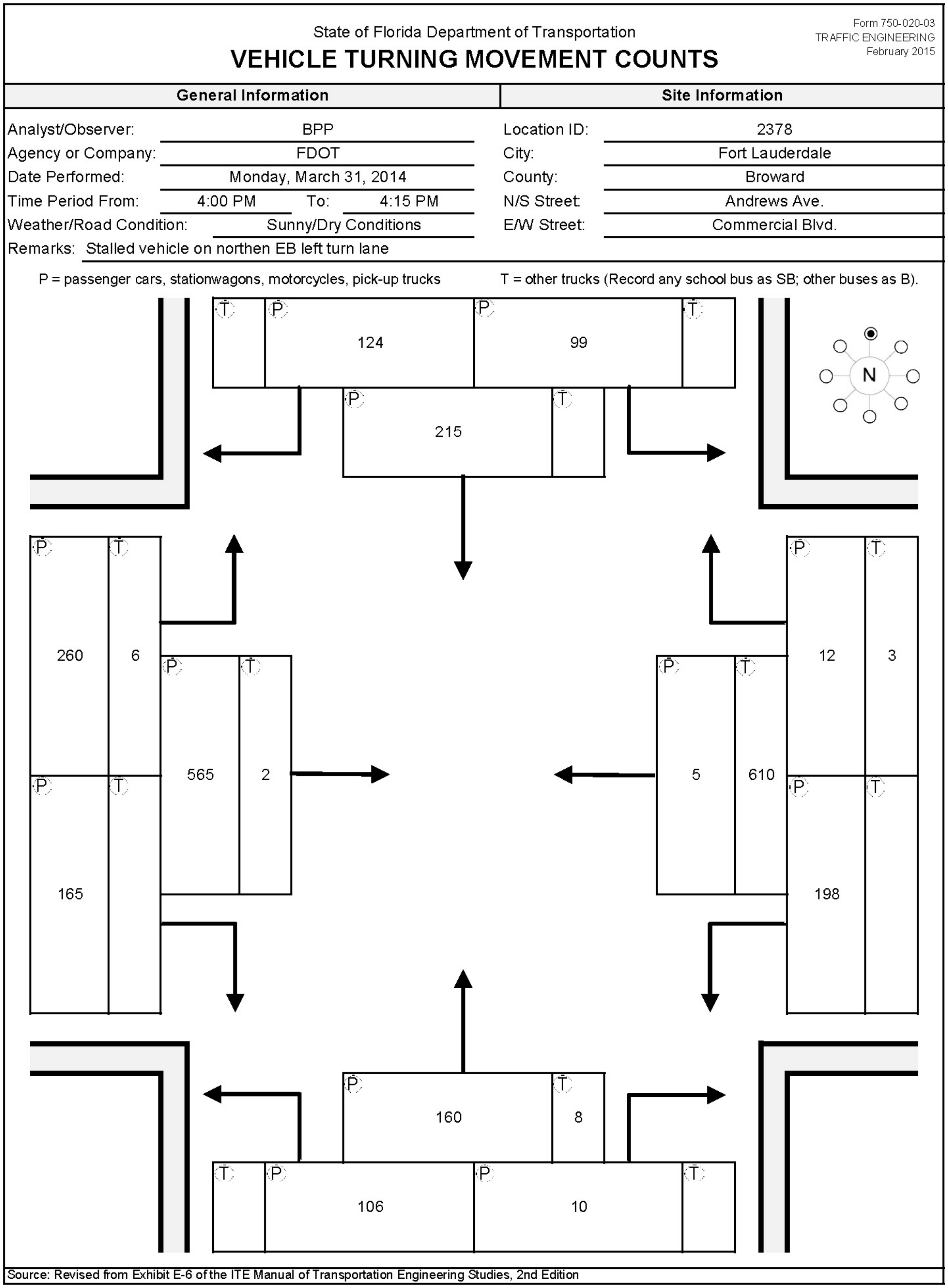
Street Name Andrews Av.

VEHICLE MOVEMENTS

Time Begins	Northbound				Southbound				Eastbound				Westbound				Total All
	L	T	R	Total	L	T	R	Total	L	T	R	Total	L	T	R	Total	
4:00 PM	106	168	10	**284**	99	215	124	**438**	266	567	165	**998**	198	615	15	**828**	2548
4:15 PM	103	200	22	**325**	107	234	133	**474**	230	498	168	**896**	200	553	33	**786**	2481
4:30 PM	147	214	17	**378**	86	250	102	**438**	257	500	187	**944**	188	539	19	**746**	2506
4:45 PM	108	199	31	**338**	95	217	125	**437**	216	545	135	**896**	213	514	28	**755**	2426
TOTAL	464	781	80	**1325**	387	916	484	**1787**	969	2110	655	**3734**	799	2221	95	**3115**	9961
5:00 PM	133	225	12	**370**	114	253	117	**484**	245	613	110	**968**	237	652	13	**902**	2724
5:15 PM	98	174	15	**287**	89	241	129	**459**	300	601	135	**1036**	225	580	25	**830**	2612
5:30 PM	102	187	9	**298**	78	215	111	**404**	287	544	89	**920**	176	573	33	**782**	2404
5:45 PM	85	211	17	**313**	101	251	131	**483**	210	477	107	**794**	219	559	21	**799**	2389
TOTAL	418	797	53	**1268**	382	960	488	**1830**	1042	2235	441	**3718**	857	2364	92	**3313**	10129
TOTAL																	0
TOTAL																	0
TOTAL	882	1578	133	**2593**	769	1876	972	**3617**	2011	4345	1096	**7452**	1656	4585	187	**6428**	20090

Source: Revised from Exhibit E-7 of the ITE Manual of Transportation Engineering Studies, 2nd Edition

Figure 4-2. Vehicle Turning Movement Count Form (Form No. 750-020-03)



Form 750-020-03
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

VEHICLE TURNING MOVEMENT COUNTS

General Information

Analyst/Observer: BPP
Agency or Company: FDOT
Date Performed: Monday, March 31, 2014
Time Period From: 4:00 PM To: 4:15 PM
Weather/Road Condition: Sunny/Dry Conditions

Site Information

Location ID: 2378
City: Fort Lauderdale
County: Broward
N/S Street: Andrews Ave.
E/W Street: Commercial Blvd.

Remarks: Stalled vehicle on northen EB left turn lane

P = passenger cars, stationwagons, motorcycles, pick-up trucks T = other trucks (Record any school bus as SB; other buses as B).

Source: Revised from Exhibit E-6 of the ITE Manual of Transportation Engineering Studies, 2nd Edition

4.3.2 Automatic Counts

(1) Equipment for automatic counts typically provides volume counts on the legs of the intersection (such as in-road count technologies) and may not always provide turning movement counts directly, with some exceptions (such as video imaging processing). Reliability of the equipment is considered the traditional disadvantage and analysts must prepare contingency plans in case of equipment failure and understand technology limitations.

(2) ***In-road Count Technologies:*** In-road count technologies are generally unable to count turning movements, pedestrians, or bicycles. A significant amount of equipment may be required to capture lane-by-lane data, depending on the intersection configuration. The set-up cost and time make this technology more suitable for longer duration counts. Manual counts are typically more cost-effective for short-term counts (8 to 12 hours).

This technology is mounted directly on the travel lanes or permanently embedded in the pavement. Some area-wide programs monitor traffic characteristics and trends over time, hence, permanent traffic monitoring stations are installed for long-term, continuous counts. Equipment options are pneumatic tubes or magnetic inductance technology mounted directly on the surface or embedded into the pavement. Collected data are stored in built-in memory and can be downloaded via USB connection or wireless transmission.

(3) ***Video Imaging Processing:*** Video-imaging processing systems may be able to capture turning movement volumes directly. Computerized measurement of lighting changes in pixels on the video are typically involved in the analysis process, but the algorithms vary among different manufacturers.

Some of the common issues with all video-based detection are the susceptibility to movement, lighting changes, and occlusion by tall objects.

4.3.2.1 Personnel Required

(1) The only personnel required for automatic counts are those needed to install and recover the equipment. Depending on the type of equipment, the installation crew might need to close lanes or install the equipment during periods of low traffic. One person can take care of the recording component. Recovery of the equipment usually takes one or two persons. Permanent installation of counters with in-pavement sensors will require a larger crew and lane-closure. Some post processing may be required even with automatic counts, the number of people needed will vary with the size of the study and schedule.

4.3.2.2 Field Procedure

(1) ***Preparation:*** A checklist should be prepared before any field work. The type of equipment to be used and the procedures to be followed are determined by the purpose of the count. Proper functioning of the equipment is crucial before going out to the field. An ample supply of accessories and necessary tools is recommended.

(2) ***Selecting the Count Location:*** The placement of the counters (proximity to the intersection) is determined by the type of study being performed. The exact location for the sensors can be determined in the field. The following steps should be followed:

(a) For each intersection leg, do not place sensors across parking lanes (marked or unmarked)

(b) For each intersection leg, deploy sensors at right angles to the traffic flow

(c) Avoid double counting of turning vehicles

(d) Sketch on a conditional diagram the exact location of sensor placement

(e) Use a test vehicle to ensure proper recordings for bi-directional counters

(f) Avoid locations where frequent queuing occurs

(g) Set the count interval to total on the hour for data consistency

(h) Note the start time

(3) Additional guidelines for in-road counters include:

(a) Avoid expansion joints, sharp pavement edges, or curves for the sensor placement

(b) Secure the sensor to the pavement to prevent loss of data or safety concerns

(c) Secure the count recorder near a sign, tree, or a locked signal control cabinet to prevent vandalism

(d) Ensure that the connection cable between the sensor and the recorder is as short as possible

(e) Check installation periodically for proper functioning

(4) Installation and Retrieval: Installation and retrieval operations should be accomplished during low-traffic-volume periods for safety reasons. Crew should wear retroreflective clothing at all times.

4.4 ROADWAY DATABASE

(1) Where available, information should be pulled from the corresponding District or Local Agency specific roadway databases. These may include information such as:

- **(a)** Location
- **(b)** Geometry
- **(c)** Site layout
- **(d)** Signal timing
- **(e)** Equipment inventory
- **(f)** Photographs of the site and equipment

4.5 FORMS ACCESS

(1) Reproducible copies of the ***Summary of Turning Movement Counts (Form No. 750-020-02)*** and the ***Vehicle Turning Movement Counts (Form No. 750-020-03)*** are available in the Department's Forms Library.

(2) An electronic version is of the forms is also available which automate the calculations.

CHAPTER 5 DATA COLLECTION FOR TRANSPORTATION SAFETY STUDIES

5.1 PURPOSE

(1) The purpose of the ***Traffic Safety Studies*** chapter is to provide guidance on the data collection requirements for conducting a safety study including application of the Highway Safety Manual (HSM). This chapter is divided into urban/suburban arterials and rural roadways. It is further subdivided into segments and intersections within each of these sections. Classifying an area as urban, suburban, or rural is subject to the roadway characteristics, surrounding population, and land uses, and is at the user's discretion. The HSM provides guidance on urban and suburban classification by population in the *Part C – Introduction and Application Guidance.*

5.2 SAFETY STUDY BASICS

(1) In broad terms, traffic safety studies can be conducted as *reactive* to a given location's historical crash accumulation, or as *predictive* of a given location's potential crash frequency.

(2) *Reactive* studies are generally based on historical crash accumulation of a specific crash type at a given location. The identification and economic justification for treatments can be supplemented by applying the *HSM Predictive Method* where applicable.

(3) *Predictive* safety studies comprise a broader category of study types supplemented by HSM methodologies for countermeasure identification and economic justification. Finally, *predictive* studies can be conducted on existing or planned facilities.

5.3 HSM PREDICTIVE METHOD PROCEDURE BASICS

(1) The Predictive Method is presented in Part C of the Highway Safety Manual. The procedure allows the user to compute two values: Predicted Average Crash Frequency (computed from safety performance functions only) and Expected Average Crash Frequency (computed from a combination of safety performance functions and historical crash data) for segments and intersections with select geometric characteristics.

(2) The Predictive Method in its most fundamental form can be summarized by the following equation. This equation is found in the HSM Part C Introduction and Application Guidance.

$$N_{predicted} = N_{spf}(CMF_1 * CMF_2 * \ldots * CMF_x)C_x$$

where:

$N_{predicted}$ = predicted crash frequency

N_{spf} = predicted average crash frequency for base conditions

CMF_x = crash modification factor for a given geometric or traffic control feature

C_x = local calibration factor.

(3) Additional detail on the application of the Predictive Method can be found in HSM Chapter 3 and the Part C Introduction and Application Guidance.

5.4 DATA COLLECTION NEEDS

(1) The data collection needs for safety studies is outlined in this section. If the study site falls into any of the categories with a check mark in ***Table 5-1***, the HSM Predictive Methodologies are applicable. If the study site does not fall into any of the categories presented in ***Table 5-1***, then the HSM Predictive Methodologies are not applicable.

(2) In situations where the HSM Predictive Method is not applicable, it is still recommended that at a minimum, the same data be collected as is required for sites where the HSM Predictive Method is applicable. Spreadsheets are provided for both of these situations and the data collection process is outlined below.

Table 5-1. Facility Types and Site Types Included in the HSM Predictive Method (Source: Highway Safety Manual, 2010, Table 3-2)

HSM Chapter	Undivided Roadway Segments	Divided Roadway Segments	Intersections			
			Stop Control on Minor Legs		Signalized	
			3-Leg	4-Leg	3-Leg	4-Leg
10. Rural Two-Lane highways	✓		✓	✓		✓
11. Rural Multi-Lane Highways[1]	✓	✓	✓	✓		✓
12. Urban and Suburban Aterials[2]	✓	✓	✓	✓	✓	✓

1. Methodology available for four lane divided and undivided. No methodology is currently available for six lane rural highways.
2. Methodology available for two lane undivided, three lane with center two way left turn lane, four lane divided and undivided, and five lane with center two way left turn lane. The methodology for six lane arterials is under development.

(3) This section is divided into the data collection guidance sections listed below. These sections provide data collection guidance for locations where the HSM Predictive Method is both applicable and not applicable:

(a) Traffic Volume and Geometric Data Collection ***(Section 5.4.1)***.

(b) Historical Crash Data Collection and Collision Diagram Development ***(Section 5.4.2)***.

(c) Local Conditions Data Collection and Condition Diagram Development ***(Section 5.4.3)***.

5.4.1 Traffic Volume and Geometry Data Collection

(1) The data collection requirements in this section are divided into roadways and intersections. Within each of these, the data requirements are further subdivided depending on the facility type being analyzed. There are corresponding spreadsheets for each facility type that can be downloaded for use in the field. The data collected within these spreadsheets may also be copied directly into the NCHRP 17-38 spreadsheets that can be obtained upon request from the ***FDOT Safety Office***. These spreadsheets facilitate the HSM Predictive Method analysis.

(2) For sites where the HSM Predictive Method is not applicable, generic data collection sheets are available. These cannot be copied into the NCHRP 17-38 spreadsheets. Details are provided in the following sections.

(3) Before proceeding, the analyst should determine if the HSM methodologies are applicable by referring to Part C Introduction and Applications Guidance Chapter.

5.4.1.1 Roadway Segments

(1) The following sections present data collection requirements for Rural Two Lane Roadways, Rural Multi-Lane Highways, and Urban/Suburban arterials having the characteristics required for HSM Predictive Method Application. A “generic” data collection requirements list for locations not having the characteristics required for HSM Predictive Method Application is provided at the end of this section.

Rural Two-Lane Roadways

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on a rural two-lane roadway segment. Figure 10-2 in Chapter 10 of the HSM provides guidance on the definition of intersections and segments. ***Rural Two-Lane Roadway Segment Data Collection Table (Form No. 750-020-05a)*** may be used to collect this data. An example of this form completed is shown in ***Figure 5-1***.

(2) Data Required To Compute Base Crash Prediction:

(a) *Roadway Annual Average Daily Traffic (AADT)*. Guidelines regarding maximum/minimum AADT values and roadway length can be found in Chapter 10 Section 10.6.1 of the HSM. AADT may be existing or future AADT.

(b) *Homogenous roadway segment length* (in miles, see guidelines in the Part C - Introduction and Applications Guidance of the HSM on the selection of homogeneous roadway segments).

(3) Data required to Compute Crash Modification Factors

The parameters noted below are used to compute twelve crash modification factors for rural two-lane roadways. These are numbered from CMF_{1r} to CMF_{12r} in the HSM. Guidelines for each of the twelve parameters used to compute CMFs can be found in Chapter 10, Section 10.7.1 of the HSM.

(a) Lane width in feet (CMF_{1r}).

(b) Shoulder width in feet and shoulder type, paved, gravel, composite, or turf (use equation 10-12 to compute CMF_{2r}).

(c) Horizontal curvature, length of curve in feet, radius in feet, and presence or absence of spiral transitions at curve entry and exit, (CMF_{3r}).

(d) Horizontal curve superelevation as a percentage (CMF_{4r}).

(e) Grade level as a percentage (CMF_{5r}).

(f) Driveway Density in driveways per mile. This CMF also requires the AADT (CMF_{6r}).

(g) Presence of center rumble strips, present or not (CMF_{7r}).

(h) Presence of passing lanes, present or not (CMF_{8r}).

(i) Presence of two-way left turn lanes, present or not (CMF_{9r}).

(j) Roadside design as a function of Roadside Hazard Rating (RHR) measured from 1 through 7 (CMF_{10r}).

(k) Presence of lighting, present or not (CMF_{11r}).

(l) Presence of automated speed enforcement, present or not (CMF_{12r}).

Rural Multi-Lane Roadways

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on a four-lane rural multi-lane roadway. Currently no methodology exists for six-lane rural multi-lane roadways. ***Rural Multi-Lane Roadway Segment Data Collection Table (Form No. 750-020-05b)*** may be used to collect this data. An example of this form completed is shown in ***Figure 5-2***.

(2) Data Required To Compute Base Crash Prediction

(a) Roadway design, divided or undivided.

(b) Roadway AADT. Guidelines regarding maximum/minimum AADT values can be found in Chapter 11 Sections 11.6.1 and 11.6.2 for undivided and divided roadway segments respectively. AADT may be existing or future AADT.

(c) Homogenous roadway segment length (miles, see guidelines in the Part C - Introduction and Applications Guidance of the HSM on the selection of homogeneous roadway segments).

(3) Data required to Compute Crash Modification Factors

The parameters noted below are used to compute five crash modification factors for rural multi-lane roadways. These are numbered from CMF_{1ru} to CMF_{5ru} for undivided roadway segments and CMF_{1rd} to CMF_{5rd} for divided roadway segments in the HSM. Guidelines for the parameters used to compute CMFs can be found in the HSM under Chapter 11, Section 11.7.1 for undivided roadway segments and 11.7.2 for divided roadway segments.

(a) Undivided Roadway Segments

- Lane width in feet (CMF_{1ru}).
- Shoulder width in feet and shoulder type, paved, gravel, composite (CMF_{2ru}).
- Sideslopes ranging from 1:7 or flatter, to 1:2 or steeper (CMF_{3ru}).
- Presence of lighting, present or not (CMF_{4ru}).
- Presence of automated speed enforcement, present or not (CMF_{5ru}).

(b) Divided Roadway Segments

- Lane width in feet (CMF_{1rd}).
- Right shoulder width in feet (CMF_{2rd}).
- Median width (CMF_{3rd}).
- Presence of lighting, present or not (CMF_{4rd}).
- Presence of automated speed enforcement, present or not (CMF_{5rd}).

Urban/Suburban Arterials

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on urban/suburban arterials up to four lanes, including five lanes having a two-way left turn lane. Currently no methodology exists for six lane arterials. ***Urban/Suburban Arterial Segment Data Collection Table (Form No. 750-020-05c)*** may be used to collect this data. An example of this form completed is shown in ***Figure 5-3***.

(2) Data Required To Compute Base Crash Prediction

(a) Roadway type (2U, 3T, 4U, 4D, 5T).

(b) Roadway AADT. Guidelines regarding maximum/minimum AADT values and roadway length can be found in Chapter 12 Section 12.6.1. AADT may be existing or future AADT.

(c) Homogenous Roadway Segment Length (miles, see guidelines in the Part C- Introduction and Applications Guidance on the selection of homogeneous roadway segments).

(3) Data required to Compute Crash Modification Factors

The parameters noted below are used to compute five crash modification factors for urban/suburban arterials. Guidelines for the parameters used to compute CMFs can be found in the HSM under Chapter 12, Section 12.7.

(a) Type of on-street parking, none/parallel/angle (CMF_{1r}).

(b) Proportion of curb length with on-street parking (CMF_{1r}).

(c) Roadside fixed object density, fixed objects per mile (CMF_{2r}).

(d) Offset to roadside fixed objects in feet, if greater than 30 feet or not present, assume 30 feet (CMF_{2r}).

(e) Median width in feet - for divided only (CMF_{3r}).

(f) Lighting, present or not present (CMF_{4r}).

(g) Auto speed enforcement, present or not present (CMF_{5r}).

Other Roadway Types

(1) The following is a list of data collection input parameters for roadways for which an HSM Predictive Method is not currently available. The ***Other Roadway Segment Data Collection Table (Form No. 750-020-05d)*** may be used to collect this data. An example of this form completed is shown in ***Figure 5-4***.

(2) Essential Elements

(a) Urban context (urban, suburban, transitioning, or rural)

(b) Homogenous roadway segment length (miles, see guidelines in the Part C - Introduction and Applications Guidance on the selection of homogeneous roadway segments)

(c) Roadway design, divided or undivided

(d) Roadway AADT

(e) Lane width in feet

(f) Shoulder width in feet and shoulder type (paved, gravel, composite, turf, or other)

(g) Presence of lighting, present or not

(h) Median width in feet (for divided only)

(i) Median type (raised, painted, depressed, or other)

(j) Speed limit

(k) Presence/absence of pedestrian crosswalks

(l) Presence/absence of school zones

(m) Presence/absence of bike lanes or shared lanes

(3) Desired Elements

(a) Functional classification

(b) Horizontal curvature, length of curve in feet, radius in feet, and presence or absence of spiral transitions at curve entry and exit

(c) Horizontal curve superelevation as a percentage

(d) Grade level as a percentage

(e) Driveway density in driveways per mile

(f) Presence of center rumble strips, present or not

(g) Presence of passing lanes, present or not

(h) Presence of two-way left turn lanes, present or not

(i) Roadside design as a function of roadside hazard rating, measured from 1 through 7

(j) Presence of automated speed enforcement, present or not

(K) Sideslopes ranging from 1:7 or flatter, to 1:2 or steeper

(l) Type of on-street parking (none/parallel/angle)

(m) Proportion of curb length with on-street parking.

(n) Major commercial driveways (number)

(o) Minor commercial driveways (number)

(p) Major industrial / institutional driveways (number)

(q) Minor industrial / institutional driveways (number)

(r) Major residential driveways (number)

(s) Minor residential driveways (number)

(t) Other driveways (number)

(u) Roadside fixed object density (fixed objects per mile)

(v) Offset to roadside fixed objects (in feet)

5.4.1.2 Intersections

Rural Two-Lane Roadways – Intersections

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on an intersection located in a rural two-lane roadway segment. Figure 10-2 in Chapter 10 of the HSM provides guidance on the definition of intersections and segments. ***Rural Two-Lane Roadway Intersection Data Collection Table (Form No. 750-020-05e)*** may be used to collect this data. An example of this form completed is shown in ***Figure 5-5***.

(2) Data Required To Compute Base Crash Prediction

(a) Determine intersection configuration, three leg stop controlled (3ST), four-leg stop controlled (4ST), or four-leg signalized (4SG).

(b) Roadway AADT on the major street approach and roadway AADT on the minor street approach. Guidelines regarding maximum/minimum AADT values and can be found in Chapter 10 Section 10.6.2. AADT may be existing or future AADT.

(3) Data required to Compute Crash Modification Factors

The parameters noted below are used to compute four crash modification factors for intersections on rural two-lane roadways. These are numbered from CMF_{1i} to CMF_{4i} in the HSM. Guidelines for the four parameters used to compute CMFs can be found in Chapter 10, Section 10.7.2 of the HSM.

(a) Intersection skew angle as an offset away from 90 degrees (CMF_{1i})

(b) Intersection approaches with left-turn lanes, number of approaches (CMF_{2i})

(c) Intersection approaches with right-turn lanes, number of approaches (CMF_{3i})

(d) Intersection lighting, present or not (CMF_{4i})

Rural Multi-Lane Roadways – Intersections

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on an intersection located in a rural multi-lane roadway segment. Figure 11-2 in Chapter 11 of the HSM provides guidance on the definition of intersections and segments. ***Rural Multi-Lane Roadway Intersection Data Collection Table (Form No. 750-020-05f)*** may be used to collect this data. An example of this form completed is shown in ***Figure 5-6***.

(2) Data Required To Compute Base Crash Prediction

(a) Determine intersection configuration, three leg stop controlled (3ST), four-leg stop controlled (4ST), or four-leg signalized (4SG).

(b) Roadway AADT on the major street approach and roadway AADT on the minor street approach. Guidelines regarding maximum/minimum AADT values and can be found in Chapter 11 Section 11.6.3. AADT may be existing or future AADT.

(3) Data required to Compute Crash Modification Factors

The parameters noted below are used to compute four crash modification factors for intersections on rural multi-lane roadways. These are numbered from CMF_{1i} to CMF_{4i} in the HSM. Guidelines for the four parameters used to compute CMFs can be found in Chapter 11, Section 11.7.3 of the HSM.

(a) Intersection skew angle as an offset away from 90 degrees (CMF_{1i})

(b) Intersection non-stop controlled approaches with left-turn lanes, number of approaches (CMF_{2i})

(c) Intersection non-stop controlled approaches with right-turn lanes, number of approaches (CMF_{3i})

(d) Intersection lighting, present or not (CMF_{4i})

Urban/Suburban Arterials – Intersections

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on an intersection located on an urban/suburban roadway segment. Figure 12-2 in Chapter12 of the HSM provides guidance on the definition of intersections and segments. ***Urban/Suburban Arterial Intersection Data Collection Table (Form No. 750-020-05g)*** may be used to collect this data. An example of this form completed is shown in ***Figure 5-7***.

(2) Data Required To Compute Base Crash Prediction

(a) Determine intersection configuration, three leg stop controlled (3ST), three leg signalized (3SG), four-leg stop controlled (4ST), or four-leg signalized (4SG).

(b) Roadway AADT on the major street approach and roadway AADT on the minor street approach. Guidelines regarding maximum/minimum AADT values and can be found in Chapter 12 Section 12.6.2. AADT may be existing or future AADT.

(c) Sum of all pedestrian crossing volumes per day, crossing all four legs combined for signalized intersections only (PedVol).

(d) Maximum number of lanes crossed by a pedestrian for signalized intersections only (nlanesx).

(3) Data required to Compute Crash Modification Factors

The parameters noted below are used to compute crash modification factors for intersections on urban-suburban roadways. These are numbered from CMF_{1i} to CMF_{6i} and from CMF_{1p} to CMF_{6p} in the HSM. Guidelines for the parameters used to compute CMFs can be found in Chapter 12, Section 12.7.2 of the HSM.

(4) Data for unsignalized intersections only:

(a) Number of major-road approaches with left-turn lanes, 0, 1, or 2 (CMF_{1i}).

(b) Number of major-road approaches with right-turn lanes, 0, 1, or 2 (CMF_{3i}).

(5) Data for signalized intersections only:

(a) Number of approaches with left-turn lanes, 0, 1, 2, 3, or 4 (CMF_{1i}).

(b) Type of left-turn signal phasing at each approach, permissive, protected/permissive, or protected (CMF_{2i}).

(c) Number of approaches with right-turn lanes, 0, 1, 2, 3, or 4 (CMF_{3i}).

(d) Number of approaches with right-turn-on-red prohibited, 0, 1, 2, 3, or 4 (CMF_{4i}).

(e) Intersection lighting, presence or absence (CMF_{5i}).

(f) Intersection red light cameras, presence or absence (CMF_{6i}).

(6) Data for vehicle/pedestrian collisions:

(a) Number of bus stops within 1,000 ft. of the intersection (CMF_{1p}).

(b) Schools within 1,000 ft. of the intersection, presence or absence (CMF_{2p}).

(c) Number of alcohol sales establishments within 1,000 ft. of the intersection (CMF_{3p}).

Other Intersection Types

(1) The following is a list of data collection input parameters for intersections for which an HSM Predictive Method is not currently available. The ***Other Intersection Data Collection Table (Form No. 750-020-05h)*** may be used to collect this data. An example of this form completed is shown in ***Figure 5-8***.

(2) Essential Elements

(a) Determine intersection configuration, three leg stop controlled (3ST), three leg signalized (3SG), four-leg stop controlled (4ST), or four-leg signalized (4SG), or other.

(b) Roadway AADT on the major street approach and roadway AADT on the minor street approach.

(c) Intersection skew angle.

(d) Number of major and minor street approaches with left-turn lanes.

(e) Number of major and minor street approaches with right-turn lanes.

(f) Type of left-turn signal phasing per approach.

(g) Lighting per approach and lighting in the middle of the intersection, presence or absence.

(h) Number of approaches with crosswalks

(i) Number of approaches with right-turn-on-red prohibited.

(j) Presence of bus stops and location, near side or far side.

(3) Desired Elements

(a) Intersection red light cameras (present/not present).

(b) Pedestrian crossing volumes per leg.

(c) Maximum number of lanes crossed by a pedestrian.

(d) Schools within 1,000 ft. of the intersection, number and distance.

(e) Number of alcohol sales establishments within 1,000 ft. of the intersection, number and distance.

5.4.2 Historical Crash Data

(1) Florida historical crash data may be obtained from the FDOT CAR System. Access to the FDOT CAR System requires FDOT permission. In 2011, the general format of police reports changed, resulting in different values assigned to harmful events. It is recommended that caution be taken when using crash data from 2011 forward and when using programs summarizing crash data automatically, as harmful event codes changed after 2011. Also, after 2011, a single form is used by Florida Highway Patrol (FHP) for long-form and short-form crashes. A check-mark on the top left of the form determines whether it is a long- or short-form crash police report. Local agencies may continue to use the short-form format.

5.4.2.1 Collision Diagrams

(1) Collision diagrams are not required for HSM Predictive Method application; however, they provide a visual representation of crash patterns and help identify crash clusters by crash type. Additionally, collision diagrams are a valuable tool during countermeasure determination.

(2) Collision diagrams should always be developed where time and resources permit. Some software programs are available for collision diagram development, but their accuracy and effectiveness varies. The results of automated collision diagrams should be spot checked to ensure crashes have been spatially located correctly. Section 5.2.2 of Chapter 5: Diagnosis in the HSM discusses summarizing crashes by location and Figure 5.3 in the same chapter illustrates a sample collision diagram. HSM Figure 5.4 contains the symbology to be used to represent crashes when developing collision diagrams in either an automated program or by hand. ***Form No. 750-020-05i*** and ***Form No. 750-020-05*** may be used to develop collision diagrams for segments and intersections, respectively. Completed examples for these forms are shown in **Figure 5-9** and **Figure 5-10**, respectively.

5.4.2.2 Collison Summaries

(1) Although the predictive method including Empirical Bayes application uses a total number of crashes, crashes should typically be summarized into at least the following categories to obtain a clearer picture of crash occurrence and to select countermeasures more readily addressing crash patterns observed. Other categories, in addition to the ones listed below, are encouraged depending on the prevailing observations made at a particular study location.

- Crash type (rear-end, angle, sideswipe, left-turn, etc.)
- Crash severity (fatal, injury, property damage only)
- Lighting and day/night conditions
- Weather
- Road surface conditions
- Date (year, month, day of the week, time of the day)
- First harmful event
- Contributing cause

(2) The ***Collision Summary (Form No. 750-020-06)*** is a detailed summary of the crashes information represented in the Collision Diagram. The heading should be filled out completely by entering the Section, State Road, Intersecting Route, Study Period, County, and other information as shown in **Figure 5-11**.

(3) Number the crashes (as they correspond with those represented on the Collision Diagram) on the Crash Summary and fill in the pertinent information. Because vehicle speed at impact may provide valuable insight into the cause of crashes, the estimated speeds as recorded in the crash report should be indicated in the Contributing Cause column.

(4) In reviewing the summary of the crash information, the following factors are important. The day of the week can be significant because certain parking and turning restrictions may apply only on weekends. The date is necessary to allow the separation of crashes which may have occurred before or after a change in control, improvement, or increased traffic volume. The time of occurrence is important from a standpoint of developing crash rates as a function of traffic volume during certain periods, of performing violation or other observance studies, and of possibly limiting applications of certain regulations during specific hours of the day.

(5) Some Districts have developed spreadsheets internally capable of using the raw crash data from the CAR system to automatically summarize the data into tables and graphs. These spreadsheets should be used to maintain consistency and meet the District's specific requirements.

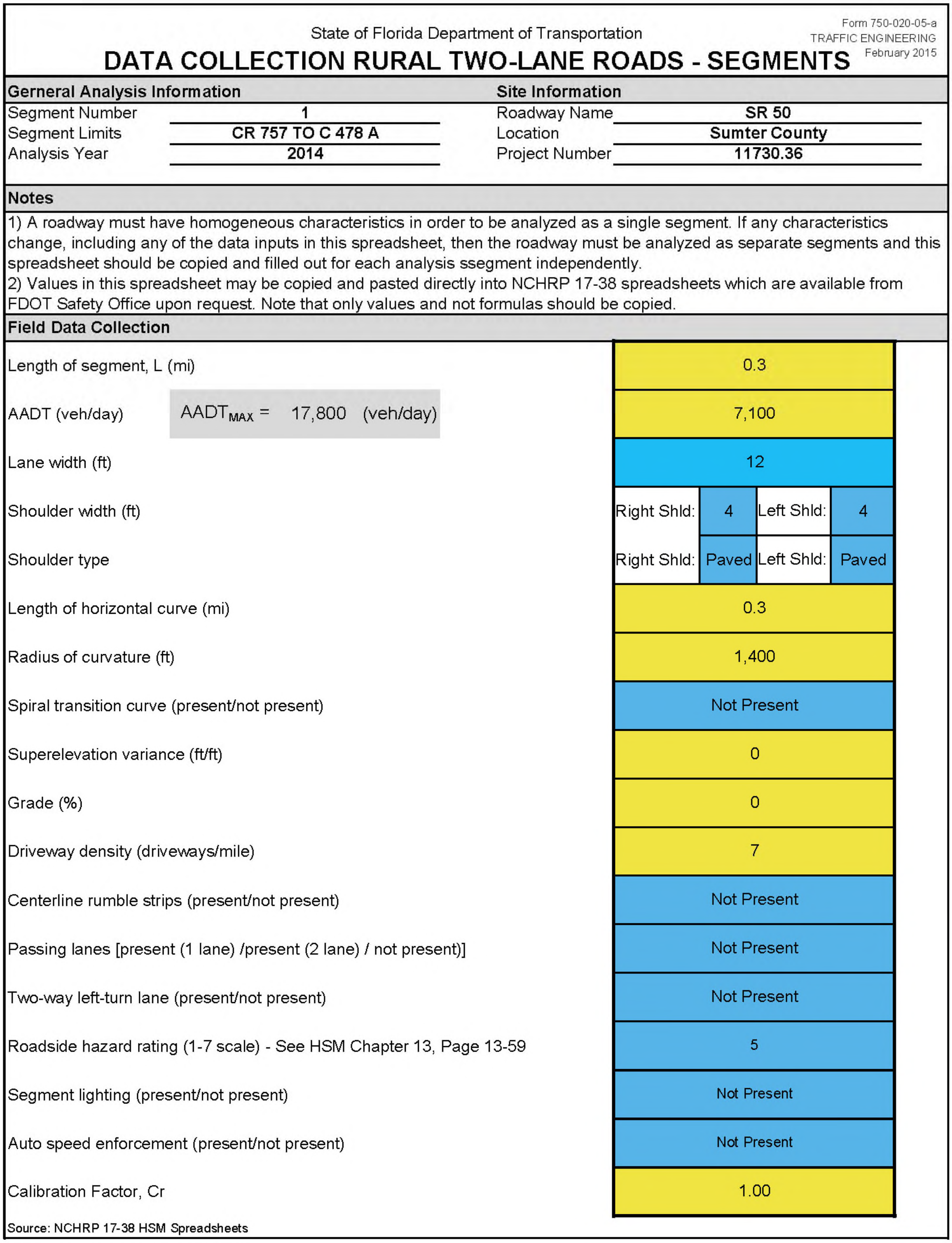
5.4.2.3 Empirical Bayes and Historical Crash Data

(1) Historical crash data of a minimum of 3 years shall be used to compute the Expected Average Crash Frequency by applying the Empirical Bayes Methodology. The methodology is explained in the Appendix to Part C of the Highway Safety Manual.

5.5 FORMS ACCESS

(1) All forms required for data collection are available from the Department's Forms Library in electronic format.

Figure 5-1. Rural Two-Lane Roadway Segment Data Collection (Form No. 750-020-05a)



Form 750-020-05-a
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

DATA COLLECTION RURAL TWO-LANE ROADS - SEGMENTS

Gerneral Analysis Information		**Site Information**	
Segment Number	**1**	Roadway Name	**SR 50**
Segment Limits	**CR 757 TO C 478 A**	Location	**Sumter County**
Analysis Year	**2014**	Project Number	**11730.36**

Notes

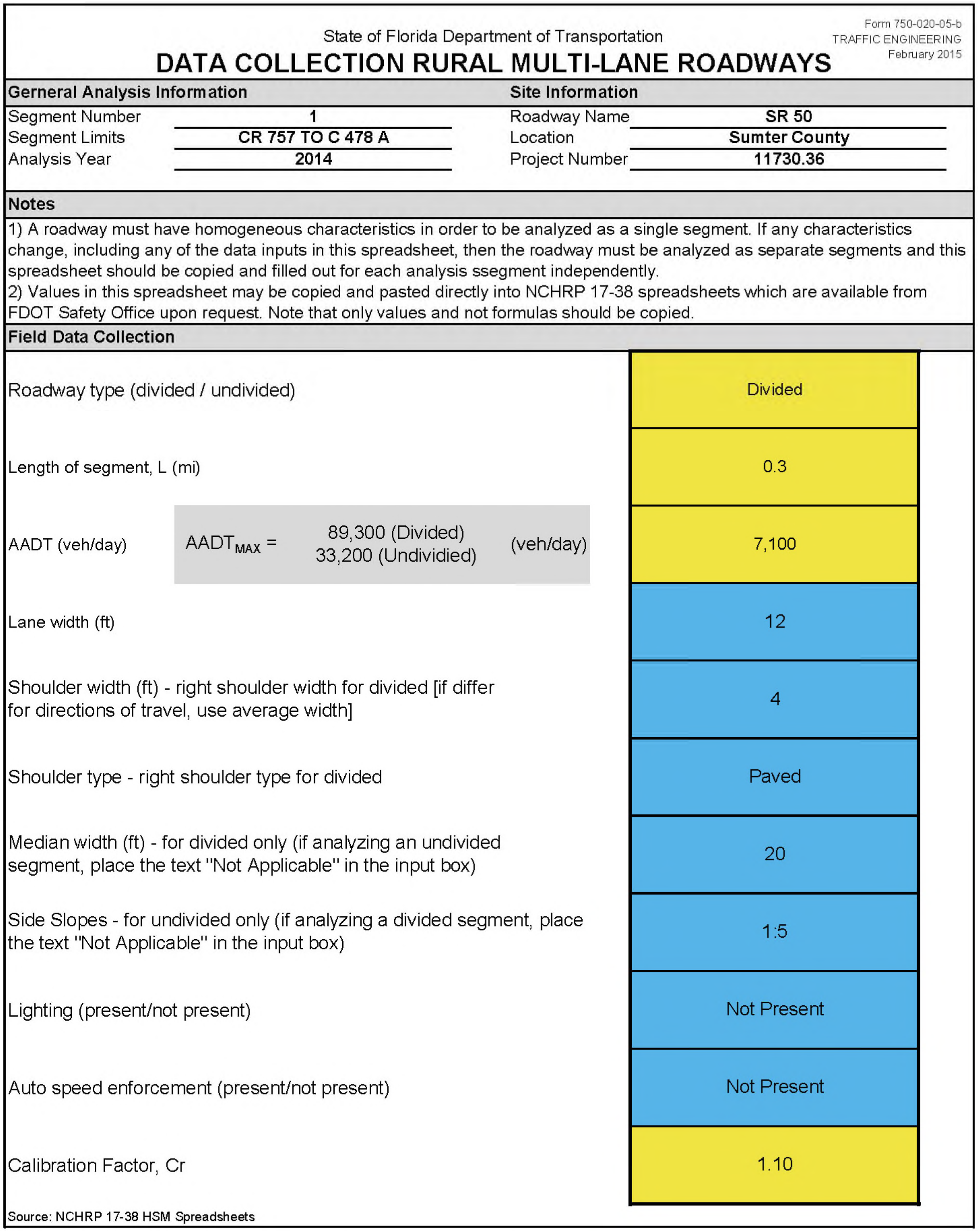
1) A roadway must have homogeneous characteristics in order to be analyzed as a single segment. If any characteristics change, including any of the data inputs in this spreadsheet, then the roadway must be analyzed as separate segments and this spreadsheet should be copied and filled out for each analysis ssegment independently.
2) Values in this spreadsheet may be copied and pasted directly into NCHRP 17-38 spreadsheets which are available from FDOT Safety Office upon request. Note that only values and not formulas should be copied.

Field Data Collection

Length of segment, L (mi)		0.3
AADT (veh/day)	$AADT_{MAX}$ = 17,800 (veh/day)	7,100
Lane width (ft)		12
Shoulder width (ft)		Right Shld: 4 Left Shld: 4
Shoulder type		Right Shld: Paved Left Shld: Paved
Length of horizontal curve (mi)		0.3
Radius of curvature (ft)		1,400
Spiral transition curve (present/not present)		Not Present
Superelevation variance (ft/ft)		0
Grade (%)		0
Driveway density (driveways/mile)		7
Centerline rumble strips (present/not present)		Not Present
Passing lanes [present (1 lane) /present (2 lane) / not present)]		Not Present
Two-way left-turn lane (present/not present)		Not Present
Roadside hazard rating (1-7 scale) - See HSM Chapter 13, Page 13-59		5
Segment lighting (present/not present)		Not Present
Auto speed enforcement (present/not present)		Not Present
Calibration Factor, Cr		1.00

Source: NCHRP 17-38 HSM Spreadsheets

Figure 5-2. Rural Multi-Lane Roadway Segment Data Collection (Form No. 750-020-05b)



Form 750-020-05-b
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

DATA COLLECTION RURAL MULTI-LANE ROADWAYS

Gerneral Analysis Information		**Site Information**	
Segment Number	**1**	Roadway Name	**SR 50**
Segment Limits	**CR 757 TO C 478 A**	Location	**Sumter County**
Analysis Year	**2014**	Project Number	**11730.36**

Notes

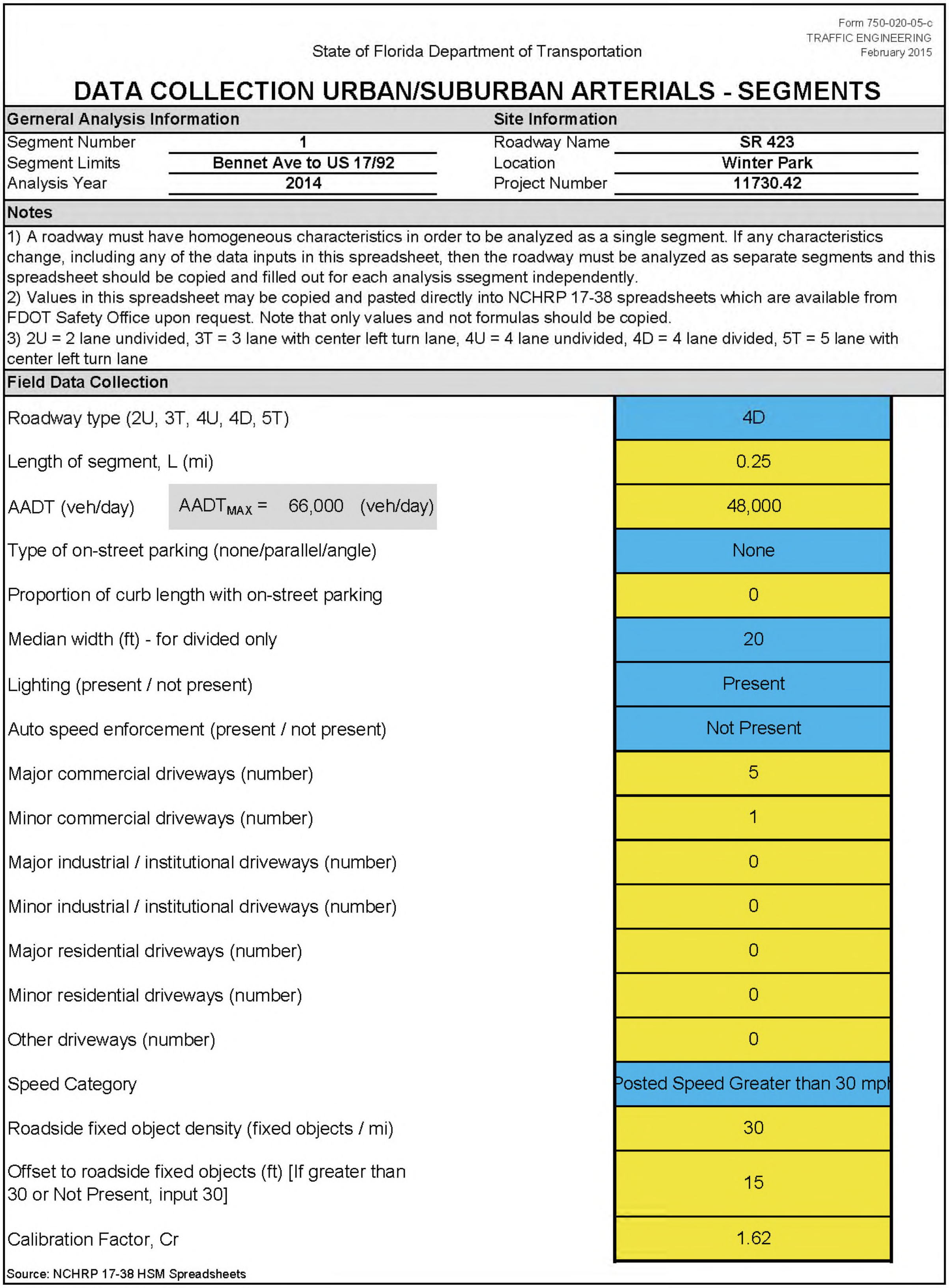
1) A roadway must have homogeneous characteristics in order to be analyzed as a single segment. If any characteristics change, including any of the data inputs in this spreadsheet, then the roadway must be analyzed as separate segments and this spreadsheet should be copied and filled out for each analysis ssegment independently.
2) Values in this spreadsheet may be copied and pasted directly into NCHRP 17-38 spreadsheets which are available from FDOT Safety Office upon request. Note that only values and not formulas should be copied.

Field Data Collection

Roadway type (divided / undivided)		Divided
Length of segment, L (mi)		0.3
AADT (veh/day)	$AADT_{MAX}$ = 89,300 (Divided) 33,200 (Undividied) (veh/day)	7,100
Lane width (ft)		12
Shoulder width (ft) - right shoulder width for divided [if differ for directions of travel, use average width]		4
Shoulder type - right shoulder type for divided		Paved
Median width (ft) - for divided only (if analyzing an undivided segment, place the text "Not Applicable" in the input box)		20
Side Slopes - for undivided only (if analyzing a divided segment, place the text "Not Applicable" in the input box)		1:5
Lighting (present/not present)		Not Present
Auto speed enforcement (present/not present)		Not Present
Calibration Factor, Cr		1.10

Source: NCHRP 17-38 HSM Spreadsheets

Figure 5-3. Urban/Suburban Arterial Segment Data Collection (Form No. 750-020-05c)



Form 750-020-05-c
TRAFFIC ENGINEERING
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State of Florida Department of Transportation

DATA COLLECTION URBAN/SUBURBAN ARTERIALS - SEGMENTS

Gerneral Analysis Information

Segment Number: **1**
Segment Limits: **Bennet Ave to US 17/92**
Analysis Year: **2014**

Site Information

Roadway Name: **SR 423**
Location: **Winter Park**
Project Number: **11730.42**

Notes

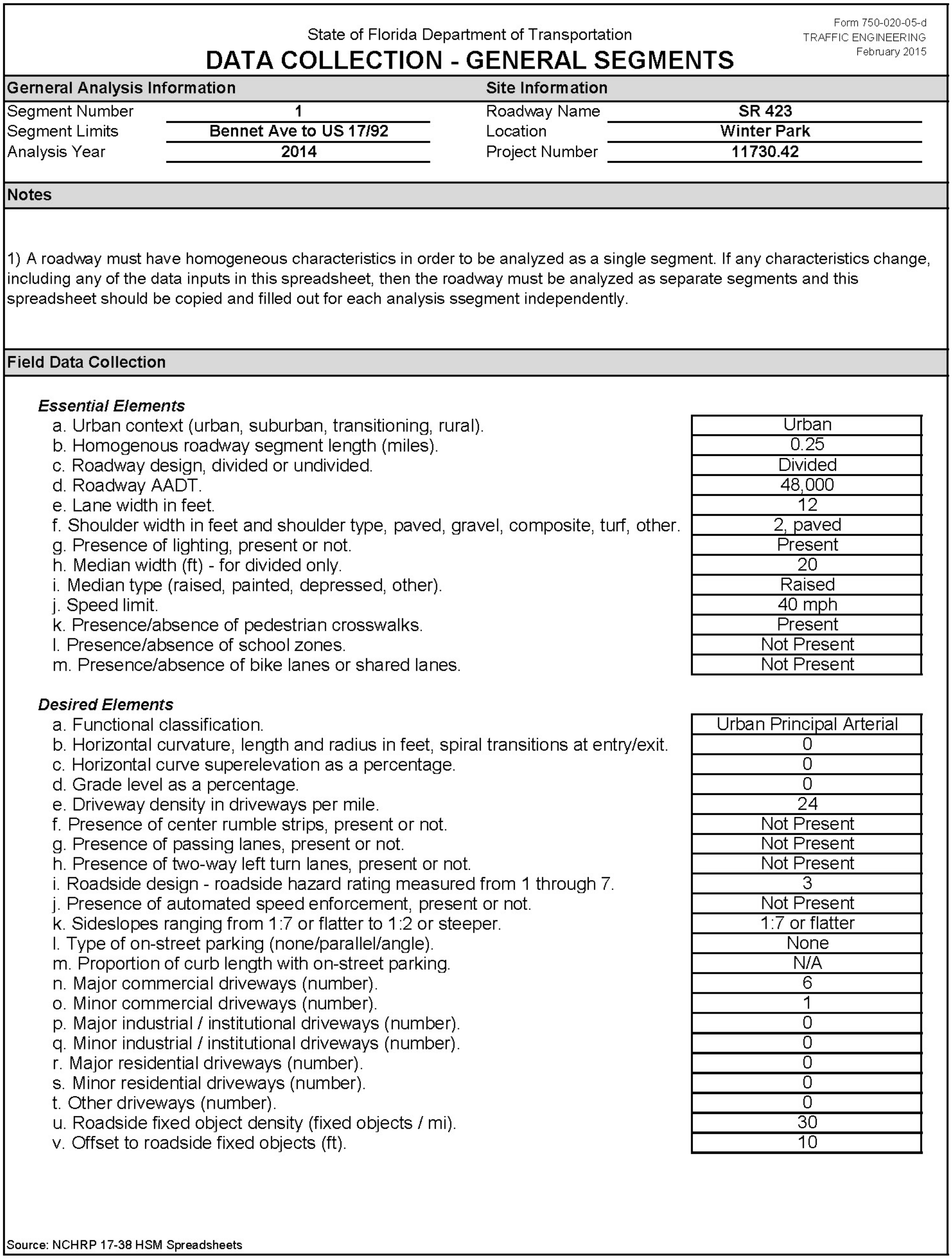
1) A roadway must have homogeneous characteristics in order to be analyzed as a single segment. If any characteristics change, including any of the data inputs in this spreadsheet, then the roadway must be analyzed as separate segments and this spreadsheet should be copied and filled out for each analysis ssegment independently.
2) Values in this spreadsheet may be copied and pasted directly into NCHRP 17-38 spreadsheets which are available from FDOT Safety Office upon request. Note that only values and not formulas should be copied.
3) 2U = 2 lane undivided, 3T = 3 lane with center left turn lane, 4U = 4 lane undivided, 4D = 4 lane divided, 5T = 5 lane with center left turn lane

Field Data Collection

Roadway type (2U, 3T, 4U, 4D, 5T)		4D
Length of segment, L (mi)		0.25
AADT (veh/day)	$AADT_{MAX}$ = 66,000 (veh/day)	48,000
Type of on-street parking (none/parallel/angle)		None
Proportion of curb length with on-street parking		0
Median width (ft) - for divided only		20
Lighting (present / not present)		Present
Auto speed enforcement (present / not present)		Not Present
Major commercial driveways (number)		5
Minor commercial driveways (number)		1
Major industrial / institutional driveways (number)		0
Minor industrial / institutional driveways (number)		0
Major residential driveways (number)		0
Minor residential driveways (number)		0
Other driveways (number)		0
Speed Category		Posted Speed Greater than 30 mph
Roadside fixed object density (fixed objects / mi)		30
Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		15
Calibration Factor, Cr		1.62

Source: NCHRP 17-38 HSM Spreadsheets

Figure 5-4. Other Roadway Segment Data Collection (Form No. 750-020-05d)



Form 750-020-05-d
TRAFFIC ENGINEERING
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State of Florida Department of Transportation

DATA COLLECTION - GENERAL SEGMENTS

Gerneral Analysis Information

Segment Number **1**
Segment Limits **Bennet Ave to US 17/92**
Analysis Year **2014**

Site Information

Roadway Name **SR 423**
Location **Winter Park**
Project Number **11730.42**

Notes

1) A roadway must have homogeneous characteristics in order to be analyzed as a single segment. If any characteristics change, including any of the data inputs in this spreadsheet, then the roadway must be analyzed as separate segments and this spreadsheet should be copied and filled out for each analysis ssegment independently.

Field Data Collection

Essential Elements

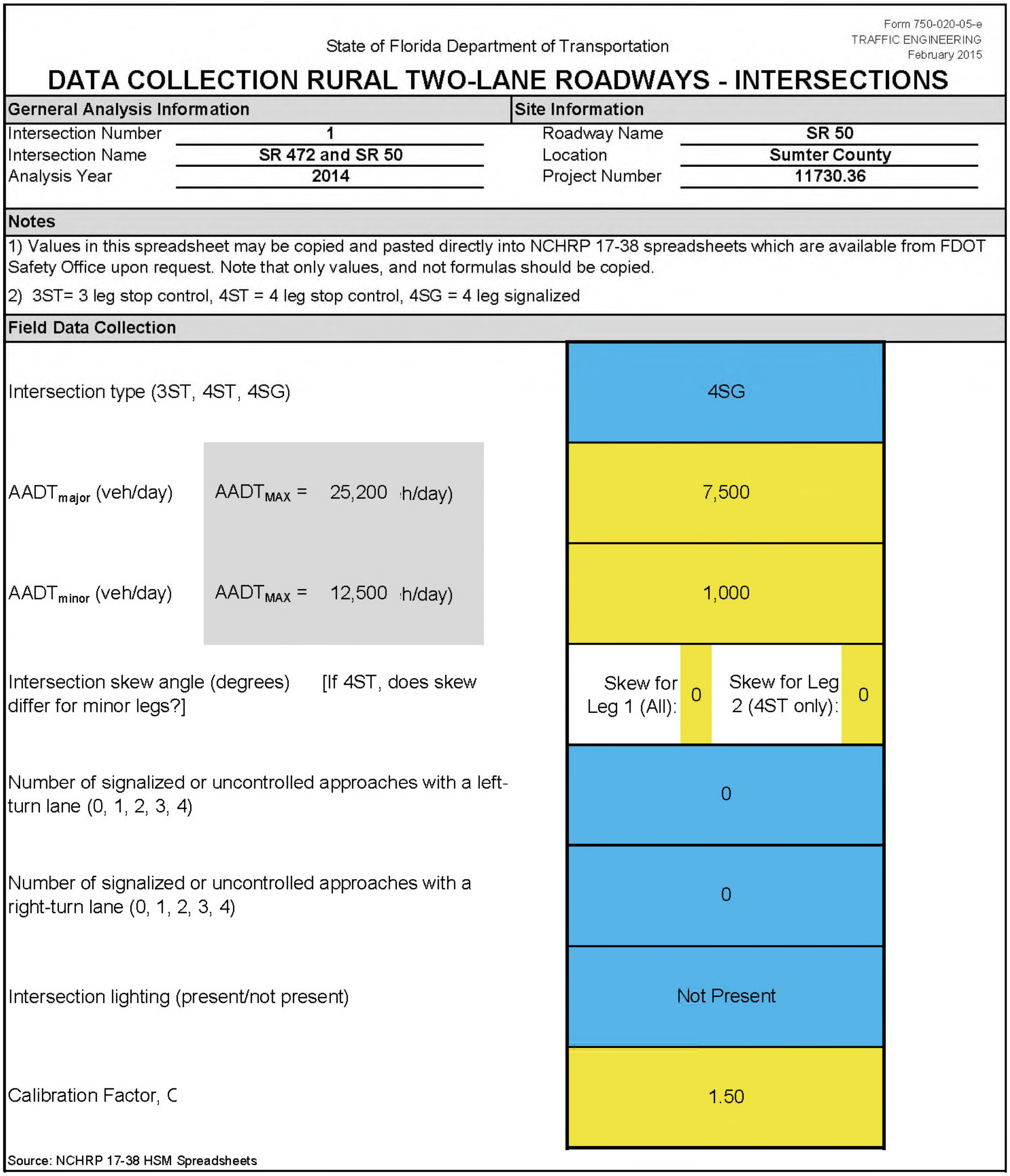
a. Urban context (urban, suburban, transitioning, rural).	Urban
b. Homogenous roadway segment length (miles).	0.25
c. Roadway design, divided or undivided.	Divided
d. Roadway AADT.	48,000
e. Lane width in feet.	12
f. Shoulder width in feet and shoulder type, paved, gravel, composite, turf, other.	2, paved
g. Presence of lighting, present or not.	Present
h. Median width (ft) - for divided only.	20
i. Median type (raised, painted, depressed, other).	Raised
j. Speed limit.	40 mph
k. Presence/absence of pedestrian crosswalks.	Present
l. Presence/absence of school zones.	Not Present
m. Presence/absence of bike lanes or shared lanes.	Not Present

Desired Elements

a. Functional classification.	Urban Principal Arterial
b. Horizontal curvature, length and radius in feet, spiral transitions at entry/exit.	0
c. Horizontal curve superelevation as a percentage.	0
d. Grade level as a percentage.	0
e. Driveway density in driveways per mile.	24
f. Presence of center rumble strips, present or not.	Not Present
g. Presence of passing lanes, present or not.	Not Present
h. Presence of two-way left turn lanes, present or not.	Not Present
i. Roadside design - roadside hazard rating measured from 1 through 7.	3
j. Presence of automated speed enforcement, present or not.	Not Present
k. Sideslopes ranging from 1:7 or flatter to 1:2 or steeper.	1:7 or flatter
l. Type of on-street parking (none/parallel/angle).	None
m. Proportion of curb length with on-street parking.	N/A
n. Major commercial driveways (number).	6
o. Minor commercial driveways (number).	1
p. Major industrial / institutional driveways (number).	0
q. Minor industrial / institutional driveways (number).	0
r. Major residential driveways (number).	0
s. Minor residential driveways (number).	0
t. Other driveways (number).	0
u. Roadside fixed object density (fixed objects / mi).	30
v. Offset to roadside fixed objects (ft).	10

Source: NCHRP 17-38 HSM Spreadsheets

Figure 5-5. Rural Two-Lane Roadway Intersection Data Collection (Form No. 750-020-05e)



Form 750-020-05-e
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DATA COLLECTION RURAL TWO-LANE ROADWAYS - INTERSECTIONS

Gerneral Analysis Information

Intersection Number: **1**
Intersection Name: **SR 472 and SR 50**
Analysis Year: **2014**

Site Information

Roadway Name: **SR 50**
Location: **Sumter County**
Project Number: **11730.36**

Notes

1) Values in this spreadsheet may be copied and pasted directly into NCHRP 17-38 spreadsheets which are available from FDOT Safety Office upon request. Note that only values, and not formulas should be copied.

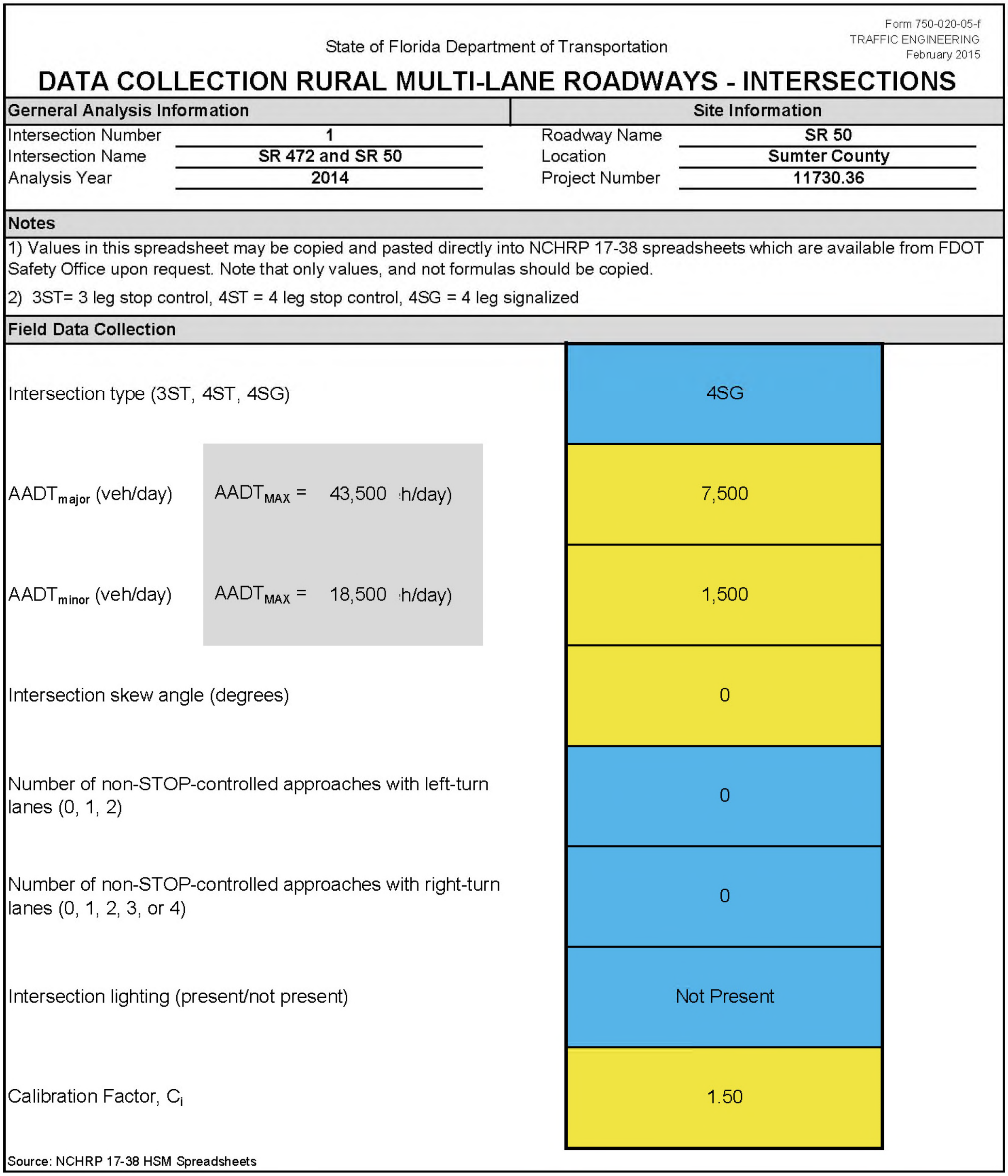
2) 3ST= 3 leg stop control, 4ST = 4 leg stop control, 4SG = 4 leg signalized

Field Data Collection

Intersection type (3ST, 4ST, 4SG)		4SG
$AADT_{major}$ (veh/day)	$AADT_{MAX}$ = 25,200 h/day)	7,500
$AADT_{minor}$ (veh/day)	$AADT_{MAX}$ = 12,500 h/day)	1,000
Intersection skew angle (degrees) [If 4ST, does skew differ for minor legs?]		Skew for Leg 1 (All): 0 Skew for Leg 2 (4ST only): 0
Number of signalized or uncontrolled approaches with a left-turn lane (0, 1, 2, 3, 4)		0
Number of signalized or uncontrolled approaches with a right-turn lane (0, 1, 2, 3, 4)		0
Intersection lighting (present/not present)		Not Present
Calibration Factor, C		1.50

Source: NCHRP 17-38 HSM Spreadsheets

Figure 5-6. Rural Multi-Lane Roadway Intersection Data Collection (Form No. 750-020-05f)



Form 750-020-05-f
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

DATA COLLECTION RURAL MULTI-LANE ROADWAYS - INTERSECTIONS

Gerneral Analysis Information		Site Information	
Intersection Number	**1**	Roadway Name	**SR 50**
Intersection Name	**SR 472 and SR 50**	Location	**Sumter County**
Analysis Year	**2014**	Project Number	**11730.36**

Notes

1) Values in this spreadsheet may be copied and pasted directly into NCHRP 17-38 spreadsheets which are available from FDOT Safety Office upon request. Note that only values, and not formulas should be copied.

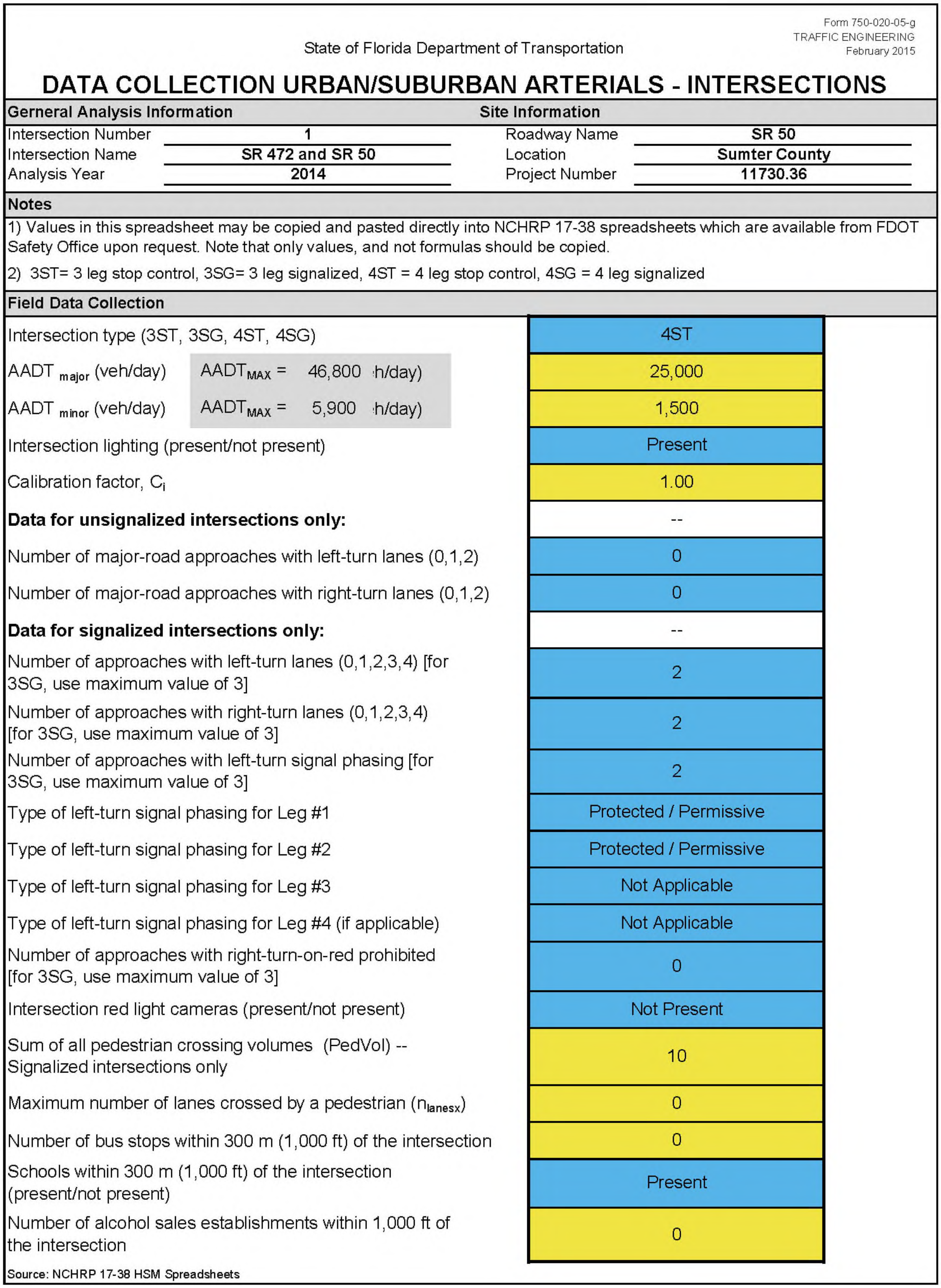
2) 3ST= 3 leg stop control, 4ST = 4 leg stop control, 4SG = 4 leg signalized

Field Data Collection

Intersection type (3ST, 4ST, 4SG)		4SG
$AADT_{major}$ (veh/day)	$AADT_{MAX}$ = 43,500 h/day)	7,500
$AADT_{minor}$ (veh/day)	$AADT_{MAX}$ = 18,500 h/day)	1,500
Intersection skew angle (degrees)		0
Number of non-STOP-controlled approaches with left-turn lanes (0, 1, 2)		0
Number of non-STOP-controlled approaches with right-turn lanes (0, 1, 2, 3, or 4)		0
Intersection lighting (present/not present)		Not Present
Calibration Factor, C_i		1.50

Source: NCHRP 17-38 HSM Spreadsheets

Figure 5-7. Urban/Suburban Roadway Intersection Data Collection (Form No. 750-020-05g)



Form 750-020-05-g
TRAFFIC ENGINEERING
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DATA COLLECTION URBAN/SUBURBAN ARTERIALS - INTERSECTIONS

Gerneral Analysis Information		**Site Information**	
Intersection Number	**1**	Roadway Name	**SR 50**
Intersection Name	**SR 472 and SR 50**	Location	**Sumter County**
Analysis Year	**2014**	Project Number	**11730.36**

Notes

1) Values in this spreadsheet may be copied and pasted directly into NCHRP 17-38 spreadsheets which are available from FDOT Safety Office upon request. Note that only values, and not formulas should be copied.

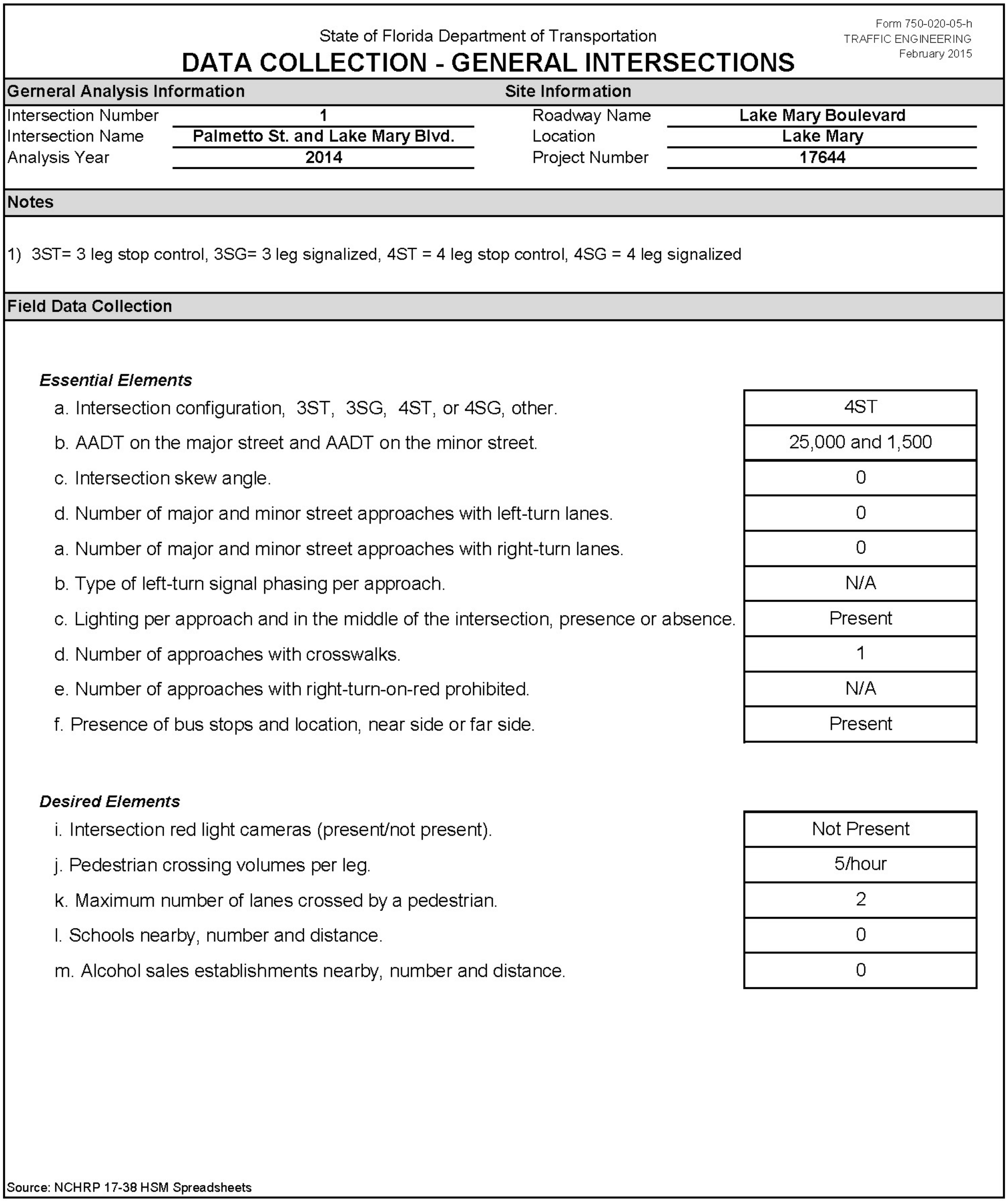
2) 3ST= 3 leg stop control, 3SG= 3 leg signalized, 4ST = 4 leg stop control, 4SG = 4 leg signalized

Field Data Collection

Intersection type (3ST, 3SG, 4ST, 4SG)		4ST
AADT $_{major}$ (veh/day)	AADT$_{MAX}$ = 46,800 h/day)	25,000
AADT $_{minor}$ (veh/day)	AADT$_{MAX}$ = 5,900 h/day)	1,500
Intersection lighting (present/not present)		Present
Calibration factor, C_i		1.00
Data for unsignalized intersections only:		--
Number of major-road approaches with left-turn lanes (0,1,2)		0
Number of major-road approaches with right-turn lanes (0,1,2)		0
Data for signalized intersections only:		--
Number of approaches with left-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		2
Number of approaches with right-turn lanes (0,1,2,3,4) [for 3SG, use maximum value of 3]		2
Number of approaches with left-turn signal phasing [for 3SG, use maximum value of 3]		2
Type of left-turn signal phasing for Leg #1		Protected / Permissive
Type of left-turn signal phasing for Leg #2		Protected / Permissive
Type of left-turn signal phasing for Leg #3		Not Applicable
Type of left-turn signal phasing for Leg #4 (if applicable)		Not Applicable
Number of approaches with right-turn-on-red prohibited [for 3SG, use maximum value of 3]		0
Intersection red light cameras (present/not present)		Not Present
Sum of all pedestrian crossing volumes (PedVol) -- Signalized intersections only		10
Maximum number of lanes crossed by a pedestrian (n_{lanesx})		0
Number of bus stops within 300 m (1,000 ft) of the intersection		0
Schools within 300 m (1,000 ft) of the intersection (present/not present)		Present
Number of alcohol sales establishments within 1,000 ft of the intersection		0

Source: NCHRP 17-38 HSM Spreadsheets

Figure 5-8. Other Intersection Data Collection (Form No. 750-020-05h)



Form 750-020-05-h
TRAFFIC ENGINEERING
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DATA COLLECTION - GENERAL INTERSECTIONS

Gerneral Analysis Information

Intersection Number: **1**
Intersection Name: **Palmetto St. and Lake Mary Blvd.**
Analysis Year: **2014**

Site Information

Roadway Name: **Lake Mary Boulevard**
Location: **Lake Mary**
Project Number: **17644**

Notes

1) 3ST= 3 leg stop control, 3SG= 3 leg signalized, 4ST = 4 leg stop control, 4SG = 4 leg signalized

Field Data Collection

Essential Elements

a. Intersection configuration, 3ST, 3SG, 4ST, or 4SG, other.	4ST
b. AADT on the major street and AADT on the minor street.	25,000 and 1,500
c. Intersection skew angle.	0
d. Number of major and minor street approaches with left-turn lanes.	0
a. Number of major and minor street approaches with right-turn lanes.	0
b. Type of left-turn signal phasing per approach.	N/A
c. Lighting per approach and in the middle of the intersection, presence or absence.	Present
d. Number of approaches with crosswalks.	1
e. Number of approaches with right-turn-on-red prohibited.	N/A
f. Presence of bus stops and location, near side or far side.	Present

Desired Elements

i. Intersection red light cameras (present/not present).	Not Present
j. Pedestrian crossing volumes per leg.	5/hour
k. Maximum number of lanes crossed by a pedestrian.	2
l. Schools nearby, number and distance.	0
m. Alcohol sales establishments nearby, number and distance.	0

Source: NCHRP 17-38 HSM Spreadsheets

Figure 5-9. Collision Diagram for Segments (Form No. 750-020-05i)

Form 750-020-05-i
TRAFFIC ENGINEERING
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COLLISION DIAGRAM - SEGMENT

Gerneral Analysis Information

Roadway ID Number **75190000**
Nearby Intersection Name **US 17/92 and Bennet Ave**
Analysis Years **2010-2014**

Site Information

Location **Winter Park**
Project Number **11730.42**

Notes

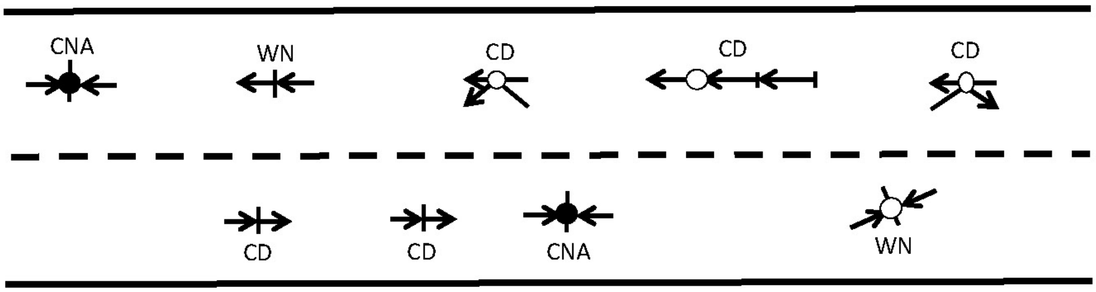
1) Collision diagram symbology illustrated in Figure 5-4 of Chapter 5 of the Highway Safety Manual should be used.

2) The legend may be used to clarify symbology that identifies total number of crashes, injuries, fatalities, pavement conditions, etc.

Field Data Collection

Legend

C	Dry Clear	L	Dawn/Dusk	→←	Head-On	⇄	Sideswipe
W	Wet	D	Day	→↙	Angle	○	Injury
N	Night	A	Alcohol/Drug-Related	←←	Rear-End	●	Fatal



SR 423 (Lee Road)
Street Name

9.6
Approximate Milepost

Total Intersection Crashes per the Crash Summary	
Total Crashes Graphed on this Page	9
Total Injury Crashes	4
Total Fatal Crashes	2
Total PDO Crashes	3

Source: Adapted from HSM Figure 5-3

Figure 5-10. Collision Diagram for Intersections (Form No. 750-020-05)

Form 750-020-05
TRAFFIC ENGINEERING
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COLLISION DIAGRAM - INTERSECTION

Gerneral Analysis Information **Site Information**

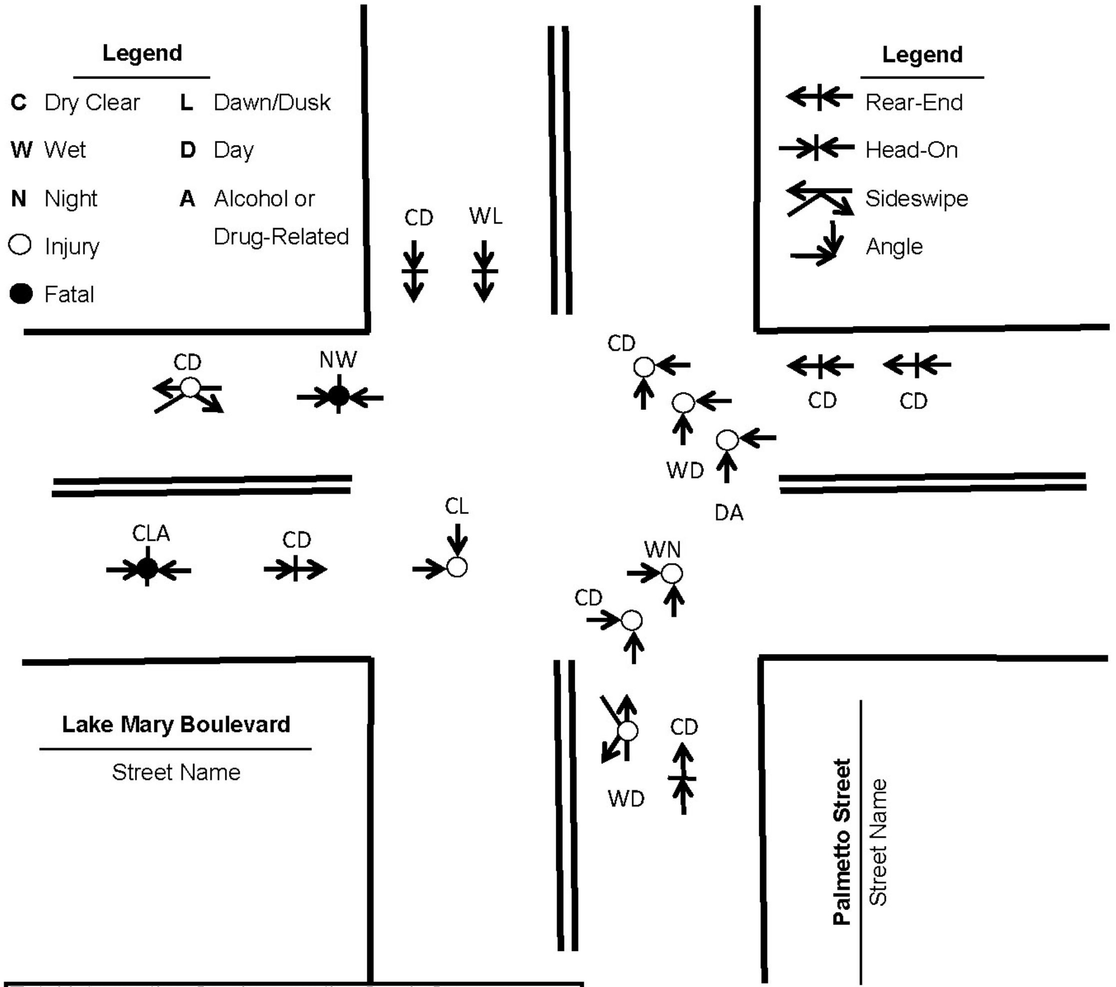
Intersection Number **1**
Intersection Name **Palmetto St. and Lake Mary Blvd.**
Analysis Years **2010-2014**
Location **Lake Mary**
Project Number **17644**

Notes

1) Collision diagram symbology illustrated in Figure 5-4 of Chapter 5 of the Highway Safety Manual should be used.

2) The legend may be used to clarify symbology that identifies total number of crashes, injuries, fatalities, pavement conditions, etc.

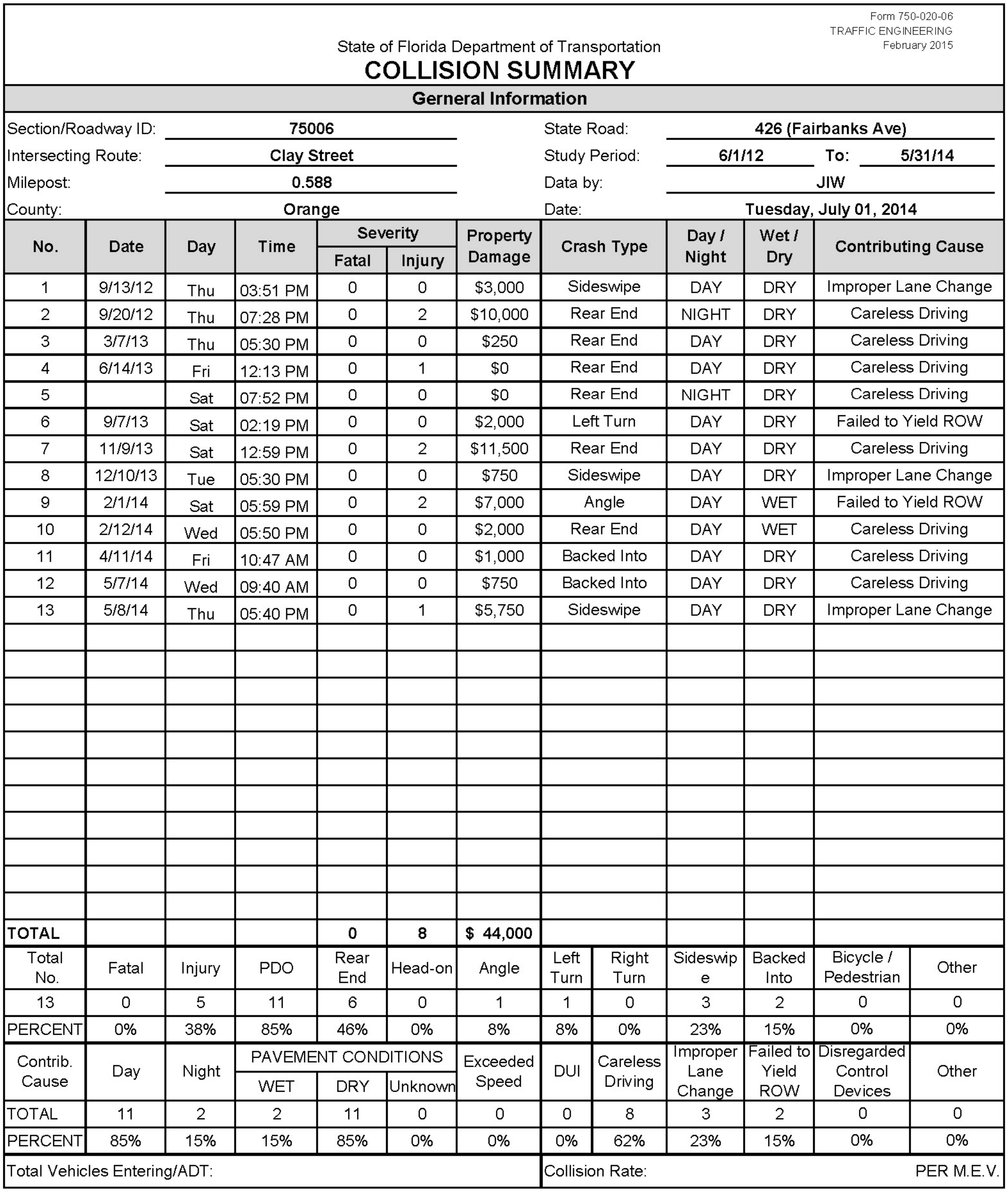
Field Data Collection



Total Intersection Crashes per the Crash Summary	
Total Crashes Graphed on this Page	16
Total Injury Crashes	8
Total Fatal Crashes	2
Total PDO Crashes	6

Source: Adapted from HSM Figure 5-4

Figure 5-11. Collision Summary (Form No. 750-020-06)



Form 750-020-06
TRAFFIC ENGINEERING
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COLLISION SUMMARY

Gerneral Information

Section/Roadway ID: **75006**
State Road: **426 (Fairbanks Ave)**
Intersecting Route: **Clay Street**
Study Period: **6/1/12** **To:** **5/31/14**
Milepost: **0.588**
Data by: **JIW**
County: **Orange**
Date: **Tuesday, July 01, 2014**

No.	Date	Day	Time	Severity		Property Damage	Crash Type	Day / Night	Wet / Dry	Contributing Cause
				Fatal	Injury					
1	9/13/12	Thu	03:51 PM	0	0	$3,000	Sideswipe	DAY	DRY	Improper Lane Change
2	9/20/12	Thu	07:28 PM	0	2	$10,000	Rear End	NIGHT	DRY	Careless Driving
3	3/7/13	Thu	05:30 PM	0	0	$250	Rear End	DAY	DRY	Careless Driving
4	6/14/13	Fri	12:13 PM	0	1	$0	Rear End	DAY	DRY	Careless Driving
5		Sat	07:52 PM	0	0	$0	Rear End	NIGHT	DRY	Careless Driving
6	9/7/13	Sat	02:19 PM	0	0	$2,000	Left Turn	DAY	DRY	Failed to Yield ROW
7	11/9/13	Sat	12:59 PM	0	2	$11,500	Rear End	DAY	DRY	Careless Driving
8	12/10/13	Tue	05:30 PM	0	0	$750	Sideswipe	DAY	DRY	Improper Lane Change
9	2/1/14	Sat	05:59 PM	0	2	$7,000	Angle	DAY	WET	Failed to Yield ROW
10	2/12/14	Wed	05:50 PM	0	0	$2,000	Rear End	DAY	WET	Careless Driving
11	4/11/14	Fri	10:47 AM	0	0	$1,000	Backed Into	DAY	DRY	Careless Driving
12	5/7/14	Wed	09:40 AM	0	0	$750	Backed Into	DAY	DRY	Careless Driving
13	5/8/14	Thu	05:40 PM	0	1	$5,750	Sideswipe	DAY	DRY	Improper Lane Change
TOTAL				**0**	**8**	**$ 44,000**				

Total No.	Fatal	Injury	PDO	Rear End	Head-on	Angle	Left Turn	Right Turn	Sideswipe	Backed Into	Bicycle / Pedestrian	Other
13	0	5	11	6	0	1	1	0	3	2	0	0
PERCENT	0%	38%	85%	46%	0%	8%	8%	0%	23%	15%	0%	0%

Contrib. Cause	Day	Night	PAVEMENT CONDITIONS			Exceeded Speed	DUI	Careless Driving	Improper Lane Change	Failed to Yield ROW	Disregarded Control Devices	Other
			WET	DRY	Unknown							
TOTAL	11	2	2	11	0	0	0	8	3	2	0	0
PERCENT	85%	15%	15%	85%	0%	0%	0%	62%	23%	15%	0%	0%

Total Vehicles Entering/ADT:

Collision Rate: PER M.E.V.

CHAPTER 6 CONDITION DIAGRAM

6.1 PURPOSE

(1) Condition diagrams are necessary to capture field conditions for later correlating with collision diagrams and crash summaries. The purpose of the condition diagram is to show the intersection and the conditions within the surrounding area as it exists. The diagram should include the intersection alignment, items such as buildings, sidewalks, trees, lighting poles, water hydrants, stop signs, number of lanes, and lane use if required, associated with the streets forming the intersection or segment. At intersections, the Condition Diagram should show the length of all exclusive lanes and associated tapers.

(2) All items associated with the streets should be drawn using the symbols as outlined on the bottom of the form. The diagram should also include traffic control devices, signal timing, and signal phasing. The scope and area to be covered within the condition diagram should be selected based on the limits of the project, historical crash data, and engineering judgment. Section 5.2.2 of Chapter 5: Diagnosis in the HSM discusses summarizing crashes by location. **Figure 6-1** illustrates the sample condition diagram that is provided in the HSM (Figure 5-5 on page 5-7 of the HSM).

6.2 FORMS ACCESS

(1) ***Form No. 750-020-04*** may be used to develop condition diagrams. Additional standardized symbols other than the ones shown in the form can be found in ***FDOT Design Standards Index No. 002*** if needed. A completed example of this form is shown in **Figure 6-2**.

(2) All forms required for data collection are available from the Department's Forms Library in electronic format.

Figure 6-1. Condition Diagram Example obtained from the HSM (Section 5.2.2)

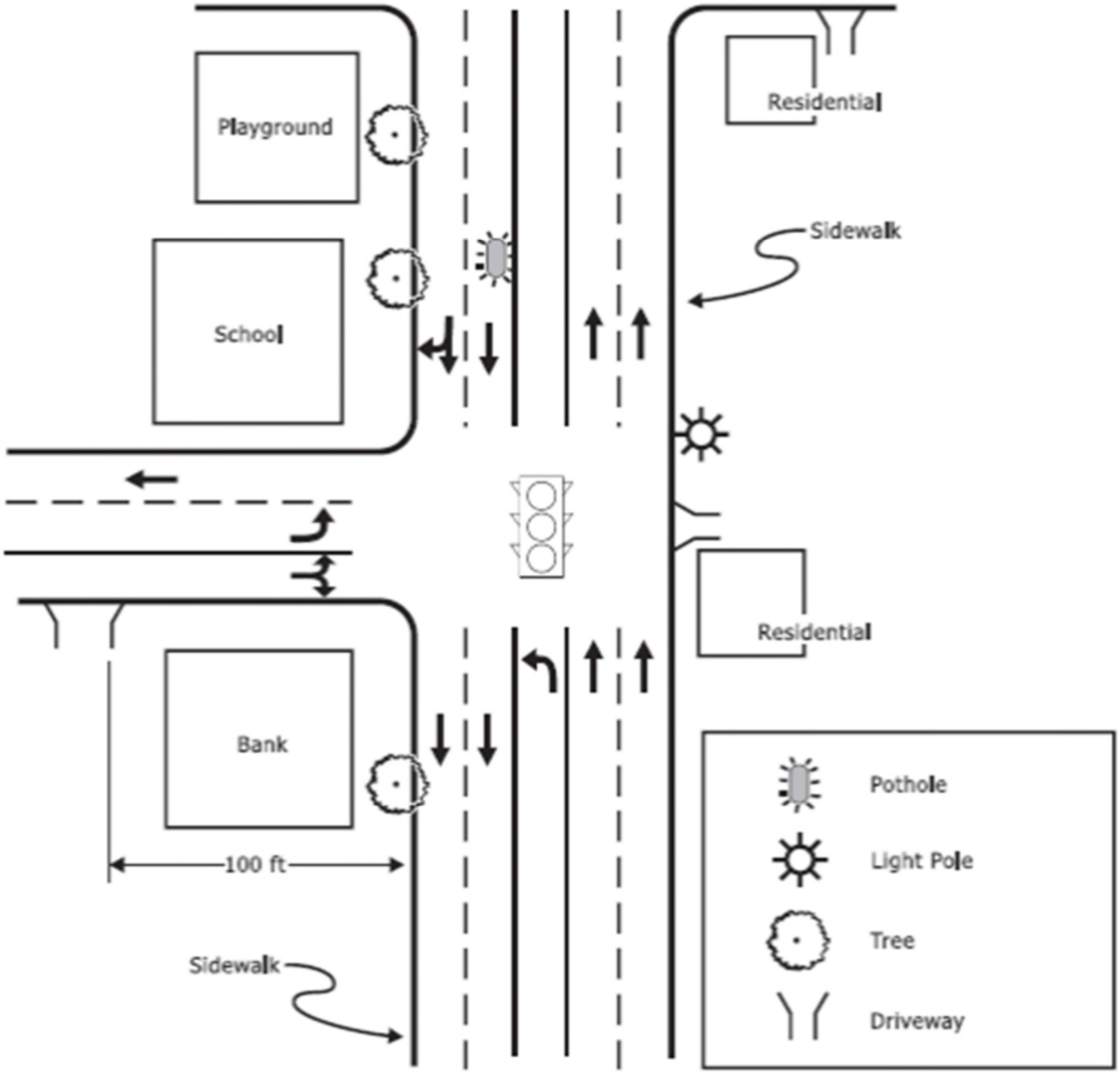

Figure 6-2. Condition Diagram (Form No. 750-020-04)

Form 750-020-04
TRAFFIC ENGINEERING
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CONDITION DIAGRAM

Gerneral Analysis Information

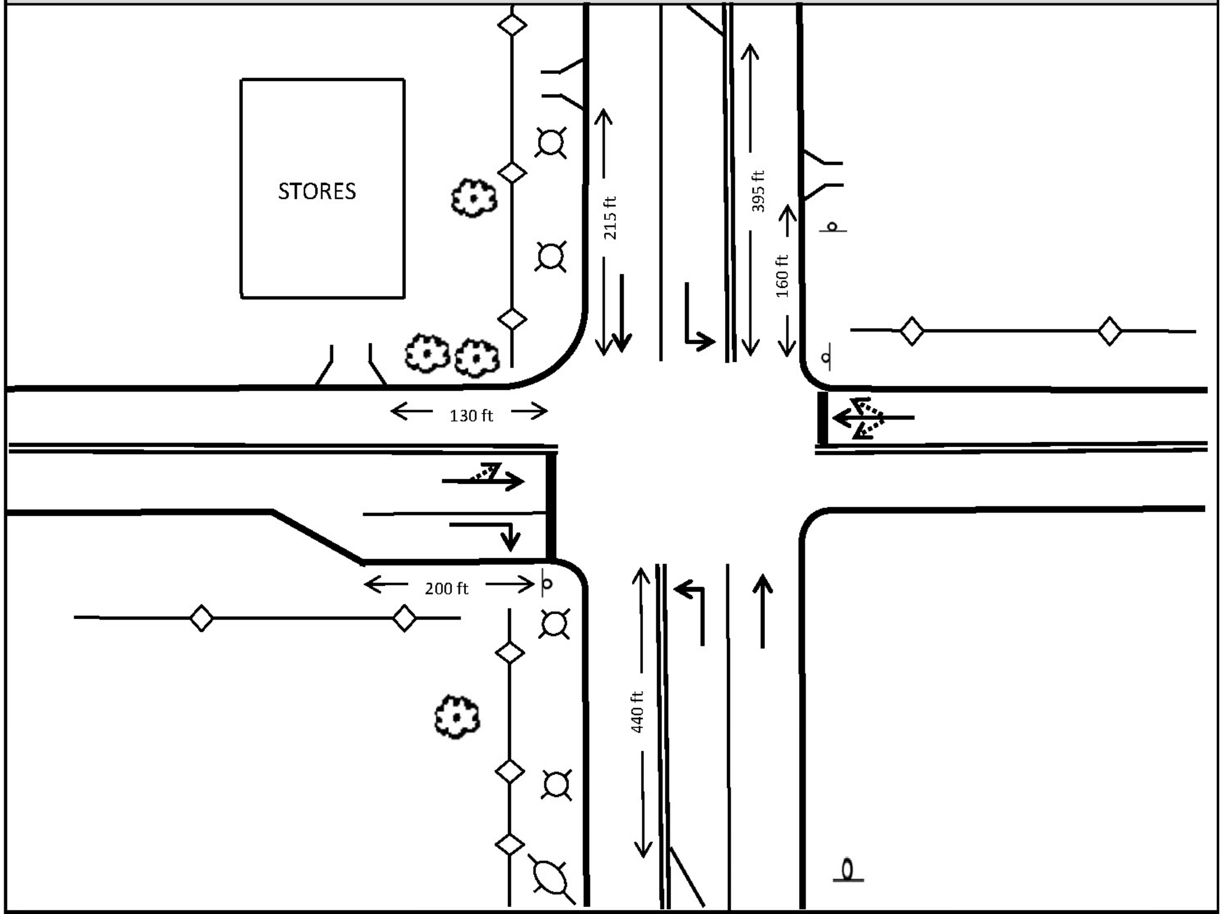
Roadway ID Number **87150000**
Nearby Intersection Name **SW 192nd Street**
Analysis Years **2008-2012**
Location **Miami-Dade County**
Project Number **11879.25**

Notes

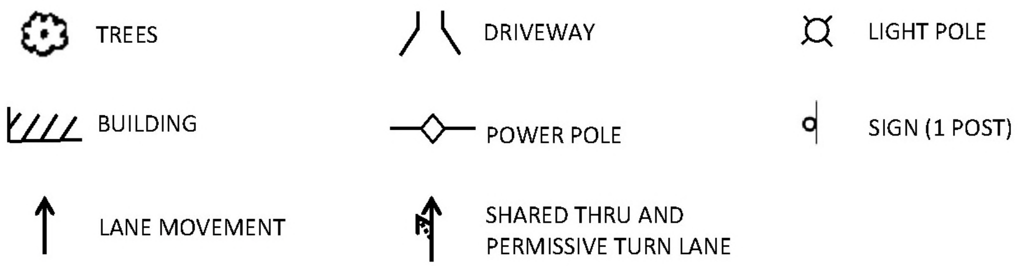
1) Condition diagrams are intended to capture detailed information that may not be easily communicated in a table format.

2) The legend may be used to clarify symbology used.

Field Data Collection



Symbols



FDOT Design Standards Index No. 002 provides additional Standarized Symbols

CHAPTER 7 INTERSECTION DELAY STUDY

7.1 PURPOSE

(1) The **Intersection Delay Study** is used to evaluate the performance of intersections in allowing traffic to enter and pass through, or to enter and turn onto another route. This study will effectively provide a detailed evaluation of delay at the intersection. It is very important to differentiate between the different types of delay, listed below are the most commonly used terms describing delay at intersections (***FHWA Traffic Signal Timing Manual***).

(a) *Time-In-Queue Delay (TIQD)* is the difference between the time a vehicle joins the rear of a queue and the time the vehicle clears the intersection.

(b) *Control delay* is the component of delay that results when a control signal causes a lane group to reduce speed or to stop; it is measured by comparison with the uncontrolled condition. Defined as the TIQD plus the time losses due to deceleration from and acceleration to free-flow speed.

(c) *Geometric delay* is the component of delay that results when geometric features cause users to reduce their speed in negotiating a facility.

(d) *Travel-Time Delay (TTD)* is the difference between the time a vehicle passes a point downstream of the intersection where it has regained normal speed and the time it would have passed that point had it been able to continue through the intersections at its approach speed. This includes all control and geometric delay.

(2) This chapter will only discuss the Time-in-queue delay (TIQD), Control delay, and Travel-time delay (TTD) since the Geometric delay is easy to estimate but impossible to measure directly in the field.

7.2 EQUIPMENT NEEDS

(1) There are different methods and equipment available to perform an Intersection Delay Study. ***Table 7-1*** lists the most commonly used equipment for this type of study. Refer to ***Chapter 4 Intersection Turning Movement Counts*** for a detailed description of the electronic equipment, new tools and available technology.

(2) The measurement of the Free-Flow Speed (FFS) of vehicles is frequently required before performing the Intersection Delay Study. Some of the methods suggested are to calculate the Space-Mean Speed (SMS) with a radar or laser gun.

Table 7-1. Commonly Used Equipment for Delay Studies

Method	Tool	Advantage	Disadvantage	Type of Study
Manually	Data sheets	Minimizes equipment cost and set-up time. Easy to use in the field	Tend to be inefficient the longer the analyst stays in the field	Control Delay Study
Electronic	Electronic counting boards	Cost-effective, labor-saving tool	Restricted to output aggregated data	
	Laptop computer	More flexible and spreadsheets can be developed to calculate various intersection parameters	Software coding and post-processing analysis are required	
	Video (w/ time stamp overlay)	Permanent record, reduce number of field personnel	Poor lighting conditions and vantage points, much more labor in the office	
Floating Car	Manual collection	Cost-effective method	Additional personnel and equipment may be necessary	Travel Time Delay
	GPS devices	Accuracy of data is increased, records additional information	Post-processing data analysis is required	
	Simulation	Labor-saving tool	Software costs, field information is still required	

7.3 PERSONNEL AND TRAINING REQUIREMENTS

(1) Personnel requirements are directly dependent of the chosen type of equipment and the traffic volume at the intersection of study. Additional observers may be necessary to conduct Turning Movement Counts (TMC) (video can be used instead, when no additional observers are available).

(2) Observers should be placed near the right shoulder or on the right sidewalk at the approximate midpoint of the maximum queue and have a clear view of the lanes they are observing is essential.

(3) ***Table 7-2*** lists the minimum personnel requirements based on the amount of queued vehicles.

Table 7-2. Minimum Personnel Requirement to conduct a Control Delay Study

Record the number of queued vehicles on:	Personnel needed	Additional requirements
Two lanes with moderate length queues (up to 25 vehicles per lane)	Single observer	-
One lane with long queues (longer than 25 vehicles)		Audio signal of the end of an interval
One lane with long queues or no audio signal available	Two observers	-

(4) The minimum number of intervals that should be recorded is 60 intervals, and usually, the peak period data is the most useful for data collection. A queued vehicle is considered as any vehicle traveling less than 3mph (5km/h) or two-three vehicle lengths from the vehicle that is queued in front of it.

7.4 FIELD PROCEDURES AND ANALYSIS

7.4.1 Time in Queue Delay (TIQD) and Control Delay (Form No. 750-020-07)

(1) The heading on the **Intersection Control Delay Study (*Form No. 750-020-07*)** should be filled out completely prior to beginning the field review. The remainder of the form will include the data collection and calculations.

Calculations should be completed by computing the *Control Delay* (Equation 7.1), *Acceleration/Deceleration Delay* (Equation 7.2) and *Time-in-Queue-Delay* (TIQD) (Equation 7.3).

When conducting this study at an intersection with stop sign control, the number of vehicles stopping (*Stopped* sub-column) should only be those vehicles that stopped completely. Vehicles which “roll” through the stop should be counted in the *Not Stopped* sub-column. ***Figure 7-1*** shows an example on how to fill out ***Form No. 750-020-07***.

The study involves counting vehicles stopped in the intersection approach at successive intervals. A typical duration for these intervals range between 10 and 20 seconds long. The sampling interval should be selected so that the traffic signal cycle length will not be divisible by the selected time interval to prevent potential survey bias due to queue buildup in a cyclical pattern. For example, if cycles conform to a cycle length of 45, 60, 75, 90, 105, 120, 135, or 150-seconds, a 15-second interval between samples should not be used. Rather, a 13-second interval could be used. If the intersection is actuated, the most convenient count interval may be chosen with consideration of the survey period duration.

(2) This methodology is applicable where queues do not exceed 20-25 vehicles per lane. If the queues are expected to be longer than 20-25 vehicles per lane or the volume to capacity (V/C) ratios are close to 1.0, the analyst should be careful with the vehicle-in-queue count after the arrival period to account for the vehicles that stay queued for two or more cycles.

$$d = d_{vq} + d_{ad} \quad \text{Equation 7.1}$$

$$Acce/Decel(d_{ad}) = FVS * CF \quad \text{Equation 7.2}$$

$$TIQD\left(d_{vq}\right) = \left(I_s * \frac{\sum V_{iq}}{\sum V_{tot}}\right) * 0.9 \quad \text{Equation 7.3}$$

where,

d = control delay

d_{vq} = time in queue delay

d_{ad} = acceleration/deceleration correction delay

FVS = fraction of vehicles stopping

CF = Acceleration/Deceleration factor (see ***Table 7-3***)

I_s = time interval between queue counts (in seconds)

$\sum V_{iq}$ = sum of all vehicles-in queue counts (vehicles)

$\sum V_{tot}$ = total number of vehicles during the study period (vehicles)

0.9 is the empirical adjustment factor

Table 7-3. Acceleration-Deceleration Delay Correction Factor, CF (s/veh) (Source: Highway Capacity Manual 2010, Exhibit 31-48)

Free-Flow Speed	**Average Number of Vehicles Stopping per Lane in Each Cycle**		
	≤ 7 veh/ln/cycle	**8-19 veh/ln/cycle**	**20-30 veh/ln/cycle***
≤ 37 mph	+5	+2	-1
37-45 mph	+7	+4	+2
> 45 mph	+9	+7	+5

*Vehicle-in-queue counts in excess of approximately 30 veh/ln/cycle are typically unreliable

(3) Prior to initializing the study, the input parameters and any general information should be recorded by the observers. Preferably, the data collection will begin at the start of a red phase with no overflowing queued vehicles from the previous cycle.

(4) It is recommended to use two observers with the following tasks:

(a) Observer 1:

- Keep track of the queues for each cycle during the study period by observing the last vehicle in every lane stopped by the control device. Including queuing vehicles during the green phase.
- At the selected sampling interval (e.g., 15 sec), the observer should record the number of queued vehicles. A stop watch can be used to provide the observer with the proper intervals for counting the stopped vehicles. A vehicle must be counted more than once in the delay determination if it is stopped during more than one sampling time. That is, a particular vehicle will continue to be counted in all sample time periods during which it remains stopped on the intersection approach.
- Record the vehicle-in-queue counts in the worksheet. The clock time should be recorded at the beginning of every fifth cycle.
- At the end of the study period, the observer should continue following any queued vehicles until they exit the intersection.

(b) Observer 2:

- The second observer performs a continuous vehicle count of the approach volume by classifying the vehicles as either stopped (V_{stop}) or not stopping (V_{tot}). Vehicles stopping multiple times should only be counted once. This vehicle count is conducted for the entire study period.

7.4.2 Travel-Time Delay (TTD)

(1) TTD can be applied at intersections and along corridors where the effect of a control device, any geometric effects, and any other factors affecting delay are needed to be determined.

(2) TTD is calculated using Equation 7.4. To calculate TTD, there are two possible methods: actual driver data or GPS data.

(3) For the actual driver data, the travel time through any of the movements could be collected during low traffic volumes and green phase for the movement under analysis. This measurement is referred to as the unimpeded travel time through the intersection (TT_1). The next step is to determine the actual travel time (TT_2) by tracing the vehicles through the superstreet intersection at the same two points: the beginning and end of the section of interest. These measurements can also be collected with the help of simulation tools assuming the default acceleration and deceleration rates.

(4) The other possible method is the use of GPS devices for determining the TTD. The GPS devices track vehicle trajectories through intersections using a time-space diagram.

$$TTD = TT_2 - TT_1 \qquad \text{Equation 7.4}$$

where,

TTD = travel time delay through the intersection

TT_1 = unimpeded travel time through the intersection

TT_2 = actual average travel time through the intersection

7.5 FORM ACCESS

(1) A reproducible copy and an electronic version of the **Intersection Control Delay Study (Form No. 750-020-07)** is available in the Department's Forms Library.

Figure 7-1. Intersection Control Delay Study (Form No. 750-020-07)

State of Florida Department of Transportation

INTERSECTION CONTROL DELAY

Form 750-020-07
TRAFFIC ENGINEERING
February 2015

Gerneral Information

Analyst: **JRF**
Agency or Company: **FDOT**
Date Performed: **Tuesday, March 18, 2014**
Analysis Time Period: **8:00 AM**

Site Information

Intersection: **Harry St and Shamrock Rd**
Area Type ☐ CBD ☑ Other
Jurisdiction: **Dixie County**
Analysis Year: **2014**

Input Parameters

Number of Lanes, N: **2**
Free-Flow speed, FFS (mph): **45**
Survey count Interval, I_s (s): **15**
Total Vehicles Arriving, V_{tot}: **530**
Stopped vehicles count V_{stop}: **223**
Cycle Length, C (s): **130**

Field Data for: Eastbound Approach

Clock Time	Cycle Number	Number of Vehicles in Queue										Approach Volume	
		Count Interval											
		1	2	3	4	5	6	7	8	9	10	Stopped	Not Stopped
8:00	**1**	**3**	**8**	**11**	**15**	**12**	**2**	**0**	**2**			**23**	**38**
	2	**6**	**12**	**15**	**16**	**6**	**0**	**0**	**2**	**3**		**28**	**36**
	3	**7**	**11**	**14**	**14**	**2**	**0**	**3**	**0**	**6**		**34**	**50**
8:10	**4**	**5**	**7**	**10**	**13**	**13**	**2**	**0**	**1**			**28**	**34**
	5	**4**	**6**	**10**	**12**	**3**	**0**	**0**	**1**	**8**		**14**	**41**
	6	**5**	**7**	**9**	**13**	**4**	**0**	**3**	**0**	**5**		**43**	**43**
8:20	**7**	**3**	**6**	**8**	**12**	**12**	**3**	**0**	**0**			**28**	**32**
	8	**4**	**7**	**11**	**16**	**9**	**0**	**0**	**0**	**1**		**25**	**33**
Subtotal		**37**	**64**	**88**	**111**	**61**	**7**	**6**	**6**	**23**		V_{stop}= **223**	$V_{not\ stop}$ = **307**
Total ($\sum V_{iq}$)		**403**										V_{tot}= **530**	

Calculations

Total Vehicles in Queue, $\sum V_{iq} =$ **403**

Time in Queue per Vehicle, $d_{vq} = I_s \times \frac{\sum V_{iq}}{V_{tot}} \times 0.9 =$ **10.27**

Number of Vehicles Stopping per Lane Each Cycle, $\frac{V_{stop}}{N_c \times N} =$ **13.94**

Accel/Decel Correction Factor, CF (See Table Below) **4**

Number of Cycles Surveyed, $N_c =$ **8**

Fraction of Vehicles Stopping, $FVS = \frac{V_{stop}}{V_{tot}} =$ **0.42**

Accel/Decel Correction Delay, $d_{ad} = FVS \times CF =$ **1.68**

Control Delay/Vehicle, $d = d_{vq} + d_{ad} =$ **11.95**

Accel/Decel Correction Factor, CF

Free-Flow Speed	Average Number of Vehicles Stopping per Lane in Each Cycle		
	<= 7 Vehicles	8-19 Vehicles	20-30 Vehicles*
<= 37 mi/h	+5	+2	-1
37 - 45 mi/h	+7	+4	+2
> 45 mi/h	+9	+7	+5

* Vehicle-in-queue counts in excess of approximately 30 vehicles per lane are typically unreliable

Source: Revised from Exhibit 6-1 of the ITE Manual of Transportation Engineering Studies, 2nd Edition

CHAPTER 8 GAP STUDY

8.1 PURPOSE

(1) The ***Gap Study*** is used to determine the size and the number of gaps in the vehicular traffic stream for unsignalized intersections and access points, pedestrian studies, and school crossing studies. This chapter discusses how to conduct gap studies and estimate the critical gap for vehicular traffic and pedestrians.

8.2 GAP STUDY

(1) In the context of this study, a *gap* is defined as the time duration (in seconds), measured at the same point in space, between the rear bumper and the front bumper of two consecutive vehicles. The *critical gap* is defined as the minimum time length (in seconds) of a gap in traffic which will permit (on average) a side street vehicle, a single pedestrian, or a group of pedestrians to cross a roadway of specified width without coming into conflict with passing vehicles. In the case of side street traffic, this value may also represent the time length of a gap in traffic permitting side street vehicles to merge into the traffic stream between two vehicles.

(2) ***Form No. 750-020-08*** should be filled out completely. The *Roadway I.D.* should be noted and provide information such as U.S. route number, state road number, or roadway name. Additionally, the corresponding checkbox shall be marked, indicating whether the subject location is an intersection or a segment, and a reference point along the street such as a cross street name and milepost should be provided. The *City* and *County* should be entered. Also, the General Information section including the Analyst and Agency or Company names along with the *Date* when the study was conducted should be included.

(3) The form is designed to record data up to four time periods. The beginning and ending time for each period should be entered, including whether the time is A.M. or P.M. Using stopwatches or other timing devices, the observer measures the length of gaps between vehicles in seconds (measured gaps are rounded to the nearest second). For each gap greater than or equal to the critical gap, the observer enters a tally mark in the appropriate row and column. When the study has been completed, the observer can add up the tally marks and enter the totals for each hour in the corresponding row and column. Gaps of less than the critical gap size are not recorded because the time required to cross the roadway would not be met. Electronic count boards or laptop computers can be used to record the data.

(4) For divided roadways with sufficient median width to accommodate two stage vehicle or pedestrian crossings, the gap size should be determined for each direction of vehicular travel.

(5) The total number of gaps exceeding the critical gap per hour should be filled in on the ***Gap Study*** form. An example of how to fill the subject form is provided in ***Figure 8-1***. These totals can then be used for signal warrant applications (such as ***Warrants 4 and Warrant 5***) described in the ***Traffic Signal Warrant Summary (Chapter 3)***.

8.3 VEHICULAR CRITICAL GAP

(1) The critical gap for vehicular traffic at a two-way stop-controlled intersection ($t_{c,x}$) can be estimated for the minor-street movements and the major-street left-turns and U-turns using the following equation (Transportation Research Board. *Highway Capacity Manual.* Washington, DC: TRB 2010, Equation 19-30, Page 19-15):

$$t_{c,x} = t_{c,base} + t_{c,HV}P_{HV} + t_{c,G}G - t_{3,LT}$$

where

$t_{c,x}$ = critical gap for movement x (s)

$t_{c,base}$ = base critical gap (s) per ***Figure 8-1***

$t_{c,HV}$ = adjustment factor for heavy vehicles (1.0 s for major streets with one lane in each direction; 2.0 s for major streets with two or three lanes in each direction).

P_{HV} = proportion of heavy vehicles for movement (decimal)

$t_{c,G}$ = adjustment factor for grade (0.1 s for minor-street right turns; 0.2 s for minor-street left turns and minor-street through movements)

G = percent grade (integer)

$t_{3,LT}$ = adjustment factor for intersection geometry (0.7 s for minor-street left turn at three-leg intersection; 0.0 s otherwise)

Table 8-1. Transportation Research Board. Highway Capacity Manual. Washington, DC: TRB 2010, Exhibit 19-10, Page 19-15

Vehicular Movement	Two Lanes	Four Lanes	Six Lanes
Left turn from major	4.1	4.1	5.3
U-turn from major	N/A	6.4 (wide)	5.6
		6.9 (narrow)	
Right turn from minor	6.2	6.9	7.1
Through traffic on minor	1-stage: 6.5	1-stage: 6.5	1-stage: 6.5*
	2-stage, Stage I: 5.5	2-stage, Stage I: 5.5	2-stage, Stage I: 5.5*
	2-stage, Stage II: 5.5	2-stage, Stage II: 5.5	2-stage, Stage II: 5.5*
Left turn from minor	1-stage: 7.1	1-stage: 7.5	1-stage: 6.4
	2-stage, Stage I: 6.1	2-stage, Stage I: 6.5	2-stage, Stage I: 7.3
	2-stage, Stage II: 6.1	2-stage, Stage II: 6.5	2-stage, Stage II: 6.7

* Use caution; estimated values.

8.4 PEDESTRIAN CRITICAL GAP

(1) The critical gap for a single pedestrian (t_c) is estimated using the following equation (Transportation Research Board. *Highway Capacity Manual*. Washington, DC: TRB 2010, Equation 19-69, Page 19-31):

$$t_c = \frac{L}{S_p} + t_s$$

where

t_c = single pedestrian critical gap (s)

S_p = average pedestrian walking speed (default 3.5 ft/s)

L = crosswalk length (ft.)

t_s = pedestrian start-up time and end clearance time (default 3 s)

(2) A walking speed study may be required to best reflect the average pedestrian walking speed (S_p) if the location's pedestrian characteristics are different from typical pedestrian areas (e.g., disabled, elderly, children, etc.).

(3) The critical gap for a group of pedestrians (t_G) is calculated by using the following equations (Transportation Research Board. *Highway Capacity Manual*. Washington, DC: TRB 2010, Equation 19-72, Page 19-32):

$$t_G = t_c + 2(N_p - 1)$$

where

t_G = group critical gap (s)

t_c = single pedestrian critical gap (s)

N_p = spatial distribution of pedestrians (ped). Assume one (1) if no platooning of pedestrian is observed in the field; otherwise, use the following equation:

$$N_p = INT\left[\frac{8.0\ (N_c - 1)}{W_c}\right] + 1$$

where

8.0 = default clear effective width used by a single pedestrian to avoid interference when passing other pedestrians

W_c = crosswalk width (ft.)

N_c = pedestrians in the crossing platoon (ped) calculated using the following equation:

$$N_c = \frac{v_p e^{v_p t_c} + v e^{-v t_c}}{(v_p + v) e^{(v_p - v) t_c}}$$

where

v_p = pedestrian flow rate (ped/s)

v = vehicular flow rate (veh/s)

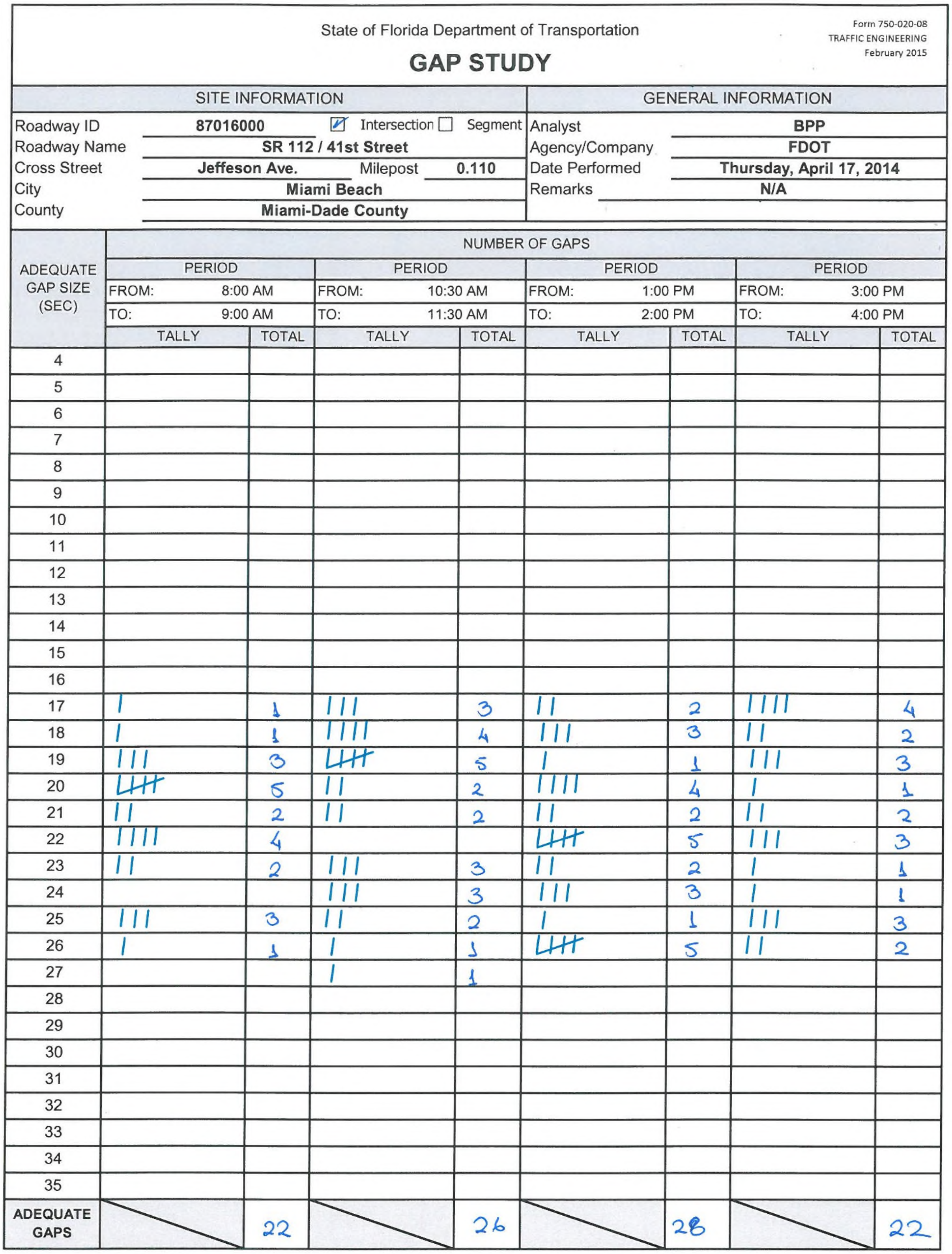
t_c = single pedestrian critical gap (s)

(4) For another approach to estimate gap acceptance characteristics (for pedestrian and vehicles), reference the procedures found in the ***Institute of Transportation Engineers, Manual of Transportation Engineering Studies, 2nd Edition, 2010, Chapter 6***.

8.5 FORMS ACCESS

(1) An electronic reproducible version of the ***Gap Study (Form 750-020-08)*** is available in the Department's Forms Library.

Figure 8-1. Gap Study (Form No. 750-020-08)



State of Florida Department of Transportation

Form 750-020-08
TRAFFIC ENGINEERING
February 2015

GAP STUDY

SITE INFORMATION				GENERAL INFORMATION	
Roadway ID	87016000	☑ Intersection ☐ Segment		Analyst	BPP
Roadway Name	SR 112 / 41st Street			Agency/Company	FDOT
Cross Street	Jeffeson Ave.	Milepost	0.110	Date Performed	Thursday, April 17, 2014
City	Miami Beach			Remarks	N/A
County	Miami-Dade County				

ADEQUATE GAP SIZE (SEC)	NUMBER OF GAPS							
	PERIOD		PERIOD		PERIOD		PERIOD	
	FROM: 8:00 AM		FROM: 10:30 AM		FROM: 1:00 PM		FROM: 3:00 PM	
	TO: 9:00 AM		TO: 11:30 AM		TO: 2:00 PM		TO: 4:00 PM	
	TALLY	TOTAL	TALLY	TOTAL	TALLY	TOTAL	TALLY	TOTAL
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17	𝍷	1	𝍷𝍷𝍷	3	𝍷𝍷	2	𝍷𝍷𝍷𝍷	4
18	𝍷	1	𝍷𝍷𝍷𝍷	4	𝍷𝍷𝍷	3	𝍷𝍷	2
19	𝍷𝍷𝍷	3	𝍸	5	𝍷	1	𝍷𝍷𝍷	3
20	𝍸	5	𝍷𝍷	2	𝍷𝍷𝍷𝍷	4	𝍷	1
21	𝍷𝍷	2	𝍷𝍷	2	𝍷𝍷	2	𝍷𝍷	2
22	𝍷𝍷𝍷𝍷	4			𝍸	5	𝍷𝍷𝍷	3
23	𝍷𝍷	2	𝍷𝍷𝍷	3	𝍷𝍷	2	𝍷	1
24			𝍷𝍷𝍷	3	𝍷𝍷𝍷	3	𝍷	1
25	𝍷𝍷𝍷	3	𝍷𝍷	2	𝍷	1	𝍷𝍷𝍷	3
26	𝍷	1	𝍷	1	𝍸	5	𝍷𝍷	2
27			𝍷	1				
28								
29								
30								
31								
32								
33								
34								
35								
ADEQUATE GAPS		22		26		28		22

CHAPTER 9 PEDESTRIAN AND BICYCLE VOLUME STUDIES

9.1 PURPOSES

(1) Pedestrian and bicycle volume studies are used to capture some aspect of pedestrian and bicycle behavior and performance. This evaluation is generally done using one or more of the following studies:

- volume
- walking or travel speed
- gaps in traffic
- conflicts with vehicles
- understanding and compliance with traffic control devices
- exhibited behaviors
- user perception
- accessibility to pedestrians with physical or vision impairments

(2) This chapter focuses on conducting volume studies. Pedestrian and bicycle volumes are obtained by recording the number of pedestrians or bicycles passing a midblock point, entering an intersection, or using a particular facility such as a crosswalk, sidewalk, or bikeway. These studies can be used for ***Warrant 4, Pedestrian Volume*** as described in the ***Traffic Signal Warrant Summary (Chapter 3)***.

For intersection or midblock crossing studies, an influence area should be determined based on the intent of the study.

(3) The length of the sampling periods usually range from 15 minutes to several hours, depending on the type of count being taken and the eventual uses of the pedestrian and bicycle volume data. Manual observation and automatic recording are the two basic methods used for pedestrian and bicycle volumes measuring.

(4) Pedestrian walking speed studies and gap studies listed in the bullets above are not discussed in this chapter. A detailed description of this type of studies can be found in the ***ITE Manual of Transportation Engineering Studies, 2nd Edition Chapter 12 Pedestrian and Bicycle Studies page 246***. Pedestrian Critical Gap procedures can be found in ***Chapter 8*** of this manual.

9.2 MANUAL OBSERVATION

(1) Some types of pedestrian and bicycle counts are more easily and accurately collected by manual observation using trained observers (e.g., counts by age group, sex, physical handicap, and other special behavior studies such as signal compliance). Also, time and resources may be good justifications for choosing manual observation over an automatic count.

9.2.1 Personnel Required

(1) Trained observers should perform the manual pedestrian counting. 10-15 minute breaks should be scheduled at least every 2 hours to avoid fatigue and degraded performance. For data collection period over 8 hours, breaks of 30-45 minutes should be permitted every 4 hours.

(2) The number of trained observers required is dependent of the length of the counting period, type of count being performed, number of crosswalks or bike lanes, and the volume of pedestrian and bicycles. A single observer can perform a pedestrian and bicycle volume count at a four-way signalized intersection with single approach lanes and low volumes as long as special classifications and/or directional counts are not required. Conducting pilot studies at the desired locations can determine the exact number or observers required. Duties should be divided among observers. For example, one observer can be assigned to record the north and west crosswalks while a second observer watches the south and east crosswalks at a signalized intersection.

9.2.2 Equipment

Tally Sheets (manual field observation forms)

(1) The use of the tally sheets is the simplest means of conducting manual counts. This method is low cost and easily adaptable to different geometries and count types. A stopwatch is required to keep track of the desired intervals.

(2) Two different study forms are to be completed for this method, the ***Pedestrian and Bicycle Volume Sheet (Form No. 750-020-09)*** and the ***Summary of Pedestrian and Bicycle Movements (Form No. 750-020-10)***.

Handheld Count Boards

(1) Battery operated, handheld count boards are commonly used to aid in the collection of traffic count data, which can include pedestrians and bicyclists.

(2) No field forms are required with this alternative and the boards contain an internal clock that separates the data by a specified interval.

Laptop Computer

(1) Battery-efficient laptop computers can be used for field data collection. Available spreadsheet software can be used to record time stamps of different events and the benefit of using macro-enabled spreadsheets to collect data is the option of customizing to specific needs of the user. A disadvantage is the software coding and post-processing analysis required.

Video-Based Counts

Manual counts can be conducted in the field or in the office during a post-processing operation from video observations. Video-based counts provide less risk of incidents for observers and minimize staff requirements. It is critical to have a well-chosen camera angle and adequate lighting conditions to capture all turning movements at a typical intersection with one or multiple cameras. A digital clock can help note the end of the intervals.

9.2.3 Field Procedure

Preparation

(1) A checklist is recommended to ensure that all preparations for the field observations were completed before field arrival. A full checklist can be found in the ***ITE Manual of Transportation Engineering Studies, 2nd Edition, Chapter 1 Introduction page 6, Exhibit 1-1***.

(2) To determine the type of equipment, field procedure, and number of required observers for the study, the following should be reviewed:

- purpose and type of count to be performed,
- count period and time intervals, and
- information about the site (e.g., geometric layout, volume levels by time of day, signal timing, etc.)

(3) Whether bicyclists are traveling in the roadway (treated as a vehicle) or on the sidewalk should be distinguished in the bicycle count. The methodology for bicycle level of service (LOS) in the *Highway Capacity Manual* (HCM 2010) is currently based on in-road bicycle volumes (possibly in a bicycle lane) and in the same direction as adjacent motorized vehicles. A more detailed distinction may be necessary for studies on multiuse paths. An example of a multiuse data collection form can be found in the ***ITE Manual of Transportation Engineering Studies, 2nd Edition, Chapter 12 Pedestrian and Bicycle Studies, page 241, Exhibit 12-2***.

Observer location

(1) A clear view of the pedestrians or bicycles is crucial to select observers' positions. The obstruction of pedestrian movements and distraction of drivers should be avoided and observers should be located well away from the edge of the travel lane as a safety precaution. To coordinate activities if several observers are at the same site, visual contact with one another and communication is important.

(2) For a successful pedestrian and bicycle volume study, it is critical to maintain organized and correctly labeled data, especially if manual field observation forms are used. If electronic count boards or handheld computers are being used, the observers have to make sure the equipment is properly oriented to the geographic and geometric layout of the intersection. Time intervals must be accurately maintained and coordinated between observers if more than two observers are present. It is critical for the observers to concentrate on accurately recording each count in the proper place on the form or with the proper button regardless of the method being used.

9.2.4 Manual Field Observation Forms

9.2.4.1 Pedestrian and Bicycle Volume Sheet (Form No. 750-020-09)

(1) Enter the *Location I.D., City, County, Type of Control, Observer(s), Agency* or *Company, Date Performed*, and *Time of Study*. Under *Remarks*, note any conditions, such as weather, and include any information that might need to be considered in addition to the data being collected. For each crossing location enter the *Distance* (curb-to-curb, edge of road, etc.), width of the street in feet, and mark the appropriate box (Yes/No) to indicate the presence of a *Raised Median*. To check *Yes*, the *Raised Median* must be at least 4 feet wide and capable of providing refuge to pedestrians crossing the street. This is a major consideration in ***Warrant 4, Pedestrian Volume*** which can be found in the ***Traffic Signal Warrant Summary (Chapter 3)***. It is also important to write the names of the two intersecting streets and indicate which way is north.

(2) At the top of each block, enter the time interval during which the counts were made. Pedestrian counts can be made by writing tally marks in the space provided, or by using denominators. Totals should be placed in the space below the space in which tally marks are written. ***Figure 9-1*** shows an example of ***Form No. 750-020-09*** completed.

(3) At certain locations, it is extremely important to know the age composition of the pedestrians crossing the streets (e.g., high number of senior citizens, young children). For such studies the observer(s) can subdivide the spaces for tally marks and *Totals,* and include a note in the study form to indicate this count.

9.2.4.2 Summary of Pedestrian and Bicycle Movements (Form No. 750-020-10)

(1) The data gathered in the field using the ***Pedestrian and Bicycle Volume Sheet*** is summarized using the ***Summary of Pedestrian and Bicycle Movements (Form No. 750-020-10)***. All pertinent information should be filled in. A circle can be drawn around the pedestrian crosswalk(s) to indicate the crosswalk(s) being studied. Also, the checkbox around the intersection diagram shall be used to denote the existence of pushbuttons or pedestrian heads where appropriate.

(2) ***Figure 9-2*** shows an example of ***Form No. 750-020-10*** completed.

9.3 AUTOMATIC COUNTS

(1) Automatic video recording provides a mean of gathering pedestrian and bicycle volume data where complex classifications are not required. This method allows the data collection at a reasonable time and resources expenditure.

9.3.1 Personnel Required and Equipment

(1) The personnel required for automatic counts are those needed to install, calibrate, and recover the equipment.

(2) The two basic components of equipment required generally include sensors to detect the presence of pedestrians or bicycles, and a data recorder. Sensors may use active or passive infrared light transmission and detection, Piezo film, time-lapse video, in-pavement loop detectors and pneumatic tubes. More detailed travel activity of pedestrians and bicycles can be recorded with new technologies, such as pedometers, accelerometers, GPS transponders, location-tracking mobile telephones and laser counters. One of the benefits of conducting automatic counts is the provision of extended counting periods at reduced labor costs compared to manual counting methods.

(3) Proper function of the equipment should be checked. Equipment interference with pedestrians and bicyclist should be avoided or minimized.

9.3.2 Field Procedure

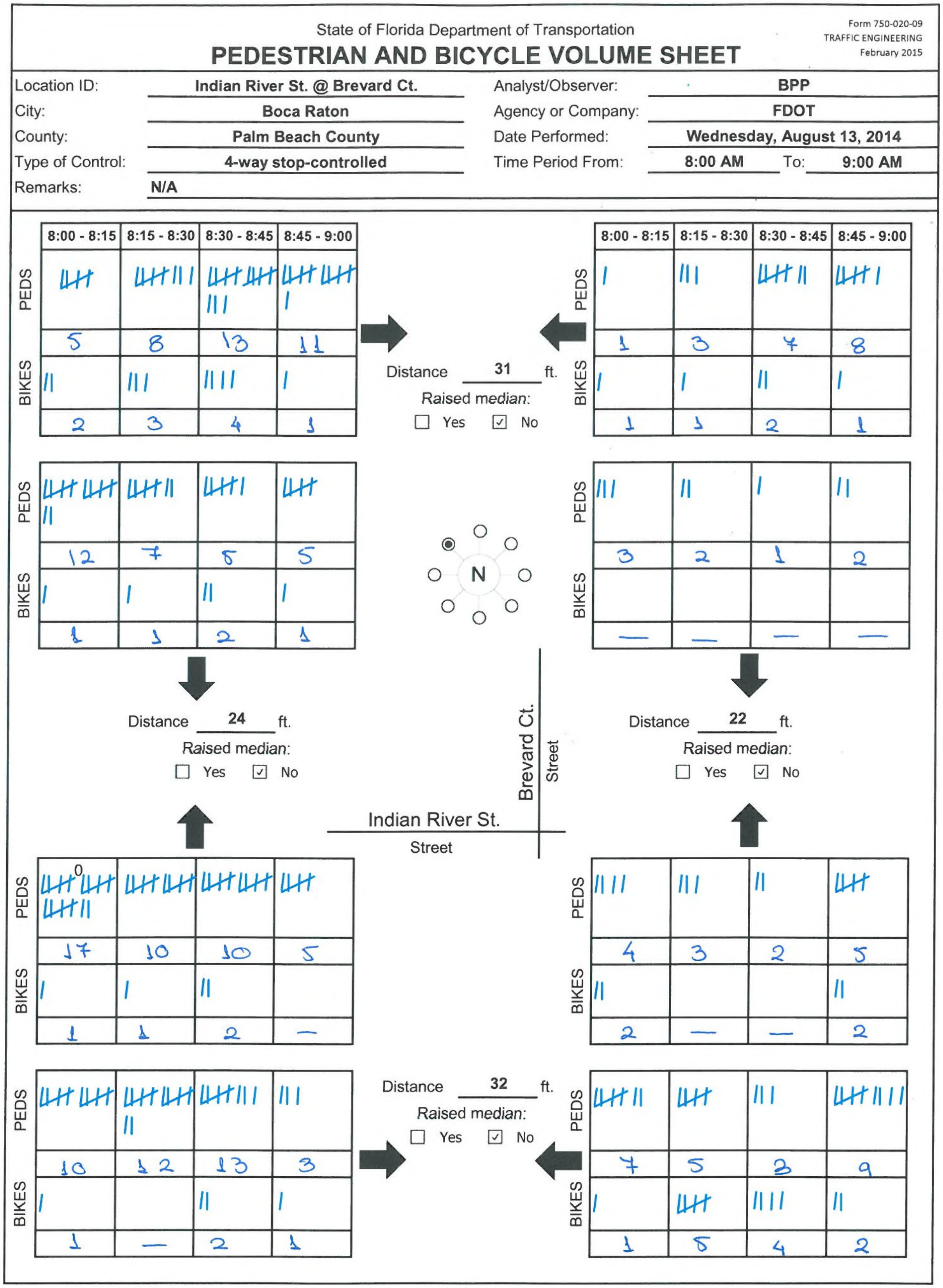
(1) The general location (midblock or intersection) where the count will be performed should be determined in the office. The exact location of the equipment is usually determined in the field. Supplemental cameras may be needed for special studies, such as compliance at signalized intersections. Additional information on count location selection can be found in ***Intersection Turning Movement Counts (Chapter 4).*** Information regarding pedestrian volume warrants for traffic signals is provided in ***Traffic Signal Warrant Summary (Chapter 3)***.

(2) Once the data has been collected, it should be summarized by calculating subtotals and totals and arranging the data in a format for performing analyses. Depending of the type of study being conducted, the data may require a simple extraction or a sophisticated statistical treatment.

9.4 FORMS ACCESS

(1) Reproducible copies of the ***Pedestrian and Bicycle Volume Sheet (Form 750-020-09)*** and the ***Summary of Pedestrian and Bicycle Movements (Form 750-020-10)*** are available in the Department's Forms Library. Also, an electronic format is available for field and office use.

Figure 9-1. Pedestrian and Bicycle Volume Sheet (Form No. 750-020-09)



State of Florida Department of Transportation

PEDESTRIAN AND BICYCLE VOLUME SHEET

Form 750-020-09
TRAFFIC ENGINEERING
February 2015

Location ID: **Indian River St. @ Brevard Ct.**
Analyst/Observer: **BPP**
City: **Boca Raton**
Agency or Company: **FDOT**
County: **Palm Beach County**
Date Performed: **Wednesday, August 13, 2014**
Type of Control: **4-way stop-controlled**
Time Period From: **8:00 AM** To: **9:00 AM**
Remarks: **N/A**

	8:00 - 8:15	8:15 - 8:30	8:30 - 8:45	8:45 - 9:00
PEDS	𝍸	𝍸𝍷𝍷𝍷	𝍸𝍸𝍷𝍷𝍷	𝍸𝍸𝍷
	5	8	13	11
BIKES	𝍷𝍷	𝍷𝍷𝍷	𝍷𝍷𝍷𝍷	𝍷
	2	3	4	1

Distance **31** ft.
Raised median:
☐ Yes ☑ No

	8:00 - 8:15	8:15 - 8:30	8:30 - 8:45	8:45 - 9:00
PEDS	𝍷	𝍷𝍷𝍷	𝍸𝍷𝍷	𝍸𝍷
	1	3	7	8
BIKES	𝍷	𝍷	𝍷𝍷	𝍷
	1	1	2	1

PEDS	𝍸𝍸𝍷𝍷	𝍸𝍷𝍷	𝍸𝍷	𝍸
	12	7	6	5
BIKES	𝍷	𝍷	𝍷𝍷	𝍷
	1	1	2	1

● ○ ○
○ N ○
○ ○ ○

PEDS	𝍷𝍷𝍷	𝍷𝍷	𝍷	𝍷𝍷
	3	2	1	2
BIKES				
	—	—	—	—

Distance **24** ft.
Raised median:
☐ Yes ☑ No

Distance **22** ft.
Raised median:
☐ Yes ☑ No

Brevard Ct.
Street

Indian River St.
Street

PEDS	𝍸 0 𝍸𝍸𝍷𝍷	𝍸𝍸	𝍸𝍸	𝍸
	17	10	10	5
BIKES	𝍷	𝍷	𝍷𝍷	
	1	1	2	—

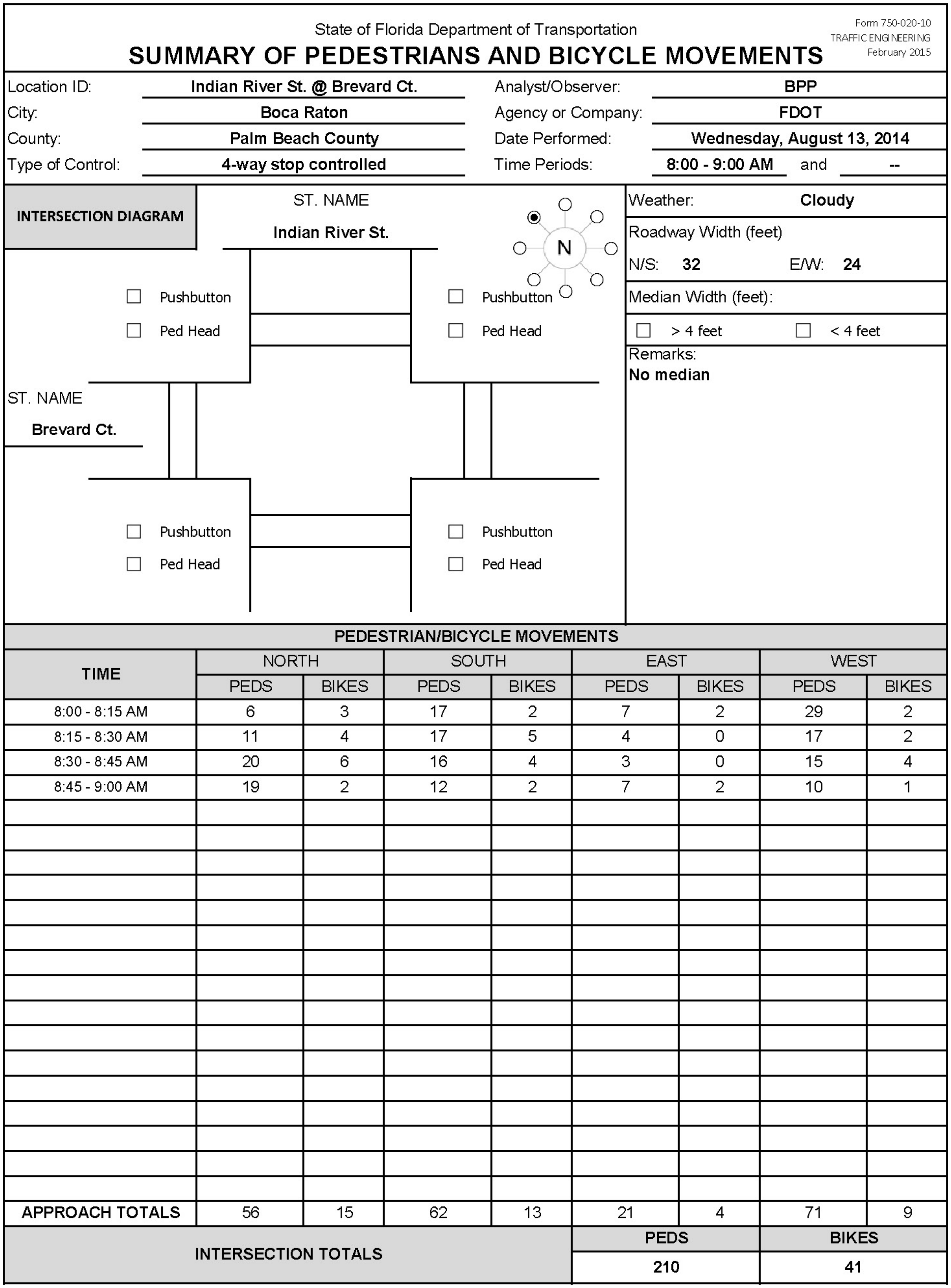
PEDS	𝍷𝍷𝍷𝍷	𝍷𝍷𝍷	𝍷𝍷	𝍸
	4	3	2	5
BIKES	𝍷𝍷			𝍷𝍷
	2	—	—	2

PEDS	𝍸𝍸	𝍸𝍸𝍷𝍷	𝍸𝍷𝍷𝍷	𝍷𝍷𝍷
	10	12	13	3
BIKES	𝍷		𝍷𝍷	𝍷
	1	—	2	1

Distance **32** ft.
Raised median:
☐ Yes ☑ No

PEDS	𝍸𝍷𝍷	𝍸	𝍷𝍷𝍷	𝍸𝍷𝍷𝍷𝍷
	7	5	3	9
BIKES	𝍷	𝍸	𝍷𝍷𝍷𝍷	𝍷𝍷
	1	5	4	2

Figure 9-2. Summary of Pedestrian and Bicycle Movements (Form No. 750-020-10)



State of Florida Department of Transportation

SUMMARY OF PEDESTRIANS AND BICYCLE MOVEMENTS

Form 750-020-10
TRAFFIC ENGINEERING
February 2015

Location ID: **Indian River St. @ Brevard Ct.**
Analyst/Observer: **BPP**
City: **Boca Raton**
Agency or Company: **FDOT**
County: **Palm Beach County**
Date Performed: **Wednesday, August 13, 2014**
Type of Control: **4-way stop controlled**
Time Periods: **8:00 - 9:00 AM** and **--**

INTERSECTION DIAGRAM

ST. NAME
Indian River St.

N

☐ Pushbutton
☐ Ped Head

☐ Pushbutton
☐ Ped Head

ST. NAME
Brevard Ct.

☐ Pushbutton
☐ Ped Head

☐ Pushbutton
☐ Ped Head

Weather: **Cloudy**

Roadway Width (feet)
N/S: **32** E/W: **24**

Median Width (feet):
☐ > 4 feet ☐ < 4 feet

Remarks:
No median

PEDESTRIAN/BICYCLE MOVEMENTS

TIME	NORTH		SOUTH		EAST		WEST	
	PEDS	BIKES	PEDS	BIKES	PEDS	BIKES	PEDS	BIKES
8:00 - 8:15 AM	6	3	17	2	7	2	29	2
8:15 - 8:30 AM	11	4	17	5	4	0	17	2
8:30 - 8:45 AM	20	6	16	4	3	0	15	4
8:45 - 9:00 AM	19	2	12	2	7	2	10	1
APPROACH TOTALS	56	15	62	13	21	4	71	9

INTERSECTION TOTALS	**PEDS**	**BIKES**
	210	**41**

CHAPTER 10 ADVISORY SPEED STUDY

10.1 PURPOSE

(1) The purpose of the ***Advisory Speed Study (Form No. 750-020-12)*** is to determine the safe speed a vehicle can negotiate a given horizontal curve under ideal conditions. The study is also used to determine where turn and curve signs with advisory speed plaques are required for horizontal curves. The study shall be sealed by a Florida registered professional engineer taking responsibility for the study recommendations and conclusions.

(2) There are currently three methods that have been developed to determine advisory speeds along horizontal curves: design speed equation, traditional ball-bank indicator, and accelerometer method.

10.2 EQUIPMENT AND PERSONNEL

(1) ***Table 10-1*** displays the three available methods to determine advisory speed and the necessary personnel and equipment for each method. The sample size varies according the method being used and it is also listed in ***Table 10-1***. An intermediate size vehicle should be used when a test vehicle is needed.

Table 10-1. Available Methods to Determine Advisory Speeds

Method	Required Personnel	Equipment	Sample Size
Design Speed Equation	2 to 3 people (only if field survey is necessary)	N/A*	3 to 5 measurements
Ball-bank Indicator	2 people (driver and observer)	Ball-bank Indicator, Test vehicle, Data Collection Sheet	minimum 3 runs at each 5 mph increment in both directions of travel
Accelerometer	1 person (driver)	Accelerometer, Test vehicle	

*Superelevation and curve radii are the inputs for the Design Speed Equation. If this data cannot be obtained from plan drawings, a field survey is required. Equipment required for filed survey: tape measure and 4-ft. (1.2m) level.

10.3 PROCEDURE FOR USE OF EQUIPMENT

10.3.1 Design Speed Equation Method

(1) The curve radius and superelevation data are required for the design equation method. If these cannot be determined from plan drawings, the following measurement and field data collection steps can be followed.

(a) To collect the curve radii data, overlay circular templates on top of an aerial image. The templates can be hand-drawn or computer-generated, scaled to the referenced aerial image.

(b) The "chord and middle ordinate" method can be an alternative to determine the radius of the curve. A graphical representation of the chord length and middle ordinate can be found in the ***ITE Manual of Transportation Engineering Studies, 2nd Edition, Chapter 18 Alternative Safety Studies, page 409, Exhibit 18-28***. The equation to determine the radius of curvature using this method is the following:

$$R = \frac{l^2}{8h} + \frac{h}{2}$$

where,

$R =$ curve radius (ft.)

$l =$ chord length (ft.)

$h =$ middle ordinate (ft.)

(c) Superelevation can be determined by using a slope meter. Alternatively, a carpenter's level can be used by laying one end on top of the pavement. The other end of the level should be raised until the bubble indicator reads true. The superelevation is measured as the vertical distance divided by the horizontal distance (level's length) and expressed as a percent. Ideally, the measurements should be taken at several locations in the center of each lane. To determine the advisory speed, the minimum superelevation in the curve should be used.

(d) The design speed equation method is based on AASHTO's *Policy on Geometric Design for Highways and Streets*. The design equation is:

$$V = \sqrt{15R(0.01e + f)}$$

where,

$V =$ design speed (mph)

$R =$ curve radius (ft.)

$e =$ superelevation (percent)

$f =$ side friction factor

(2) The side friction factor can be obtained from ***Table 10-2***, which is denoted as the lateral acceleration (g) or side friction factor (f). A good method is to select a side friction factor associated with an advisory speed of 25-30 mph and check if the design speed falls within the selected bounds. If not, compute iteration at the nearest speed previously calculated. Design speeds should be rounded to the nearest 5 mph.

Table 10-2. Recommended Criteria for Curve Advisory Speed Determination

Speeds (in multiples of 5 mph)	Ball-bank Reading (degrees of deflection)	Accelerometer Reading Lateral Acceleration (g) or Side Friction Factor (f)
≤ 20	16°	0.28
25, 30	14°	0.24
≥ 35	12°	0.21

Source: Seyfried, K. and J. Pline. “Guidelines for the Determination of Advisory Speeds.” ITE Journal, January 2009.

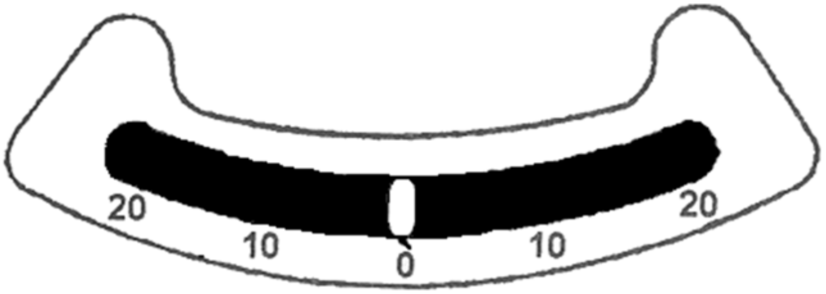
10.3.2 Ball-Bank Indicator Method

(1) The ball bank indicator is used to measure the overturning force, measured in degrees, on a vehicle negotiating a horizontal curve. Before conducting the study, the speedometer and ball-bank indicator must be calibrated. For further information regarding speedometer and ball-bank indicator calibration, refer to the ***ITE Manual of Transportation Engineering Studies, 2nd Edition, Chapter 18, page 408***.

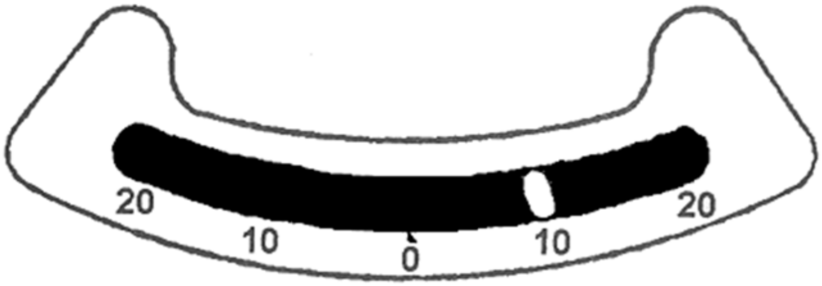
(2) The ball bank can be easily mounted to the dashboard by means of rubber suction cups or other stable methods. It should be mounted in a position that allows the ball to rest freely at the zero degree position when the vehicle is standing level. The movement of a car around a curve to the left, for example, causes the ball to swing to the right of the zero degree position (see ***Figure 10-1***).

The faster the car moves around the curve or the sharper the curve, the greater distance the ball swings away from the zero degree position. However, superelevation tends to bring the ball back to the zero position. The net result is the indicator reading in degrees of deflection.

Figure 10-1. Ball Bank Indicator



ZERO POSITION



(3) Beginning well in advance of the curve being tested, the driver should enter the curve at a predetermined speed, drive the car parallel with the centerline of that travel lane, and maintain that uniform speed throughout the curve.

The maximum negotiable safe speed for the first trial run can be chosen by choosing a speed 10 mph below the posted speed limit or drive 5 mph below the driver’s comfortable speed. Subsequent trial runs are conducted at 5 mph speed increments or reductions, until the average ball-bank reading matches or is one increment lower than the degrees of deflection for the corresponding speed in ***Table 10-2***.

(4) The curve should be driven a number of times until at least two identical ball bank readings (degrees) for each direction of travel are obtained. Each direction of travel should be considered independently and may require different speeds.

A minimum of three runs should be completed at each 5 mph increment in each direction of travel, for a total of six runs per 5 mph increment. The values in ***Table 10-2*** represent the usually accepted limits beyond which riding discomfort will be excessive and loss of vehicle control may occur.

(5) The recommended advisory speed should be to the nearest 5 mph less than the maximum negotiable safe speed, determined separately for each direction of travel. Considerations of sign location distance, intersections, crash records, and other conditions may result in a recommended speed lower than that derived by the ball bank indicator method.

(6) Advisory speed plaques (mph) should be used in conjunction with curve and turn signs when the safe operating speed is below the posted or prevailing speed on the roadway. See ***Section 2C of the MUTCD*** to determine the appropriate warning signs for the subject location. When plates are used with curve and turn signs, the miles-per-hour value shown on each plate shall be determined by an engineering study using any of the three methods discussed.

10.3.3 Accelerometer

(1) This method is very similar to the ball-bank indicator method and should be conducted in a similar manner. When using an accelerometer, the lateral acceleration should be considered instead of the ball-bank readings. Accelerometers measure lateral acceleration only. Some accelerometers have the capability of correlating this measurement to a ball-bank reading. If not, the lateral acceleration should be equated to the values in ***Table 10-2*** to convert to ball-bank readings. Either of these measurements can be used to determine the posted advisory speed. This method only requires one person to conduct the study as the data is stored in the accelerometer and can be downloaded at a later time.

10.4 PLACEMENT OF WARNING SIGNS

(1) Since warning signs are primarily for the benefit of the driver who is unfamiliar with the road, it is very important that care be given to the placement of such signs. Warning signs should provide adequate time for the driver to perceive, identify, decide, and perform any necessary maneuver to safely negotiate the curve. The advance distance for the placement of warning signs is determined by the posted speed limit. Additional information on sign placement and establishing advisory speeds is contained in ***Section 2C-05 and Table 2C-4 of the MUTCD***.

(2) Warning signs and advisory speed plaques shall be erected in accordance with the general requirements of ***Section 2C.08 of the MUTCD*** and **Section 2.39.2** of the Department's ***Traffic Engineering Manual (TEM).***

10.5 USE OF ADVISORY SPEED STUDY FORM (FORM NO. 750-020-12)

(1) Enter the *Roadway I.D.* and *Location* so that the advisory speed study location is thoroughly identified. The street name(s), state road number(s), county, and section number(s) should be included in the top section of the form.

(2) Enter the *Posted Speed Limit, Pavement Condition, Date and Time Period of Study, Observer(s),* and *Agency or Company* in the appropriate spaces. Include any information that may need to be considered in addition to data being collected in the *Remarks* area.

(3) In the *Direction of Travel* column enter *North, East, South,* or *West*, indicating the direction of the study vehicle. In the *Milepost* column, enter the milepost for the beginning and ending of the curve; this value should be obtained from straight line diagrams.

(4) In the *Speed on Curve* column, enter the constant speed of the study vehicle as the vehicle travels through the curve. In the *Degree of Deflection* column, enter the degree of deflection as shown on the ball bank indicator for constant speed of the study vehicle as the vehicle passed through the curve.

Figure 10-2 shows an example on how this form should be completed.

10.6 FORMS ACCESS

(1) A reproducible copy of the ***Advisory Speed Study (Form No. 750-020-12)*** is available in the Department's Forms Library.

Figure 10-2. Advisory Speed Study (Form No. 750-020-12)

State of Florida Department of Transportation

ADVISORY SPEED STUDY

Form 750-020-12
TRAFFIC ENGINEERING
February 2015

Site information

Roadway ID: **87090000**
Roadway Name: **SR 25**
City: **Unincorporated**
County: **Miami-Dade**
Posted Speed Limit: **55 mph**

General Information

Analyst/Observers: **BPP**
Agency or Company: **FDOT**
Date: **Monday, March 31, 2014**
Time Period From: **6:00 PM** To: **7:30 PM**
Pavement Condition: **Dry**

Remarks: **Free-flow conditions were present**

DIRECTION OF TRAVEL	MILEPOST		SPEED ON CURVE (mph)	DEGREE OF DEFLECTION
	BEGIN CURVE	END CURVE		
North	1.469	1.698	50	5
South	1.698	1.469	50	3
North	1.469	1.698	50	4
South	1.698	1.469	50	4
North	1.469	1.698	50	5
South	1.698	1.469	50	4
North	1.469	1.698	55	7
South	1.698	1.469	55	8
North	1.469	1.698	55	7
South	1.698	1.469	55	10
North	1.469	1.698	55	8
South	1.698	1.469	55	10
North	1.469	1.698	60	10
South	1.698	1.469	60	11
North	1.469	1.698	60	10
South	1.698	1.469	60	10
North	1.469	1.698	60	10
South	1.698	1.469	60	11
North	1.469	1.698	65	11
South	1.698	1.469	65	11
North	1.469	1.698	65	11
South	1.698	1.469	65	12
North	1.469	1.698	65	11
South	1.698	1.469	65	12

Speeds (in multiples of 5 mph)	Ball-bank Reading (degrees of deflection)	Accelerometer Reading Lateral Acceleration (g) or Side Friction Factor (f)
≤ 20	16°	0.28
25, 30	14°	0.24
≥ 35	12°	0.21

CHAPTER 11 NO-PASSING ZONE STUDY

11.1 PURPOSE

(1) The Florida Department of Transportation is authorized by ***Section 316.0875, F.S.,*** to determine those portions of any highway under its jurisdiction where overtaking and passing or driving to the left of the roadway would be hazardous. Such portions of the highway shall be marked as a no-passing zone with appropriate signage and pavement marking on the roadway. All no-passing zones shall be established in accordance with the guidelines provided in this chapter.

(2) The purpose of the no-passing zone study is to establish limits on the roadway which would permit the passing driver the necessary sight distance at the critical position (passing and passed vehicle abreast) to allow a safe completion of the passing maneuver.

(3) The no-passing areas include vertical and horizontal curves, railroad grade crossings, narrow bridges, intersections, transitions to and from multi-lane sections of roadway, and other locations where passing must be prohibited because of inadequate sight distance or other special conditions.

(4) A no-passing zone study shall be signed and sealed by a Florida registered professional engineer taking responsibility for the study recommendations and conclusions.

11.2 NO-PASSING ZONE CRITERIA

(1) The criteria for checking and establishing no-passing zones in the State of Florida shall be the ***Minimum Passing Sight Distance (Table 11-1)*** and ***Minimum Stopping Sight Distance (Table 11-2)***. Minimum passing sight distance represents the minimum sight distance necessary at the critical position (passing and passed vehicle abreast) to permit a passing driver to perceive an opposing vehicle at a distance sufficient to allow safe completion of a passing maneuver. According to ***ITE's Introduction to Transportation Engineering***, minimum stopping sight distance is the minimum distance required for a driver to stop a vehicle while traveling at or near the 85th percentile speed, design speed or speed limit, whichever is greater, before reaching an object seen in the path.

(2) The regulatory Do Not Pass (R4-1) sign may be used in addition to pavement markings to emphasize passing restriction. The sign may be installed at the beginning of an identified No Passing Zone and at intervals within, where sight distance is restricted or other conditions make passing inappropriate. No Passing Zone warning signs (W14-3) can be installed on the left side of the roadway at the beginning of no-passing zones identified by pavement markings.

Table 11-1. Minimum Passing Sight Distance (For Marking)

85th Percentile or Posted or Statutory Speed Limit (mph)	Minimum Passing Sight Distance (feet)
30	500
40	600
50	800
60	1000
70	1200

Source: Manual on Uniform Traffic Control Devices, 2009 Table 3B-1

Table 11-2. Minimum Stopping Sight Distance

85th Percentile Speed or Design Speed (mph)	Minimum Stopping Sight Distance (feet)
15	80
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730

Source: Florida Plans Preparation Manual Table 2.7.1. Note: Adjustments for grades greater than 2% should be applied and are included in Table 2.7.1.

(3) The eye height and object height of 3.5 feet shall be used for minimum passing sight distance. Where centerlines are installed and a no-passing zone is warranted, it should be marked where the sight distance is equal to or less than that listed in ***Table 11-2*** using prevailing off-peak 85th percentile speed or posted speed limit, whichever is higher. In the event the 85th percentile speed is between table increments, the next higher 5 mph increment is to be used.

(4) The beginning of a no-passing zone is the point at which the sight distance is less than specified in ***Table 11-1***. The end of the zone is the point at which the sight distance again becomes greater than the minimum specified. In no case shall a no-passing zone marking be less than 500 feet in length. If the actual no-passing distance is less than 500 feet, the additional length of marking shall be added to the beginning of the zone.

(5) Where the distance between successive no-passing zones is less than the minimum passing sight distance or 400 feet, whichever is greater, the appropriate no-passing marking (one direction or two directions) should connect the zones. The criteria above and as stated in ***Section 3B of the MUTCD*** and the Department's ***Roadway and Traffic Design Standards*** shall be used to check and determine no-passing zones.

11.3 WARRANTS FOR NO-PASSING ZONES

11.3.1 Warrant 1: Horizontal and Vertical Curves

(1) ***Section 316.087, F.S.,*** requires a no-passing zone at a horizontal or vertical curve where the sight distance is less than the minimum necessary for safe passing at the prevailing speed of traffic. Passing sight distance on a vertical curve is the distance at which an object 3.5 feet above the pavement surface can just be seen from a point 3.5 feet above the pavement. Similarly, the passing sight distance on a horizontal curve is the distance measured along the centerline (or right hand lane line of a three-lane highway with general use middle lane) between two points 3.5 feet above the pavement on a line tangent to the embankment or other obstruction that cuts off the view on the inside of the curve. Where centerlines are installed and a curve warrants a no-passing zone, it should be so marked where the sight distance is equal to or less than that listed in ***Table 11-1***.

11.3.2 Warrant 2: Railroad Grade Crossing (Urban and Rural)

(1) ***Section 316.087, F.S.,*** requires a no-passing zone when approaching within 100 feet of or traversing a railroad grade crossing.

(2) Railroad grade crossings shall be marked in accordance with ***Index Number 17346 of the Roadway and Traffic Design Standards***. The no-passing zone marking shall extend from the railroad crossing down the roadway through the last 24-inch white bar of the railroad crossing pavement message. This distance should always exceed distance "A" (illustrated in Index Number 17346) as constructed in the field or the minimum values presented in ***Table 11-1,*** whichever is longer. Note that adjustments for grades greater than 2% should be applied per Table 2.7.1 of the ***Florida Plans Preparation Manual***.

11.3.3 Warrant 3: Intersections (Urban and Rural)

(1) ***Section 316.087, F.S.,*** requires no-passing when approaching within 100 feet of or traversing any intersection. An exception to this requirement is locations on either state or county maintained roadways, which are outside city limits, and are not marked at least 100 feet before the intersection by an official traffic control device (either symbol or words) indicating an approaching intersection.

(2) When an intersection is located within the city limits and the major roadway has parking, that roadway shall be marked with a continuous no-passing zone. If the roadway does not have parking, a no-passing zone is required in advance of each intersecting roadway at a distance that is equal to or greater than that listed in ***Table 11-1***. The intersecting roadway (stop controlled) shall be marked with a minimum no-passing zone of 200 feet before the intersection. Note that adjustments for grades greater than 2% should be applied per Table 2.7.1 of the ***Florida Plans Preparation Manual***.

(3) When roadways form an intersection outside the city limits and the intersecting roadway (stop controlled) is marked by an official Florida Department of Transportation or County road department traffic control device indicating an intersection, either by symbol or by words, a no-passing zone is required on the major roadway. The length of the zone shall be equal to or greater than that listed in ***Table 11-2***. The intersecting roadway (stop required) shall be marked with a minimum no-passing zone of 250 feet before the intersection.

(4) The engineer may mark a roadway with a continuous no-passing zone when it lies outside of the city limits but has closely spaced driveways and streets typical of urban and suburban streets.

11.3.4 Warrant 4: Narrow Bridges

(1) Narrow bridges require a no-passing zone marking. Narrow bridges shall be marked in accordance with Index Number 17359 of the ***Roadway and Traffic Design Standards***.

(2) A narrow bridge is defined as (1) approach roadways with paved shoulders when the bridge width, including shoulders, is less than the width of the approach roadway, or (2) approach roadways without paved shoulders when the bridge shoulder width is less than 2 feet. The no-passing zone should be extended 1570 feet in advance of the narrow bridge.

11.3.5 Warrant 5: Roadway Transitions

(1) Roadway transitions shall be marked in accordance with Index Number 17346 of the ***Roadway and Traffic Design Standards***.

(2) At a minimum, a no-passing zone should be marked from the beginning of the transition down the roadway a distance equal to or greater than that listed in ***Table 11-2***.

11.3.6 Warrant 6: Obstruction

(1) ***Section 316.087, F.S.*** requires a no-passing zone when the view is obstructed approaching within 100 feet of any bridge, viaduct, or tunnel.

(2) For a two lane roadway, a no-passing zone shall precede and follow the tapered obstruction diagonal markings computed using ***Section 3B.10 of the MUTCD***, by a distance equal to twice the length computed of the tapered area to the obstruction (as shown in ***Figure 3B-15 of the MUTCD***) or that distance contained in ***Table 11-2,*** whichever is greater. For traffic conditions where vehicles can pass to either side of the obstruction, such as a multi-lane roadway, the length of a single solid white lane line, preceding and following the tapered area, shall be equal to the length of the tapered area to the obstruction.

(3) The minimum taper length is 100 feet in an urban area, and 200 feet in a rural area.

11.3.7 Warrant 7: Special Conditions

(1) Other special conditions may arise which require a no-passing zone. For those conditions, the engineer in charge should seek the assistance of the District Traffic Operations Engineer for the marking of that particular condition.

11.4 PERSONNEL AND EQUIPMENT

(1) The personnel and equipment necessary for establishing no-passing zones is described in each separate method.

11.5 METHODS FOR PROVIDING OR ESTABLISHING NO-PASSING ZONES

(1) There are five different methods available for establishing no-passing zones within the State of Florida. Method One is the two vehicle, Method Two the one vehicle, Method Three the two person, Method Four involves ITS techniques, and Method Five involves measuring no-passing zones from detailed construction drawings of the site.

(2) The Department prefers the two vehicle method to be used on the State Highway System. However, the other methods provide a viable alternative for cities, counties, and consultants who might not have the necessary equipment to perform the two vehicle method.

(3) A traffic control plan is required for conducting Methods 1 through 4.

11.5.1 Method One - Two Vehicle

(1) This method requires two vehicles equipped with drivers and a recorder, two-way radios, calibrated Distance Measuring Instruments (DMI), two flashing amber lights, and a target for eye height on the lead vehicle. The vehicles used shall be intermediate size. The vehicles with drivers are deployed with the appropriate minimum sight distance between them.

(2) To set the minimum sight distance interval, both cars should park abreast on the roadway or shoulder with the DMIs at 0.000. The lead vehicle will then move forward the minimum passing sight distance for the speed indicated. When the lead vehicle has traveled the required distance, it should stop and the DMI should be reset to 0.000.

(3) From then on, radio contact should be maintained between the vehicles to coordinate their movement. Upon a signal from the trailing vehicle, both vehicles can move forward. The vehicles are to be kept at the correct distance and speed by the lead vehicle observer calling off the readings in feet often enough to keep identical readings on the DMI's. To practice this procedure, readings should be called off every 100 feet with the vehicles traveling approximately at 3 to 5 mph. Later with added experience, this speed may be increased to 15 to 20 mph. If identical readings cannot be maintained, the trailing vehicle should have a lower reading. This will result in the vehicles being farther apart than required.

One note of caution: The vehicles should not be backed up to adjust the spacing, unless the DMI's being used are capable of operating backwards.

(4) While making measurements, the driver of the trailing vehicle should stop both vehicles just before the lead vehicle goes out of sight. At this time, the trailing vehicle can move up to obtain identical DMI readings. From this point, each vehicle should move forward 50 feet, stop, then move another 50 feet until the target on the lead vehicle goes out of sight over the crest of a hill or is obscured by obstructions along the roadside on horizontal curves.

(5) With practice, a team may be able to move continuously and stop only when the lead vehicle goes out of sight. When the lead vehicle's target disappears, the pavement should be marked with spray paint or by some other method.

(6) The trailing vehicle operator should mark to the right of the centerline and the leading vehicle to the left. The trailing vehicle marks will represent the beginning and end of the no-passing zone for vehicles traveling in the direction of the study. The lead vehicle marks will represent the no-passing zone for the opposite direction of travel. At the first stop, the lead driver should make an upside-down "T" on the left of the centerline or left shoulder, and the trailing driver an upside-down "T" on the right of the centerline or right shoulder.

(7) The two vehicles should then proceed forward with identical DMI readings until the driver of the trailing vehicle sees the top of the lead vehicle. Both vehicles should be stopped and the trailing vehicle should move forward to obtain identical DMI readings. Both vehicles should then move forward 50 feet, and stop to determine if the target has re-appeared. This "stepping" should be repeated until the target re-appears. Both drivers should then stop and mark two more "T's" on the roadway, with the lead driver marking an upright "T" on the left of the centerline or left shoulder and the trailing driver marking an upright "T" on the right of the centerline or right shoulder.

(8) It is possible for vehicles positioned between the study vehicles to become lost in depressions although the vehicles are spaced the minimum sight distance apart and the drivers may see each other. Reverse horizontal curves can create similar situations. The following procedure is suggested for handling these lost vehicle situations.

The driver of the lead vehicle should decide where he or she believes the low point of a depression is and stop there, after notifying the trailing vehicle of what he or she is doing. The trailing vehicle should then move forward until the target on the lead vehicle is seen. If the trailing driver notes that other oncoming vehicles continue to become lost, the trailing vehicle must move forward to a point where the driver does not lose an oncoming car in the depressions. At this point, an upright "T" should be marked to the right of the centerline or right shoulder by the trailing vehicle's driver.

With the trailing vehicle stopped, the lead vehicle should move forward so it has a DMI reading identical to the trailing vehicle and an upright "T" marked to the left of the centerline or left shoulder by the lead vehicle's driver. The two vehicles are now together and may proceed with the study. The lead vehicle should stop at major intersections and radio the trailing vehicle that he or she is at an intersection. The recorder in the trailing vehicle should add the minimum passing sight distance to the DMI reading and record the correct location of the intersection.

(9) The minimum passing sight distance used during the study may be changed to accommodate a change in the speed limit without restarting the procedure. If the distance is to be increased, the DMI of the lead vehicle is turned back the difference in distance and then driven ahead until the DMI again reads the distance when originally stopped. To decrease the distance, the DMI of the lead vehicle is turned ahead to the difference in distance and then the trailing vehicle is driven forward to the new reading.

(10) Given the slow vehicle pace necessary to conduct this study, care must be taken when locating no-passing zones to see that traffic does not become confused or congested. Both vehicles should pull over on the shoulder when the rear driver notices several cars being held back.

11.5.2 Method Two - One Vehicle

(1) This method only requires one driver in a vehicle equipped with DMI. To mark a curve or hill for passing sight distance, the driver should move slowly through it. When the driver reaches the point at which the vista opens up and the driver is sure there is a stretch of road ahead which is sufficient for safe passing, he or she should stop the vehicle, preferably on the shoulder, and place a paint mark on the right side of the roadway. Drivers usually sight down the ditch-line as an aid to finding this point when measuring curves for sight distance. This point is the end of the no-passing zone in the direction of travel. The point where the vista opens is usually much easier to locate accurately than the point where the sight distance decreases below the minimum while coming into a curve or hill.

(2) The driver should then reset the DMI to 0.000, travel the required passing sight distance, and stop to place a paint mark on the left side of the roadway. This marks the end of the no-passing zone for vehicles traveling in the opposite direction. This point also represents the minimum passing length for both directions and could be adjusted further downstream in the analysis vehicle's direction if visibility allows. Likewise, if the vehicle travels past the point where the vista opens and is unable to reach the minimum passing sight distance, the entire section should be marked as a no-passing zone.

(3) A trip through the site in the opposite direction, following the same procedure, completes the determination of the location of the no-passing zones for that site in both directions. This one vehicle method essentially assumes a zero-height object as there is no practical way to adjust the object height. The method is therefore more likely to be conservative, especially on hills where 3.5 feet high objects could be seen some distance further than zero-height objects.

11.5.3 Method Three - Two Person

(1) The two person method, also known as the walking method, is the most accurate, yet time consuming method. In this method, two people using walkie-talkies walk along the centerline of the roadway, maintaining the minimum passing sight distance between them. This minimum distance can be maintained by a taut rope, chain, or wire. However, pre-stationing is the preferred method and allows more attention to be directed to task and less conflict with the motorists. The height of eye is established by means of a target carried by each person.

(2) An advantage of this technique is that no-passing zones may be determined for both lanes of traffic when both people have targets. A disadvantage of this technique is a safety factor as two people are in the centerline of the roadway. To ensure overall safety in using this method, proper work zone traffic control should be set up to stop vehicles in at least one direction of travel.

11.5.4 Method Four - ITS Techniques

(1) This method involves ITS techniques that use global positioning systems or other high-tech procedures as they become available.

(2) One of these techniques is a computer-based system developed to determine highway no-passing zones. The system is a two vehicle method. The system requires a lead vehicle equipped with a specially modified DMI, modem, telemetry, and a trailing vehicle with a standard DMI, modem, telemetry, and an event logging laptop computer. The lead vehicle continuously transmits its travel distance to the trailing vehicle. The trailing vehicle computes its own travel distance and the difference between these two values is the separated distance between the two vehicles.

(3) The in and out visibility of a target on the lead vehicle, monitored from the trailing vehicle, is recorded to determine if a no-passing zone is required. The driver in the trailing vehicle can adjust the vehicle separation by controlling his speed. In addition, data may be entered pertaining to physical events on the roadway such as intersections, school zones, and bridges so that further analysis allows accurate establishing of no-passing zones.

(4) This system is safe and accurate, but rather expensive.

11.5.5 Method Five - Plans Review

(1) When appropriate, the District Traffic Operations Engineer, or his equivalent in the city or county, may establish a no-passing zone based on available construction plans, CADD files, aerials, etc. A field review to verify actual site conditions is recommended.

11.6 NO-PASSING ZONE STUDY FORM *(FORM NO. 750-020-13)*

(1) An example of the ***No-Passing Zone Study (Form No. 750-020-13)*** is shown in ***Figure 11-1***. To fill out this sheet properly, the following information should be completed.

(2) Enter the *Roadway I.D., Roadway Name, City* and *County* so that the no-passing zone study location is thoroughly identified. The *Name(s), State Road Number(s),* and *County Section Number* should be included.

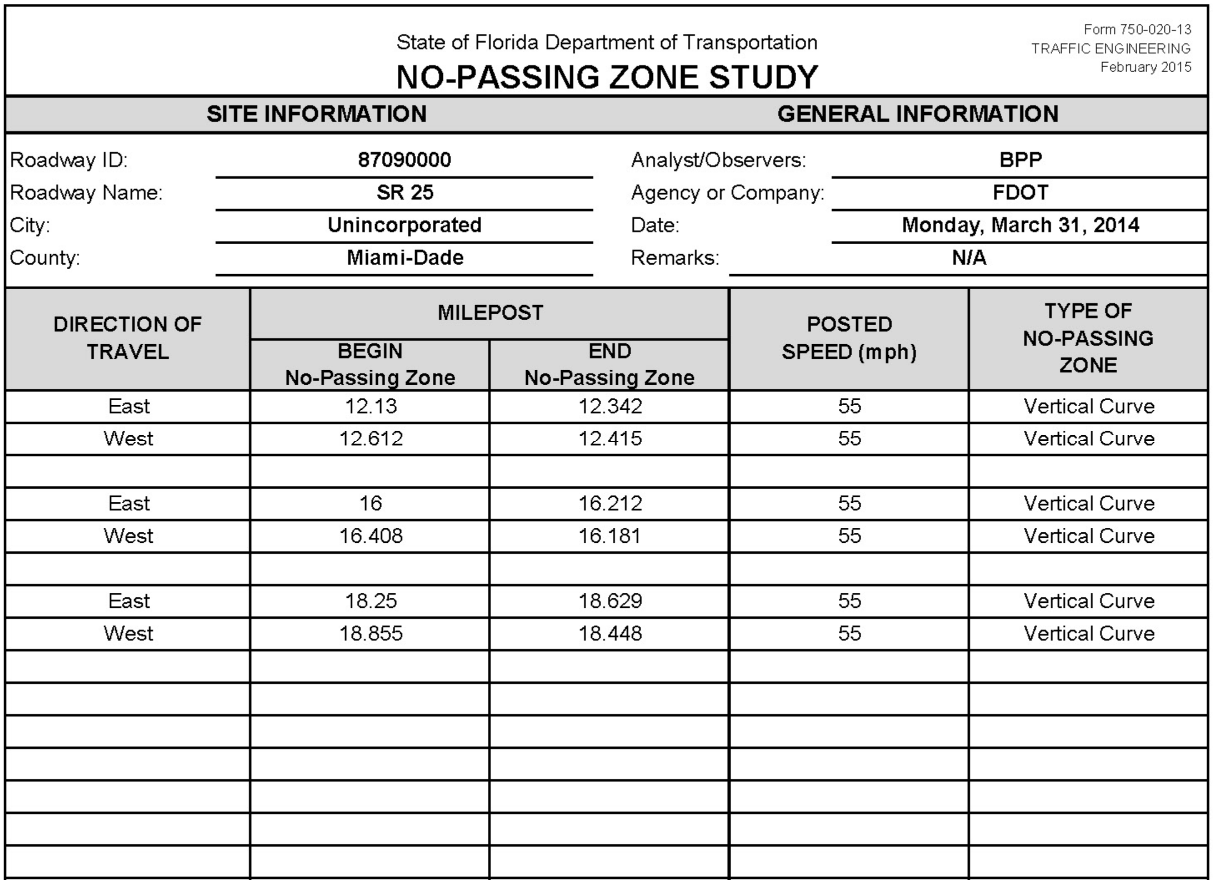
(3) Enter *Observer(s), Agency or Company* and *Date of Study* in the appropriate spaces. On the line provided for *Remarks*, include any information that may need to be considered in addition to data being collected.

(4) In the *Direction of Travel* column, indicate the direction of the study by entering Northbound, Eastbound, Southbound, or Westbound. In the *Milepost* column, enter the milepost number for the beginning and ending of the no-passing zone. In the *Posted Speed* column, enter the posted speed limit for the roadway. In the *Type of No-Passing Zone* column, enter the type of no-passing zone being studied (e.g., vertical curve, horizontal curve, obstruction, etc.).

11.7 FORMS ACCESS

(1) A reproducible copy of the ***No-Passing Zone Study (Form 750-020-13)*** is available in the Department's Forms Library.

Figure 11-1. No-Passing Zone Study (Form No. 750-020-13)



Form 750-020-13
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

NO-PASSING ZONE STUDY

SITE INFORMATION

Roadway ID: **87090000**
Roadway Name: **SR 25**
City: **Unincorporated**
County: **Miami-Dade**

GENERAL INFORMATION

Analyst/Observers: **BPP**
Agency or Company: **FDOT**
Date: **Monday, March 31, 2014**
Remarks: **N/A**

DIRECTION OF TRAVEL	MILEPOST		POSTED SPEED (mph)	TYPE OF NO-PASSING ZONE
	BEGIN No-Passing Zone	END No-Passing Zone		
East	12.13	12.342	55	Vertical Curve
West	12.612	12.415	55	Vertical Curve
East	16	16.212	55	Vertical Curve
West	16.408	16.181	55	Vertical Curve
East	18.25	18.629	55	Vertical Curve
West	18.855	18.448	55	Vertical Curve

CHAPTER 12 VEHICLE SPOT SPEED STUDY

12.1 PURPOSE

(1) The ***Vehicle Spot Speed Study*** is designed to measure the speed characteristics at a specified location under the traffic and environmental conditions prevailing at the time of the study. Spot speed data are used in many traffic engineering activities, such as determining traffic signal timing, roadway capacity, evaluating the effectiveness of improvements, and installing speed zones.

(2) The location, time, and conditions of the study shall be dictated by its objective and scope. If approach speeds to an intersection are needed, the measurements should be taken upstream of the intersection prior to vehicle deceleration for a possible stop at the intersection. If the study requires free-flow speeds, the measurements should be taken during off-peak time periods. The same logic should be followed for measurements needed during nighttime conditions, wet pavement, etc.

(3) There are two commonly used approaches to collect vehicle speeds at spot locations: individual vehicle selection method and all-sampling vehicle method. The individual vehicle selection method entails using a manual speed measurement technique and is generally used for short-term speed measurements. The all-sampling method uses automated in-road or roadside measurement equipment (e.g., pneumatic tubes, standard induction loops, point loops, etc.) and is appropriate to use for system performance monitoring system. This chapter focuses on the individual vehicle selection method. For more information on the all-sampling method, refer to the ***ITE Manual of Transportation Engineering Studies, 2nd Edition, Chapter 5.3, page 86.***

(4) Vehicle speed is determined using the direct measurement technique with radar, laser, or infrared technologies, which generally operate on the Doppler Principle. The positioning of the radar or laser unit should be determined considering the following:

(a) The capabilities of the unit – manufacturer’s specifications and instructions shall be followed for the units set up and operation

(b) Minimize the angle of incidence – to maintain the cosine error below 2 mph, it is recommended to maintain an angle of incidence of less than 15 degrees between the radar beam and the direction of travel target vehicle.

(c) Conceal the unit from the view of the motorists – this measure will prevent motorist distraction and reaction.

(5) For a graphical example of potential positions of the radar unit, review the ***ITE Manual of Transportation Engineering Studies, 2nd Edition, Exhibit 5-8.***

12.2 VEHICLE SPOT SPEED STUDY FORM

(1) ***Form No. 750-010-03*** is designed to allow for several options in the collection of speed data. Data can be collected by direction, **Option 1**, in which case both sides (i.e., left and right of the column showing the speed ranges) of the form are used, or as a cumulative for both directions, in which case either side of the form can data by direction. This data can then be used to represent data for both directions. Using data, it is possible to calculate the 85th percentile speed and 10 mph pace for each direction of travel. An example of this option is shown in ***Figure 12-1.*** The observer enters a number "1" in a data block under the appropriate direction for each observance of a speed; if blocks run out, each number "1" can be modified to be any number greater than "1" if needed. For example, to represent two vehicles observed at the same speed, a number "2" can be entered into a single box or two separate number "1" values can be inserted in two separate boxes.

(2) The number of observations of each speed shall be summed under the *Total* column for each direction of travel, and the individual totals are cumulatively summed from lowest to highest speed for each direction of travel under the *Cum Total* column. If the electronic version of the form is used and the data is input properly, the 85th percentile vehicle is automatically computed for each direction and shown at the bottom of the form. That vehicle's corresponding speed category represents the 85th percentile speed. This speed is computed by interpolating two *Cum Total* column values (higher and lower than the 85th percentile vehicle) using the average of the speed ranges under the Speed column. The 10 mph pace in each direction is also calculated automatically in the electronic version of the form and it displays at the bottom an "OK" message if a single 10 mph pace was identified. If more than one speed ranges have the highest 10 mph pace, then the highest range of speed is shown in the corresponding field and a warning message is displayed at the bottom of the spreadsheet.

(3) Data can be collected as a function of vehicle classification either for the *Total* or for both directions. This is accomplished by utilizing the classification partitions at the top of the spreadsheet to help classify data collected. Vehicles of a particular class type should be entered within the column bounds and the designated class should be noted. To help automatically summarize the data, the spreadsheet can be copied as many times as there are vehicle classes, and summaries can be computed for one given vehicle class by deleting the data for all other vehicle classes collected. This process is repeated for all vehicle classes. The engineer performing the calculations should sign the study and enter the date the calculations were completed in the space provided.

(4) ***The Speed Zoning for Highways, Roads, and Streets in Florida Manual*** (750-

010-002) requires at a minimum 100 vehicle speed records per direction of travel, or all free flowing vehicles during a two-hour period when the traffic volumes are low.

(5) If a more accurate method is needed to determine the minimum number of measured speeds, the following equation shall be used (Equation 12-1).

$$N = \left(S * \frac{K}{E}\right)^2 \qquad \text{Equation 12-1}$$

where,

N = minimum number of measured speeds

S = estimated sample standard deviation, mph

K = constant corresponding to the desired confidence level

E = permitted error or tolerance in the average speed estimate, mph

(6) Estimation of sample standard deviation (S) can be derived from previous studies under similar condition or from speed monitoring data. If no data is available, use estimated values as a function of traffic area and highway type from ***Table 12-1***.

(7) The confidence level (K) represents the probability that the difference between the calculated mean speed from the sample and the true average speed at the study location is less than the permitted error. ***Table 12-2*** provides corresponding K values for selected confidence levels; these values are only valid for any sample size greater than 100 measurements.

(8) The permitted error (E) or precision required for the mean speed is expressed as plus and minus a specified value. Typical permitted errors range from ±1 to ±5 mph (±1.6 to ±8 km/h).

Table 12-1. Average Standard Deviation (S) for sample-size determination

Traffic Areas	Highway Type	mph	km/h
Rural	Two-lane	5.3	8.5
	Four-lane	4.2	6.8
Intermediate	Two-lane	5.3	8.5
	Four-lane	5.3	8.5
Urban	Two-lane	4.8	7.7
	Four-lane	4.9	7.9
	Rounded value:	5.0	8.0

Source: *Exhibit 5-5 of the ITE Manual of Transportation Engineering Studies, 2nd Edition, page 83*

Table 12-2. Constant Corresponding to Level of Confidence

Constant, K	Confidence Level (%)
1.00	68.3%
1.50	86.6%
1.64	90.0%
1.96	95.0%
2.00	95.5%
2.50	98.8%
2.58	99.0%
3.00	99.7%

Source: *Exhibit 5-6 of the ITE Manual of Transportation Engineering Studies, 2nd Edition, page 83*

(9) **Option 2** allows for the collection of speed data without the separation of speeds by direction. To do this, the observer enters a tally mark for each observance of a speed on only the right side of the study form. The number of observations of each speed is entered under the *Total* column for *Both Directions*. The individual totals are then cumulatively summed under the *Cum Total* column. Calculations are then made for the 85th percentile speed and 10 mph pace and entered under *Both Directions* in the *Speed Data Summary* section. The electronic version of ***Form No. 750-010-03*** can also be used for this option. An example of this option is shown in **Figure 12-2*.***

(10) **Options 3 and 4** are available by collecting speed data as a function of vehicle classification, either by direction or for both directions, similar to the first two options. This is accomplished by utilizing one-letter classification codes rather than the tally mark. An example of this option is shown in **Figure 12-3*.*** Classification codes that may be used include the following:

- **C** = passenger car
- **B** = buses
- **T** = truck (six or more tires, single unit)
- **M** = multi-unit (semi and vehicle with trailers)

(11) Any classification codes used should be noted on the study form by the observer. The one-letter code for each vehicle is inserted in a data block in the row for the appropriate speed. This allows summarization of speed data for each class of vehicle, providing that a statistically adequate number of vehicles from each class are sampled.

(12) The remainder of the study form computes the 85th percentile speed and 10 mph pace using the standard procedures identified in the ***Chapter 5 of the ITE Manual of Transportation Engineering Studies, 2nd Edition.***

(13) The user is referred to the ***Manual on Speed Zoning for Highways, Roads, and Streets in Florida*** (FDOT Manual Number 750-010-002) for further details regarding speed data collection and analysis. This manual is available from the State Traffic Engineering and Operations Office, 605 Suwannee Street, M.S. 36, Tallahassee, Florida 32399-0450, phone (850) 410-5600.

12.3 FORMS ACCESS

(1) A reproducible copy of the ***Vehicle Spot Speed Study (Form No. 750-010-03)*** can be downloaded from the MUTS website. This form is also available from the Department's Forms and Procedures Office.

Figure 12-1. Advisory Speed Study - Option 1 (Form No. 750-010-03)

State of Florida Department of Transportation

VEHICLE SPOT SPEED STUDY

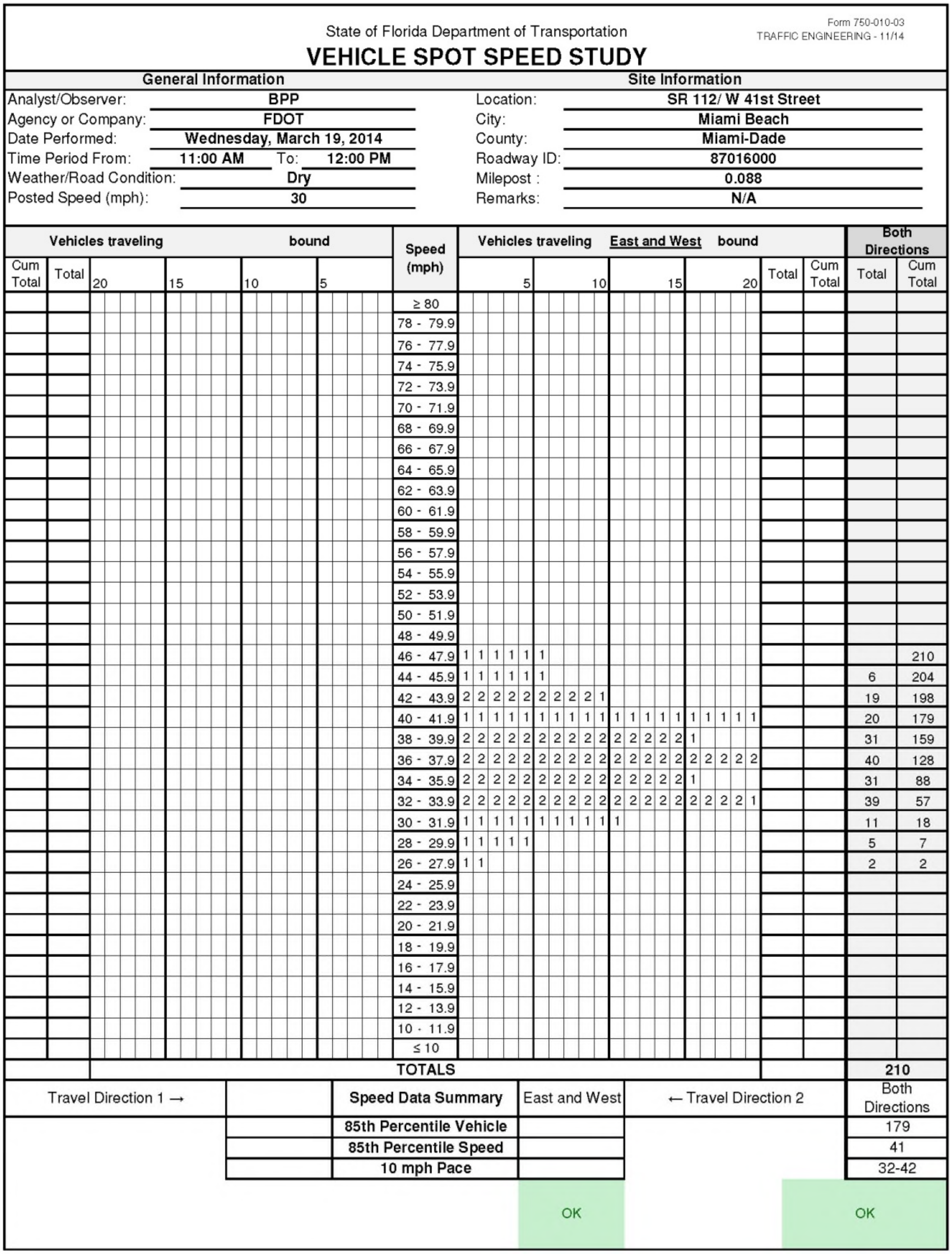
Form 750-010-03
TRAFFIC ENGINEERING
February 2015

General Information		Site Information	
Analyst/Observer:	**BPP**	Location:	**SR 112/ W 41st Street**
Agency or Company:	**FDOT**	City:	**Miami Beach**
Date Performed:	**Wednesday, March 19, 2014**	County:	**Miami-Dade**
Time Period From:	**11:00 AM** To: **12:00 PM**	Roadway ID:	**87016000**
Weather/Road Condition:	**Dry**	Milepost :	**0.088**
Posted Speed (mph):	**30**	Remarks:	**N/A**

Vehicles traveling **East** bound Cum Total	 Total	 20 15 10 5	Speed (mph)	Vehicles traveling **West** bound 5 10 15 20	 Total	 Cum Total	Both Directions Total	 Cum Total
			≥ 80					
			78 - 79.9					
			76 - 77.9					
			74 - 75.9					
			72 - 73.9					
			70 - 71.9					
			68 - 69.9					
			66 - 67.9					
			64 - 65.9					
			62 - 63.9					
			60 - 61.9					
			58 - 59.9					
			56 - 57.9					
105	2	1 1	54 - 55.9					215
103	2	1 1	52 - 53.9				2	213
101	3	1 1 1	50 - 51.9	1	1	110	4	211
98	3	1 1 1	48 - 49.9	1 1 1	3	109	6	207
95	4	1 1 1 1	46 - 47.9	1	1	106	5	201
91	7	1 1 1 1 1 1 1	44 - 45.9	1 1 1 1 1 1 1 1 1	9	105	16	196
84	9	1 1 1 1 1 1 1 1 1	42 - 43.9	1 1 1 1 1 1 1 1 1 1	10	96	19	180
75	13	1 1 1 1 1 1 1 1 1 1 1 1 1	40 - 41.9	1 1 1 1 1 1 1 1 1 1	10	86	23	161
62	10	1 1 1 1 1 1 1 1 1 1	38 - 39.9	1 1 1 1 1 1 1 1 1 1	10	76	20	138
52	13	1 1 1 1 1 1 1 1 1 1 1 1 1	36 - 37.9	1 1 1 1 1 1 1 1 1 1 1 1	12	66	25	118
39	17	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	34 - 35.9	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	16	54	33	93
22	11	1 1 1 1 1 1 1 1 1 1 1	32 - 33.9	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	15	38	26	60
11	4	1 1 1 1	30 - 31.9	1 1 1 1 1 1 1 1 1 1 1 1	12	23	16	34
7	4	1 1 1 1	28 - 29.9	1 1 1 1 1 1 1 1 1 1	10	11	14	18
3	2	1 1	26 - 27.9	1	1	1	3	4
1	1	1	24 - 25.9				1	1
			22 - 23.9					
			20 - 21.9					
			18 - 19.9					
			16 - 17.9					
			14 - 15.9					
			12 - 13.9					
			10 - 11.9					
			≤ 10					
105			**TOTALS**		**110**		**215**	

Travel Direction 1 →	East	Speed Data Summary	West	← Travel Direction 2	Both Directions
	89	**85th Percentile Vehicle**	94		183
	45	**85th Percentile Speed**	43		45
	32-42	**10 mph Pace**	30-40		32-42
	OK		Warning: Multiple 10 mph Paces. Highest range shown		OK

Figure 12-2. Advisory Speed Study - Option 2 (Form No. 750-010-03)



Form 750-010-03
TRAFFIC ENGINEERING - 11/14

State of Florida Department of Transportation

VEHICLE SPOT SPEED STUDY

General Information

Analyst/Observer: **BPP**
Agency or Company: **FDOT**
Date Performed: **Wednesday, March 19, 2014**
Time Period From: **11:00 AM** To: **12:00 PM**
Weather/Road Condition: **Dry**
Posted Speed (mph): **30**

Site Information

Location: **SR 112/ W 41st Street**
City: **Miami Beach**
County: **Miami-Dade**
Roadway ID: **87016000**
Milepost : **0.088**
Remarks: **N/A**

Vehicles traveling bound																						Speed (mph)	Vehicles traveling East and West bound																						Both Directions	
Cum Total	Total	20					15					10					5										5					10					15					20	Total	Cum Total	Total	Cum Total
																						≥ 80																								
																						78 - 79.9																								
																						76 - 77.9																								
																						74 - 75.9																								
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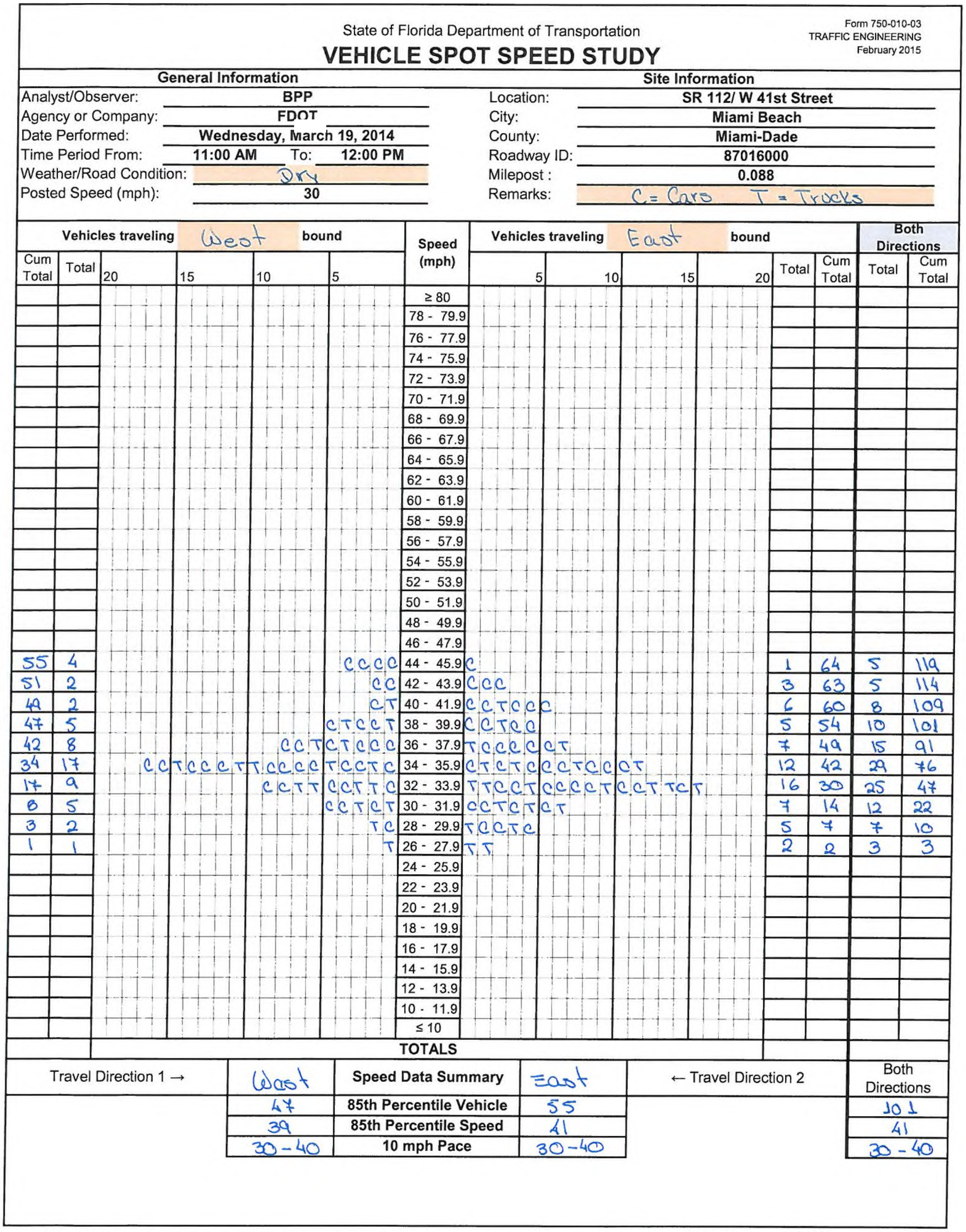
																						50 - 51.9																								
																						48 - 49.9																								
																						46 - 47.9	1	1	1	1	1	1																		210
																						44 - 45.9	1	1	1	1	1	1																	6	204
																						42 - 43.9	2	2	2	2	2	2	2	2	2	1													19	198
																						40 - 41.9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			20	179
																						38 - 39.9	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1							31	159
																						36 - 37.9	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2			40	128
																						34 - 35.9	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1							31	88
																						32 - 33.9	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1			39	57
																						30 - 31.9	1	1	1	1	1	1	1	1	1	1	1												11	18
																						28 - 29.9	1	1	1	1	1																		5	7
																						26 - 27.9	1	1																					2	2
																						24 - 25.9																								
																						22 - 23.9																								
																						20 - 21.9																								
																						18 - 19.9																								
																						16 - 17.9																								
																						14 - 15.9																								
																						12 - 13.9																								
																						10 - 11.9																								
																						≤ 10																								
																						TOTALS																							210	

Travel Direction 1 →		Speed Data Summary	East and West	← Travel Direction 2	Both Directions
		85th Percentile Vehicle			179
		85th Percentile Speed			41
		10 mph Pace			32-42
			OK		OK

Figure 12-3. Advisory Speed Study - Option 3 (Form No. 750-010-03)



State of Florida Department of Transportation

VEHICLE SPOT SPEED STUDY

Form 750-010-03
TRAFFIC ENGINEERING
February 2015

General Information

Analyst/Observer: BPP
Agency or Company: FDOT
Date Performed: Wednesday, March 19, 2014
Time Period From: 11:00 AM To: 12:00 PM
Weather/Road Condition: Dry
Posted Speed (mph): 30

Site Information

Location: SR 112/ W 41st Street
City: Miami Beach
County: Miami-Dade
Roadway ID: 87016000
Milepost : 0.088
Remarks: C= Cars T = Trucks

Vehicles traveling West bound			Speed (mph)	Vehicles traveling East bound			Both Directions	
Cum Total	Total	20 15 10 5		5 10 15 20	Total	Cum Total	Total	Cum Total
			≥ 80					
			78 - 79.9					
			76 - 77.9					
			74 - 75.9					
			72 - 73.9					
			70 - 71.9					
			68 - 69.9					
			66 - 67.9					
			64 - 65.9					
			62 - 63.9					
			60 - 61.9					
			58 - 59.9					
			56 - 57.9					
			54 - 55.9					
			52 - 53.9					
			50 - 51.9					
			48 - 49.9					
			46 - 47.9					
55	4	CCCC	44 - 45.9	C	1	64	5	119
51	2	CC	42 - 43.9	CCC	3	63	5	114
49	2	CT	40 - 41.9	CCTCCC	6	60	8	109
47	5	CTCCT	38 - 39.9	CCTCC	5	54	10	101
42	8	CCTCTCCC	36 - 37.9	TCCCCCT	7	49	15	91
34	17	CCTCCCTTCCCCTCCTC	34 - 35.9	CTCTCCCTCCCT	12	42	29	76
17	9	CCTTCCTTC	32 - 33.9	TTCCTCCCCTCCTTCT	16	30	25	47
8	5	CCTCT	30 - 31.9	CCTCTCT	7	14	12	22
3	2	TC	28 - 29.9	TCCTC	5	7	7	10
1	1	T	26 - 27.9	TT	2	2	3	3
			24 - 25.9					
			22 - 23.9					
			20 - 21.9					
			18 - 19.9					
			16 - 17.9					
			14 - 15.9					
			12 - 13.9					
			10 - 11.9					
			≤ 10					
			TOTALS					

Travel Direction 1 →	Speed Data Summary	← Travel Direction 2	Both Directions
West		East	
47	85th Percentile Vehicle	55	101
39	85th Percentile Speed	41	41
30 - 40	10 mph Pace	30 - 40	30 - 40

CHAPTER 13 TRAVEL TIME AND DELAY STUDY

13.1 PURPOSE

(1) The purpose of a ***Travel Time and Delay Study*** is to evaluate the quality of traffic movement along a route and determine the locations, types, and extent of traffic delays by using a test vehicle, vehicle observation, or probe vehicle.

(2) This study can be used to compare and evaluate operational conditions before and after roadway or intersection improvements have been made. It can also be used as a tool to assist in prioritizing projects by comparing the magnitude of the operational deficiencies (e.g., delays and stops) for each project under consideration.

(3) The ***Travel Time and Delay Study*** can also be used by planners to monitor system performance measurements for local government comprehensive plans.

(4) The methodology presented herein provides the quantitative information with which the analyst can develop recommendations for improvements, such as traffic signal retiming, safety improvements, turn lane additions, and channelization enhancements.

13.2 DEFINITIONS

(1) **Acceleration Noise (AN)**. Represents the degree of driver discomfort due to acceleration and deceleration. It is computed (approximately) as the root mean square value of acceleration (feet per second squared), considering each second of operation separately *(The Theory of Road Traffic Flow)*. Stopped times (i.e., speeds less than 5 mph) are excluded from the computations.

(2) **Control Point (CP**). A node at the beginning or end of a link, usually the stop line at a signalized intersection, but can be any physical feature, e.g., power pole. The stop line or physical feature selected within the intersection must be located in the same direction of travel. The control point may be different for each direction of travel. However, once a control point is chosen, it shall be used for each run in that particular direction**.**

(3) **Delay (D).** The elapsed time (in seconds) spent driving at a speed less than 5 mph.

(4) **Distance.** The length of a link or the length of a run (feet for computerized method, miles for manual method).

(5) **Fuel Consumption Rate (FC).** The miles per U.S. gallon computed from a mathematical model that considers the length of the run, the total delay, and the effect of acceleration and deceleration (NCHRP Report 111, Running Costs of Motor Vehicles as Affected by Road Design and Traffic).

(6) **Running Speed (RS).** The test vehicle's average speed (in miles per hour) while the vehicle is in motion (does not include delay time) is calculated by the formula:

$$\boldsymbol{RS} = \frac{Distance}{TT\ -\ D}$$

(7) **Running Time (RT).** The elapsed time (in seconds), excluding delay, spent driving a distance.

(8) **Special Control Points (SCP).** Beginning and end points of the study route. They shall be located outside the influence of a signalized intersection or other highway feature which might cause delay. The vehicle must be at normal operating speed for the route when passing these points.

(9) **Stop (S).** The average number of times per link or run that the test vehicle's speed falls below 5 mph. After a stop, an additional stop will not be recorded unless the speed first exceeds 15 mph (Institute of Transportation Engineers, Manual of Traffic Engineering Studies).

(10) **Travel Speed (TS) or Average Speed (AS).** The test vehicle's average speed (in miles per hour) over a distance.

(11) **Travel Time (TT).** The total elapsed time (in seconds) spent driving a specified distance.

13.3 STUDY PROCEDURES

(1) Test vehicle, vehicle observation, and probe vehicle are among the most common methods to conduct a ***Travel Time and Delay Study***. The selection of the study method depends on the purpose of the study, roadway characteristics, length of segment, study period of interest, personnel, equipment, and resources available.

(2) To conduct a ***Travel Time and Delay Study***, one must first define the study area by selecting all control points before beginning the study. The time periods recommended for studies are A.M. and P.M. peak hours, as well as off peak hours in the direction of heaviest traffic movements (other times may be requested by the District Traffic Operations Engineer).

(3) These studies should be made during reasonably good weather so that unusual conditions do not influence the study. Additionally, as crashes or other unusual delays produce erroneous results, any runs made during such an occurrence should be terminated and another run conducted. These studies should be conducted during average or typical weekday traffic conditions.

13.3.1 Test vehicle

(1) When conducting a ***Travel Time and Delay Study*** using the test vehicle method, there are three techniques that can be used:

(a) Average-Car: the speed of travel is determined by the driver's judgment of the average speed of the traffic stream.

(b) Floating-Car: the driver floats with traffic by passing as many vehicles as pass the test car. The idea is to emulate an average driver for each section of roadway.

(c) Maximum-Car: the speed of travel is the posted speed limit unless impeded by safety considerations or actual traffic conditions.

(2) This method is most widely used on arterial streets with at-grade intersections, although, is applicable to any type of route. The selection of the technique is based on the purpose of the study and which technique best reflects the traffic stream being studied.

(3) The following attributes can be determined along the study route when using the test vehicle method: travel time; running time; type, location, duration, and cause of traffic delays; distance traveled; and space-mean speed (SMS).

(4) A minimum of 1 mile is recommended for the total route length to be studied. To determine the number of runs required for statistical significance, the engineer/analyst should follow the Sample Size Requirements method described below.

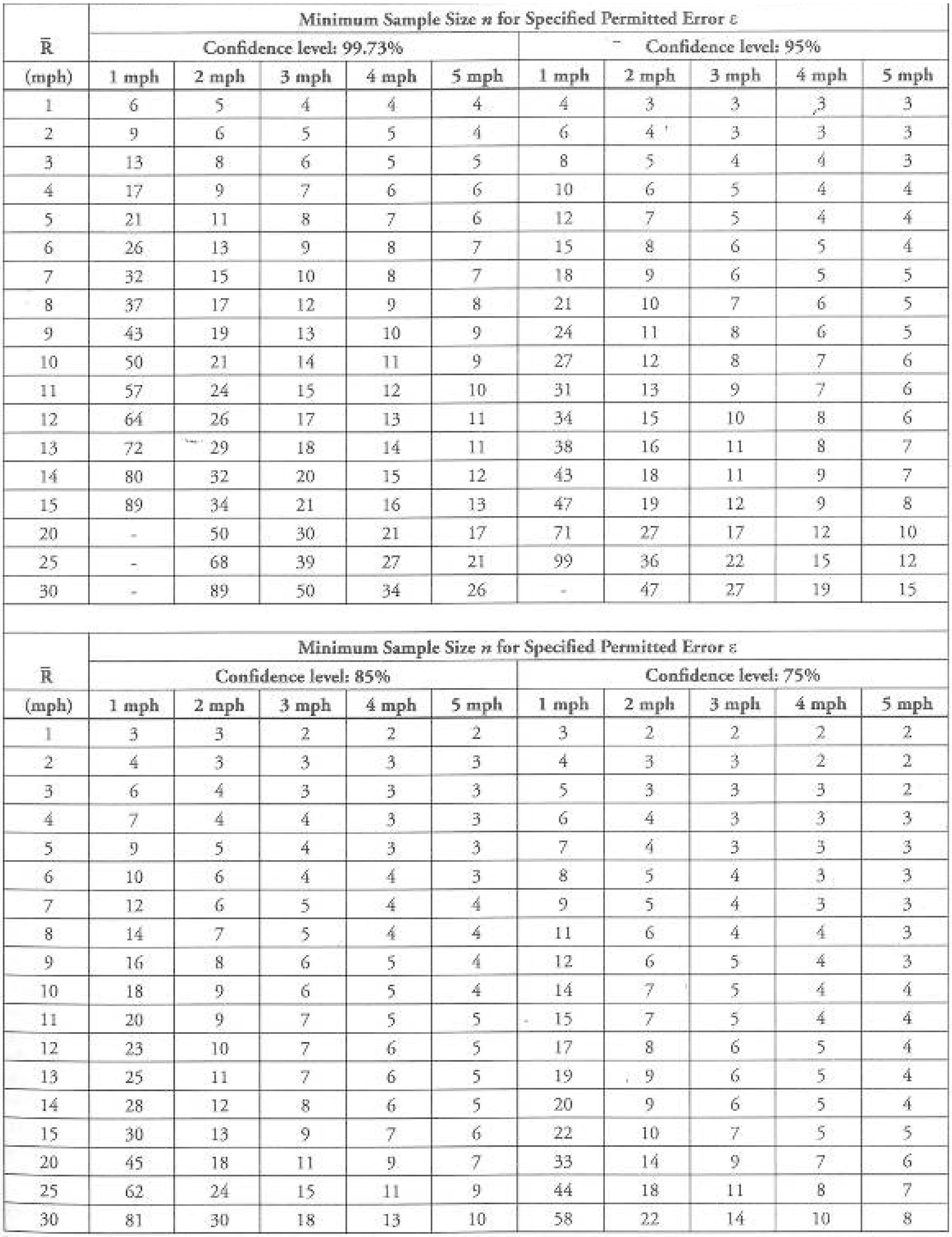
(5) Sample Size Requirements:

(a) Estimate the number of initial test runs by using ***Figure 13-1***. The confidence levels are provided to allow the analyst to select the level consistent with the study's needs.

(b) Conduct the runs.

(c) Calculate the difference between minimum and maximum speeds of the test runs $(\bar{R})$ upon completion of the initial test runs.

Figure 13-1. Approximate Minimum Sample-Size Requirements for Travel Time and Delay Studies



$\bar{R}$	Minimum Sample Size n for Specified Permitted Error ε									
	Confidence level: 99.73%					Confidence level: 95%				
(mph)	1 mph	2 mph	3 mph	4 mph	5 mph	1 mph	2 mph	3 mph	4 mph	5 mph
1	6	5	4	4	4	4	3	3	3	3
2	9	6	5	5	4	6	4	3	3	3
3	13	8	6	5	5	8	5	4	4	3
4	17	9	7	6	6	10	6	5	4	4
5	21	11	8	7	6	12	7	5	4	4
6	26	13	9	8	7	15	8	6	5	4
7	32	15	10	8	7	18	9	6	5	5
8	37	17	12	9	8	21	10	7	6	5
9	43	19	13	10	9	24	11	8	6	5
10	50	21	14	11	9	27	12	8	7	6
11	57	24	15	12	10	31	13	9	7	6
12	64	26	17	13	11	34	15	10	8	6
13	72	29	18	14	11	38	16	11	8	7
14	80	32	20	15	12	43	18	11	9	7
15	89	34	21	16	13	47	19	12	9	8
20	-	50	30	21	17	71	27	17	12	10
25	-	68	39	27	21	99	36	22	15	12
30	-	89	50	34	26	-	47	27	19	15

$\bar{R}$	Minimum Sample Size n for Specified Permitted Error ε									
	Confidence level: 85%					Confidence level: 75%				
(mph)	1 mph	2 mph	3 mph	4 mph	5 mph	1 mph	2 mph	3 mph	4 mph	5 mph
1	3	3	2	2	2	3	2	2	2	2
2	4	3	3	3	3	4	3	3	2	2
3	6	4	3	3	3	5	3	3	3	2
4	7	4	4	3	3	6	4	3	3	3
5	9	5	4	3	3	7	4	3	3	3
6	10	6	4	4	3	8	5	4	3	3
7	12	6	5	4	4	9	5	4	3	3
8	14	7	5	4	4	11	6	4	4	3
9	16	8	6	5	4	12	6	5	4	3
10	18	9	6	5	4	14	7	5	4	4
11	20	9	7	5	5	15	7	5	4	4
12	23	10	7	6	5	17	8	6	5	4
13	25	11	7	6	5	19	9	6	5	4
14	28	12	8	6	5	20	9	6	5	4
15	30	13	9	7	6	22	10	7	5	5
20	45	18	11	9	7	33	14	9	7	6
25	62	24	15	11	9	44	18	11	8	7
30	81	30	18	13	10	58	22	14	10	8

Source: ITE Manual of Transportation Engineering Studies, 2nd Edition, Exhibit 9-1

(d) Using the difference in minimum and maximum running speeds ($\overline{\boldsymbol{R}}$) and the desired permitted error (**ε**) from ***Table13-1***, again use ***Figure 13-1*** to determine the number of runs required. A sample size has to be determined for each direction of travel and for each set of traffic and/or environmental conditions of interest.

(e) Make additional runs if required.

Table13-1. Suggested Ranges of Permitted Errors in the Estimate of the Mean Travel Speed Related to Study Purpose

Study Purpose	Permitted Errors (ε)
Transportation planning and highway needs studies	± 3.0 to ± 5.0 mph
Traffic operation, trend analysis and economic evaluations	± 2.0 to ± 4.0 mph
Before-and-after studies*	± 1.0 to ± 3.0 mph

* ± 3.0 mph for studies predominately involving efficiency, ± 2.0 mph for studies predominately concerned with safety

Source: ITE Manual of Transportation Engineering Studies, 2nd Edition, Exhibit 9-1.

(6) The approximate minimum sample size is selected from ***Figure 13-1*** for the calculated difference in minimum and maximum running speeds and the desired permitted error. If the required sample size is greater than the number of runs made, then additional runs must be performed under similar traffic and environmental conditions to reach the minimum sample size. The observer also needs to be sensitive to changes in traffic and environmental conditions. The sample number of runs represents a single set of conditions. For example, speeds will probably vary during a peak period. Therefore, it may be necessary to have multiple observers to obtain an appropriate sample size for different portions of the peak period.

(7) ***Travel Time and Delay Studies*** shall be conducted using either the manual method or the computerized method which are explained in the following section.

13.3.1.1 Data Collection

(1) To conduct test vehicle runs, incident-free conditions along a representative lane are necessary. Use the second lane from median for roadways that have two-lanes in the direction of travel, and use the middle lane for roadways with three-lanes in the direction of travel. The run duration will determine the number of test vehicles needed and the desired run interval. For personnel and equipment requirements, refer to ***Table 13-2*** below.

Table 13-2. Equipment and personnel requirements for the Test Vehicle Method

Data Collection	Personnel	Equipment	Optional
Manual	Driver and observer-recorder	Test vehicle Two stopwatches Data collection forms Distance measuring Instrument Odometer	Voice recorder (notes of queues or other incidents) Video camera (photographs or videos of unusual events)
Automatic	Driver	Test vehicle GPS Field forms Approved computerized system (GPS)	

Automatic Data Collection

(1) The automatic method requires a test vehicle, driver, observer, GPS device, GPS connector to laptop, laptop computer, and approved data collection software. Computer software exists that automatically identifies the GPS location by time interval. This information can be automatically summarized to obtain vehicle location as a function of time. Key locations along a corridor can also be identified and recorded by tapping a computer key during the data collection process.

(2) Calibrate the GPS device before arriving at the field and ensure it is placed within the vehicle at a location receiving a clear satellite signal. The duties of the driver and observer (if required) should be reviewed prior initiation of the study. Ensure the laptop computer is connected to the GPS device. Thus, the computer program has constant input from the GPS device. All data should be recorded by the laptop computer for data analysis and report creation.

(3) Place the test vehicle upstream of the beginning point. Turn on the data recording equipment. Conduct a dry run and input the necessary information to the data recorder (beginning, ending and control points).

(4) From the data collected, an analysis program determines the time spent stopped and the speed at any time or distance. The program is thus able to calculate average speed, running speed, amount of delay, number of stops, distance and time between traffic signals, fuel consumption, and miles per gallon.

(5) These outputs must then be analyzed and engineering judgment should be applied to the numbers and graphs to determine if problem areas exist. If they do, then the appropriate corrective action must be determined.

Manual Data Collection

(1) The manual method requires a test vehicle, driver, observer, two stopwatches or one stopwatch with double sweep, odometer, scaled plans or maps, and two field forms.

(2) The ***Travel Time and Delay Study*** can be conducted manually by using the following procedures. There are two different areas of this study, the field form ***(Form No. 750-020-14)*** is used to collect field data and the field summary ***(Form No. 750-020-19)*** is used to perform the required calculations and analysis. The instructions noted below should be followed when completing this study.

(3) There are six runs per field form. The rows of run data are completed from left to right as the run is conducted. If more than six control points are identified, at least two more field forms must be used. The first control point on Sheet Two must be the same as the last control point on Sheet One, to allow space for the delays to be recorded. The number of sheets used for the data collection shall be specified under the General Information section.

(4) The **Travel Time and Delay Study Field Data (Form No. 750-020-14)** should be completed as follows and an example is provided in ***Figure 13-2*** and ***Figure 13-3***.

(a) Place the test vehicle upstream of the begin point. “Zero” both stopwatches and complete the header with the following information:

- *Roadway I.D* - Local name of roadway to be studied (include Section Number, U.S. Route Number, State Road Number).
- *Site* - Enter begin and end intersection names or physical feature (begin/end control points).
- *City* - City where study is being conducted.
- *County* - County where study is being conducted.
- *Milepost* - If the actual milepost is unknown, the milepost for the begin control point may be designated as 0.00.
- *Posted Speed* - Posted speed limit along study roadway.
- *Observer(s)* - Name(s) of personnel conducting study.
- *Agency or Company* - Name of the responsible agency or company of conducting study
- *Date* - Date of study.
- *Time Period* - Time period range for data collection.
- *Weather* - General description of weather conditions during study.
- *Control Point* - Describe each control point by intersection name or physical feature.

- *Location* - The cumulative distance of each control point from the begin control point.

(b) The duties of the driver and observer should be reviewed prior initiation of the study. Several rehearsal runs are recommended to measure the distances between checkpoints and to rehearse the procedure. The distance can be measured using a variety of tools, including plans, maps, online mapping services, vehicle-mounted distance measuring instruments (DMIs), GPS receivers, or vehicle odometers (less accuracy provided). The precision of the measurement should be within 1 percent or 2 percent of the actual length.

(c) In the first space in the row for Run 1, under *Time* (first control point that equals 0), write the clock time the run is started (e.g., 7:30 A.M.). This is the time the first stopwatch is started.

(d) As each control point is passed, the cumulative time (sec.) on the first stopwatch should be written in the *Cum. Time* box. The box below is for the individual lapse time between control points and can be calculated at the end of the runs.

(e) Between all control points, the delay should be noted in *Seconds* (time) and *Cause* (see *Delay Codes* on field form). A second stopwatch or the second sweep of a dual sweep stopwatch is used to collect the delay data. Delay should be recorded when the test vehicle is travelling at speeds less than 5 mph.

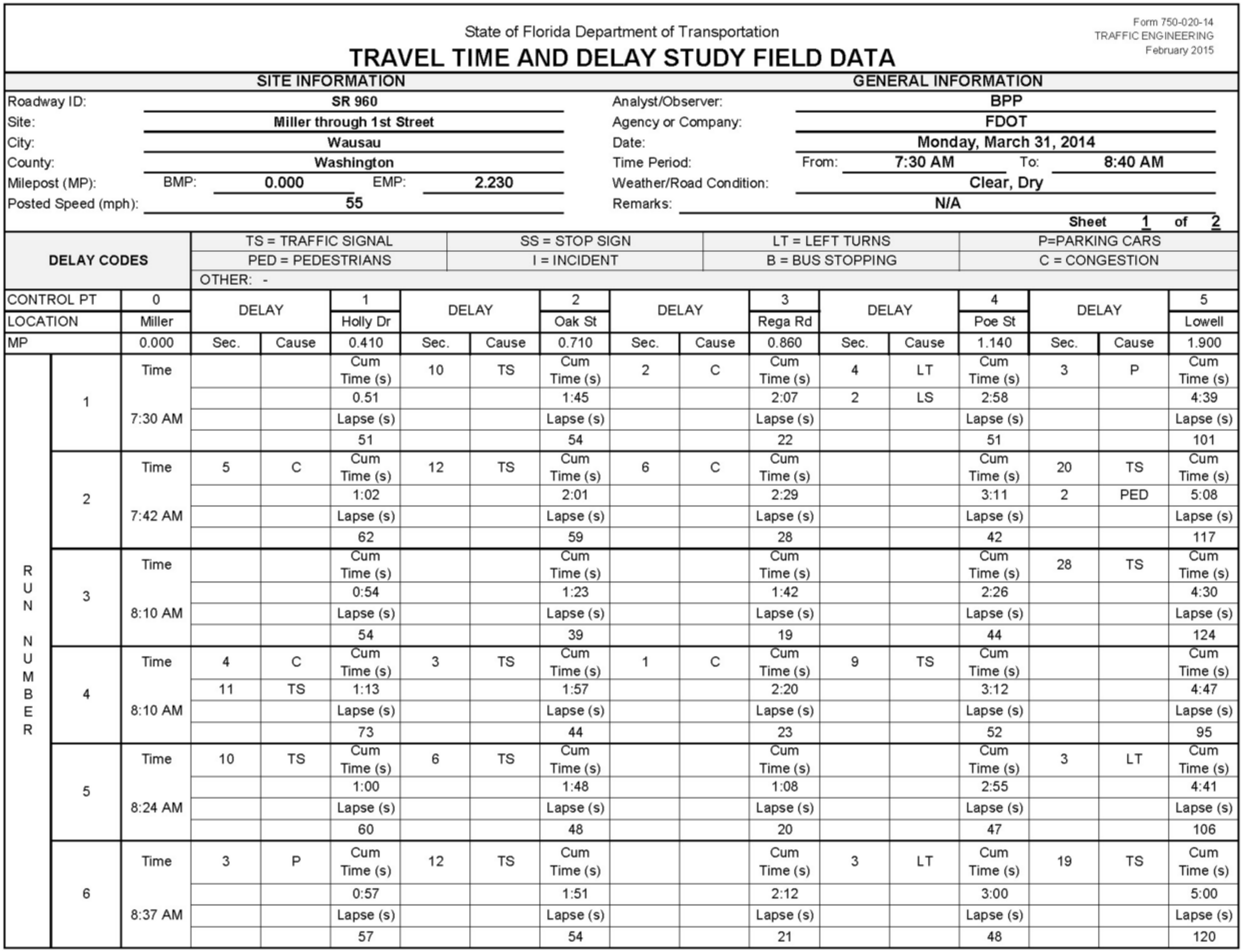
(f) Each run is made from the Begin Point to the End Point, noting the times from the first stopwatch and the delay between control points from the second stopwatch. A space for delay codes not listed in the *Delay Codes* section is provided at the bottom of the field form.

(g) The procedure is repeated to fulfill the required number of sample runs or until the study conditions change affecting the study. Stopwatches can be replaced with laptop computer software programs, which can reduce workload by capturing the locations and delays.

(5) The ***Travel Time and Delay Study Field Summary (Form No. 750-020-19)*** should be completed as follows. ***Figure 13-4*** provides an example of this form completed.

- *Miles (M)* - Distance in miles from one control point to the next.
- *Travel Time (TT)* -Time in seconds from one control point to the next.
- *Delay (D)* - The time in seconds of delay experienced from one control point to the next.
- *Totals* - The miles, travel time, and delay are summed vertically and written in the *Totals* area.
- *Running Time (RT)* - Total travel time minus total delay for each run.

Figure 13-2. Travel Time and Delay Study Field Data Form - Sheet 1
(Form No. 750-020-14)



Form 750-020-14
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

TRAVEL TIME AND DELAY STUDY FIELD DATA

SITE INFORMATION

Roadway ID: **SR 960**
Site: **Miller through 1st Street**
City: **Wausau**
County: **Washington**
Milepost (MP): BMP: **0.000** EMP: **2.230**
Posted Speed (mph): **55**

GENERAL INFORMATION

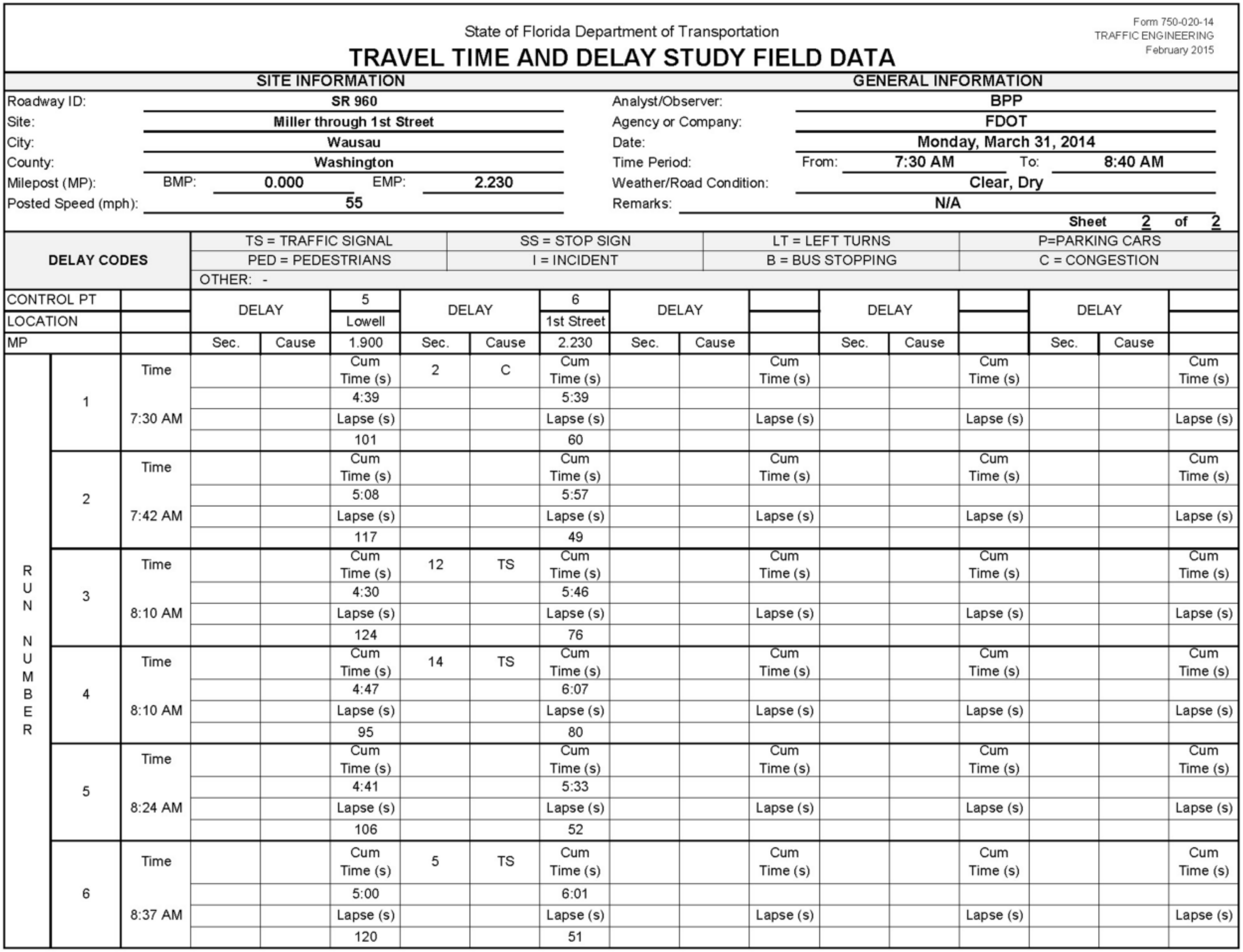
Analyst/Observer: **BPP**
Agency or Company: **FDOT**
Date: **Monday, March 31, 2014**
Time Period: From: **7:30 AM** To: **8:40 AM**
Weather/Road Condition: **Clear, Dry**
Remarks: **N/A**

Sheet 1 of 2

DELAY CODES	TS = TRAFFIC SIGNAL	SS = STOP SIGN	LT = LEFT TURNS	P=PARKING CARS
	PED = PEDESTRIANS	I = INCIDENT	B = BUS STOPPING	C = CONGESTION
	OTHER: -			

CONTROL PT		0	DELAY		1	DELAY		2	DELAY		3	DELAY		4	DELAY		5
LOCATION		Miller			Holly Dr			Oak St			Rega Rd			Poe St			Lowell
MP		0.000	Sec.	Cause	0.410	Sec.	Cause	0.710	Sec.	Cause	0.860	Sec.	Cause	1.140	Sec.	Cause	1.900
RUN NUMBER	1	Time			Cum Time (s)	10	TS	Cum Time (s)	2	C	Cum Time (s)	4	LT	Cum Time (s)	3	P	Cum Time (s)
					0.51			1:45			2:07	2	LS	2:58			4:39
		7:30 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					51			54			22			51			101
	2	Time	5	C	Cum Time (s)	12	TS	Cum Time (s)	6	C	Cum Time (s)			Cum Time (s)	20	TS	Cum Time (s)
					1:02			2:01			2:29			3:11	2	PED	5:08
		7:42 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					62			59			28			42			117
	3	Time			Cum Time (s)			Cum Time (s)			Cum Time (s)			Cum Time (s)	28	TS	Cum Time (s)
					0:54			1:23			1:42			2:26			4:30
		8:10 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					54			39			19			44			124
	4	Time	4	C	Cum Time (s)	3	TS	Cum Time (s)	1	C	Cum Time (s)	9	TS	Cum Time (s)			Cum Time (s)
			11	TS	1:13			1:57			2:20			3:12			4:47
		8:10 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					73			44			23			52			95
	5	Time	10	TS	Cum Time (s)	6	TS	Cum Time (s)			Cum Time (s)			Cum Time (s)	3	LT	Cum Time (s)
					1:00			1:48			1:08			2:55			4:41
		8:24 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					60			48			20			47			106
	6	Time	3	P	Cum Time (s)	12	TS	Cum Time (s)			Cum Time (s)	3	LT	Cum Time (s)	19	TS	Cum Time (s)
					0:57			1:51			2:12			3:00			5:00
		8:37 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					57			54			21			48			120

Figure 13-3. Travel Time and Delay Study Field Data Form - Sheet 2
(Form No. 750-020-14)



Form 750-020-14
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

TRAVEL TIME AND DELAY STUDY FIELD DATA

SITE INFORMATION

Roadway ID: **SR 960**
Site: **Miller through 1st Street**
City: **Wausau**
County: **Washington**
Milepost (MP): BMP: **0.000** EMP: **2.230**
Posted Speed (mph): **55**

GENERAL INFORMATION

Analyst/Observer: **BPP**
Agency or Company: **FDOT**
Date: **Monday, March 31, 2014**
Time Period: From: **7:30 AM** To: **8:40 AM**
Weather/Road Condition: **Clear, Dry**
Remarks: **N/A**

Sheet 2 of 2

DELAY CODES				
	TS = TRAFFIC SIGNAL	SS = STOP SIGN	LT = LEFT TURNS	P=PARKING CARS
	PED = PEDESTRIANS	I = INCIDENT	B = BUS STOPPING	C = CONGESTION
	OTHER: -			

CONTROL PT			DELAY		5	DELAY		6	DELAY			DELAY			DELAY		
LOCATION					Lowell			1st Street									
MP			Sec.	Cause	1.900	Sec.	Cause	2.230	Sec.	Cause		Sec.	Cause		Sec.	Cause	
RUN NUMBER	1	Time			Cum Time (s)	2	C	Cum Time (s)			Cum Time (s)			Cum Time (s)			Cum Time (s)
					4:39			5:39									
		7:30 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					101			60									
	2	Time			Cum Time (s)			Cum Time (s)			Cum Time (s)			Cum Time (s)			Cum Time (s)
					5:08			5:57									
		7:42 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					117			49									
	3	Time			Cum Time (s)	12	TS	Cum Time (s)			Cum Time (s)			Cum Time (s)			Cum Time (s)
					4:30			5:46									
		8:10 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					124			76									
	4	Time			Cum Time (s)	14	TS	Cum Time (s)			Cum Time (s)			Cum Time (s)			Cum Time (s)
					4:47			6:07									
		8:10 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					95			80									
	5	Time			Cum Time (s)			Cum Time (s)			Cum Time (s)			Cum Time (s)			Cum Time (s)
					4:41			5:33									
		8:24 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					106			52									
	6	Time			Cum Time (s)	5	TS	Cum Time (s)			Cum Time (s)			Cum Time (s)			Cum Time (s)
					5:00			6:01									
		8:37 AM			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)			Lapse (s)
					120			51									

13.3.1.2 Data Reduction and Analysis

(1) For travel-time data analysis purposes, the time and distance measures are converted to space-mean speed.

(a) Calculated Control Point to Control Point Averages (Right Side of Summary Sheet)

$$Average\ Travel\ Time\ (ATT) = \frac{\text{Sum of TT}}{\text{Total No. of Runs}}$$

$$Average\ Travel\ Speed\ (ATS) = \frac{Miles\ x\ 3600\ seconds\ per\ hour}{ATT}$$

$$Average\ Delay\ (AD) = \frac{Sum\ of\ Delay}{Total\ No.of\ Runs}$$

$$Average\ Running\ Time\ (ART) = ATT - AD$$

$$Average\ Running\ Speed\ (ARS) = \frac{Miles\ x\ 3600\ seconds\ per\ hour}{ART}$$

(b) Calculated Route Averages (Bottom of Summary Sheet)

$$Total\ Trip\ Length\ (TTL) = Total\ distance\ between\ all\ control\ points\ (miles)$$

$$Travel\ Time\ Total\ (TTT) = Sum\ of\ travel\ times\ between\ control\ points\ for\ an\ individual\ run$$

$$Average\ Total\ Travel\ Time\ (ATTT) = \frac{Sum\ of\ all\ TTT's}{Total\ No.of\ Runs} = Sum\ of\ ATT's$$

$$Average\ Total\ Travel\ Speed\ (ATTS) = \frac{TTL\ x\ 3600\ seconds\ per\ hour}{ATTT}$$

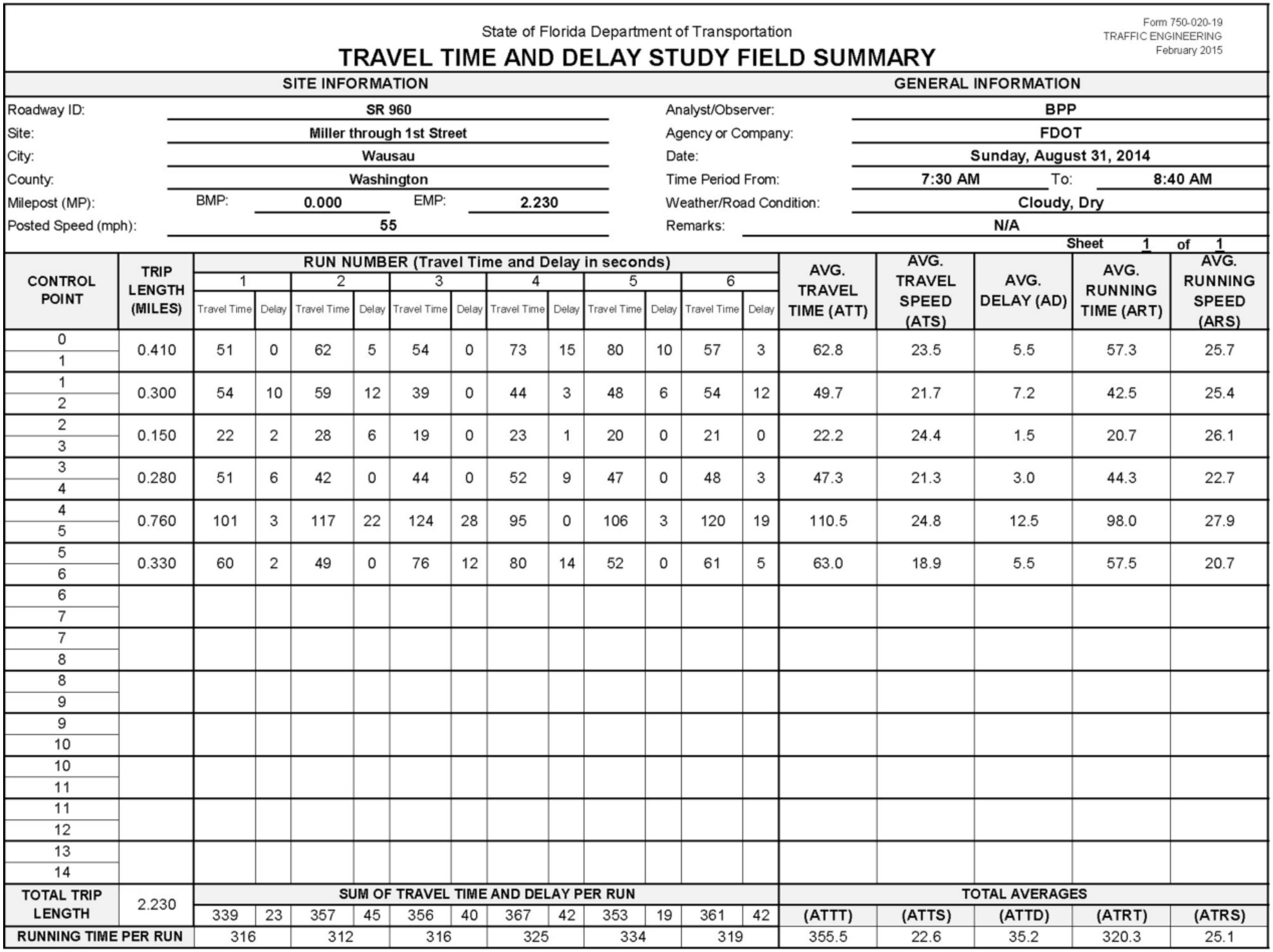
$$Average\ Total\ Trip\ Delay\ (ATTD) = \frac{Sum\ of\ Delay\ Totals}{Total\ No.of\ Runs} = Sum\ of\ AD's$$

$$Average\ Total\ Running\ Time\ (ATRT) = \frac{Sum\ of\ RT's}{Total\ No.of\ Runs} = Sum\ ART's$$

$$Average\ Total\ Running\ Speed\ (ATRS) = \frac{TTL\ x\ 3600\ seconds\ per\ hour}{ATRT}$$

(2) Once this data is collected, the results must be analyzed to determine the appropriate corrective measures.

Figure 13-4. Travel Time and Delay Study Field Summary Form (Form No. 750-020-19)



State of Florida Department of Transportation

Form 750-020-19
TRAFFIC ENGINEERING
February 2015

TRAVEL TIME AND DELAY STUDY FIELD SUMMARY

SITE INFORMATION

Roadway ID: **SR 960**
Site: **Miller through 1st Street**
City: **Wausau**
County: **Washington**
Milepost (MP): BMP: **0.000** EMP: **2.230**
Posted Speed (mph): **55**

GENERAL INFORMATION

Analyst/Observer: **BPP**
Agency or Company: **FDOT**
Date: **Sunday, August 31, 2014**
Time Period From: **7:30 AM** To: **8:40 AM**
Weather/Road Condition: **Cloudy, Dry**
Remarks: **N/A**

Sheet 1 **of** 1

CONTROL POINT	TRIP LENGTH (MILES)	RUN NUMBER (Travel Time and Delay in seconds)												AVG. TRAVEL TIME (ATT)	AVG. TRAVEL SPEED (ATS)	AVG. DELAY (AD)	AVG. RUNNING TIME (ART)	AVG. RUNNING SPEED (ARS)
		1		2		3		4		5		6						
		Travel Time	Delay	Travel Time	Delay	Travel Time	Delay	Travel Time	Delay	Travel Time	Delay	Travel Time	Delay					
0 1	0.410	51	0	62	5	54	0	73	15	80	10	57	3	62.8	23.5	5.5	57.3	25.7
1 2	0.300	54	10	59	12	39	0	44	3	48	6	54	12	49.7	21.7	7.2	42.5	25.4
2 3	0.150	22	2	28	6	19	0	23	1	20	0	21	0	22.2	24.4	1.5	20.7	26.1
3 4	0.280	51	6	42	0	44	0	52	9	47	0	48	3	47.3	21.3	3.0	44.3	22.7
4 5	0.760	101	3	117	22	124	28	95	0	106	3	120	19	110.5	24.8	12.5	98.0	27.9
5 6	0.330	60	2	49	0	76	12	80	14	52	0	61	5	63.0	18.9	5.5	57.5	20.7
6 7																		
7 8																		
8 9																		
9 10																		
10 11																		
11 12																		
13 14																		
TOTAL TRIP LENGTH	2.230	SUM OF TRAVEL TIME AND DELAY PER RUN												TOTAL AVERAGES				
		339	23	357	45	356	40	367	42	353	19	361	42	(ATTT)	(ATTS)	(ATTD)	(ATRT)	(ATRS)
RUNNING TIME PER RUN		316		312		316		325		334		319		355.5	22.6	35.2	320.3	25.1

13.3.2 Vehicle Observation

(1) This method employs technologies having the capabilities to select the vehicles to be observed, and non-intrusively study them. The following methods are some examples and are explained in greater detail in **Chapter 9, Section 3.1 of the ITE *Manual of Transportation Engineering Studies, 2nd Edition*.**

- License Plate Method
- Interview Method
- Wireless Technology Method
- Cellular Telephone Observation Method
- Extrapolation Method
-

13.3.3 Probe Vehicle

(1) Some technologies noted below are explained in greater detail in **Chapter 9, Section 3.1 of the ITE *Manual of Transportation Engineering Studies, 2nd Edition*.**

- Signpost-based Method
- AVI Transponders
- Ground-based Radio Navigation
- Cellular Telephone Probe Method
-

13.4 FORMS ACCESS

(1) Reproducible copies of the ***Travel Time and Delay Study Field Data (Form No. 750-020-14)*** and the ***Travel Time and Delay Study Field Summary (Form No. 750-020-19)*** are available in the Department's Forms Library.

CHAPTER 14 ROADWAY LIGHTING JUSTIFICATION PROCEDURE

14.1 PURPOSE

(1) The procedures for roadway lighting justification are based on FHWA guidelines contained in the ***August 2012 FHWA Lighting Handbook***. In Florida, the predictive methodologies contained in Part C of the ***Highway Safety Manual*** (HSM) are given priority and should be used for the lighting justification crash cost analysis where applicable. The safety impact of existing or proposed lighting projects can be quantified with predictive equations (safety performance functions – SPFs) available in the HSM. These formulas allow for the prediction of crash frequency for a given facility with and without lighting. The crash benefit of lighting installation is then converted to dollars and a benefit/cost (B/C) ratio and/or net present value (NPV) is computed using the cost of the lighting project.

(2) The procedure allows lighting projects to be ranked according to priority for construction. Those with a higher NPV have more value in benefits to the public than those with a lower NPV. For explanation of the NPV analysis see ***HSM Section 7.6.1.1***. The procedure compares benefits to the public from crash reduction to the project cost for installation, maintenance, and operation. Analysis of existing lighting systems to determine if they should be retained is also possible.

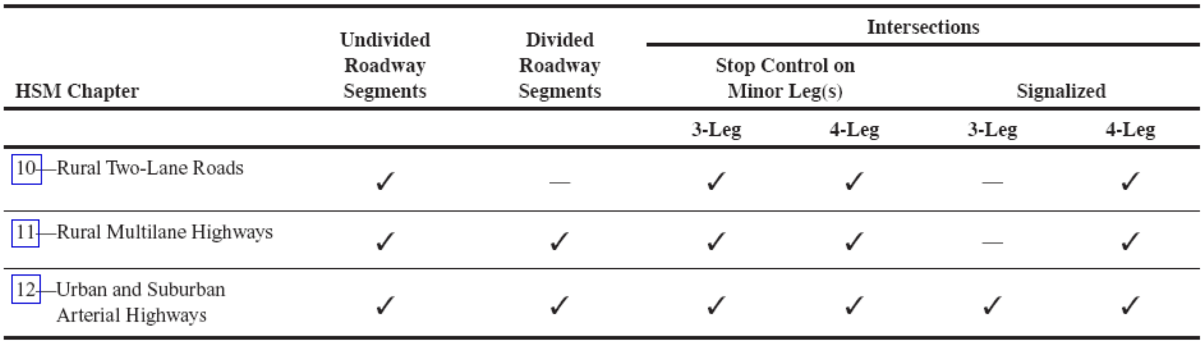
14.2 STEP 1: LIGHTING JUSTIFICATION - FHWA LIGHTING HANDBOOK

(1) The procedures outlined in Section 4 of the ***August 2012 FHWA Lighting Handbook*** should be followed to determine roadway lighting justification. For collectors, major arterials, and local streets, the warrant system is based on Transportation Association of Canada (TAC) Guide for the Design of Roadway Lighting. For freeways, bridges, and interchanges, the American Association of State Highway and Transportation Officials (AASHTO) Roadway Lighting Design Guide Warranting System is used. Per ***FDOT Plans Preparation Manual Volume I, Section 7.3.4***, all interchanges on the interstate highway system shall be lighted. A warrant analysis may be required for federal funding, but will not be used as the determining factor for the installation of lighting at interstate interchanges. Consistent with the ***Florida Intersection Design Guide***, lighting is required at all roundabouts. Further, signalized intersections having marked crosswalks with pedestrian signals shall be lighted.

(2) It should be noted the conditions described in the ***August 2012 FHWA Lighting Handbook*** are roadway conditions under which lighting may be considered warranted and do not necessarily describe the sites where lighting is specifically justified. Designers should first address ***TAC*** and ***AASHTO*** warrants; if these conditions are met, then a NPV analysis should be made. The initial lighting justification analysis is based upon geometric factors. The spreadsheet has been modified to English Units and is provided in ***Lighting Geometric and Operational Factors*** **(*Form No. 750-020-20).*** A completed example of the form is shown in ***Figure 14-1***.

(3) The procedure to justify a lighting project consists of quantifying the safety benefits of the lighting project versus the cost of construction, maintenance, and operation of the lighting project. The safety benefits should be quantified using HSM predictive method procedures if applicable. Currently, crash reduction due to lighting can be predicted for rural two-lane roadways, rural multi-lane roadways up to four through lanes, and urban/suburban arterials up to four through-lanes. The urban/suburban arterials analysis can also be conducted for five lane roadways with a two-way left turn lane. Crash reduction due to lighting at intersections within these roadway types can also be predicted. A summary of applicable facilities is shown in Table 1. The Predictive Method procedures can be applied to existing or proposed roadway facilities. For facilities not listed above and in Table 1, the crash modification factors (CMFs) shown in Part D of the HSM (Section 13.13) should be applied. Should the FHWA CMF Clearinghouse be used, only CMFs having four or five stars are acceptable.

Table 14-1. Facility Types and Site Types Included in the HSM Predictive Method

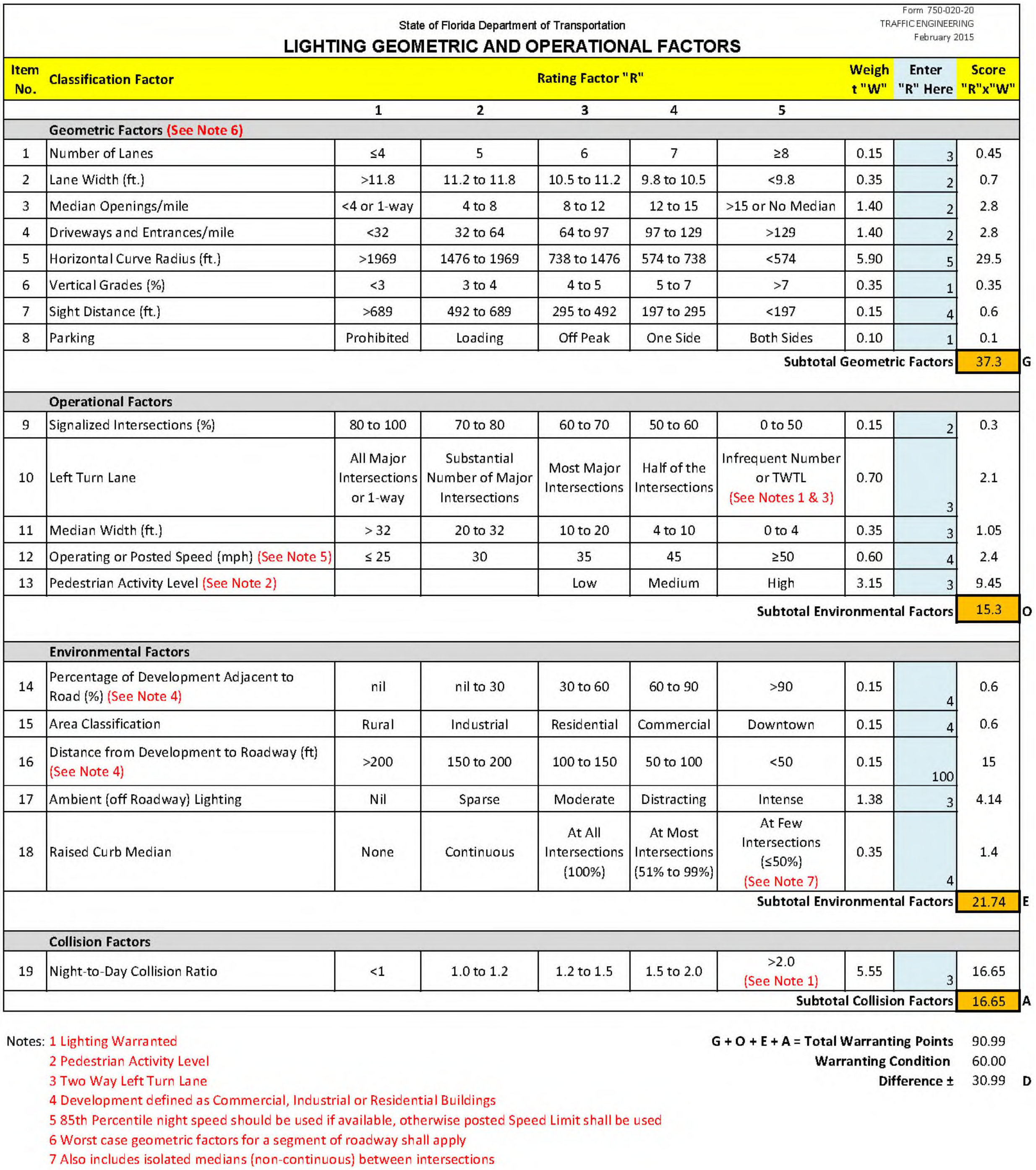


HSM Chapter	Undivided Roadway Segments	Divided Roadway Segments	Intersections			
			Stop Control on Minor Leg(s)		Signalized	
			3-Leg	4-Leg	3-Leg	4-Leg
10—Rural Two-Lane Roads	✓	—	✓	✓	—	✓
11—Rural Multilane Highways	✓	✓	✓	✓	—	✓
12—Urban and Suburban Arterial Highways	✓	✓	✓	✓	✓	✓

Source: Highway Safety Manual, 2010, Table 3-2

(4) The difference in crash frequency can then be converted to dollars using FDOT crash costs provided in ***Chapter 23 of the Plans Preparation Manual (PPM)***. Data needs and additional details for applying the HSM Predictive Method are provided in ***Chapter 5 of the MUTS*** for surface streets. After reviewing Chapter 5, if the HSM methodologies are not applicable to the facility type being analyzed, then ***Section 14.3.2*** of this chapter should be considered.

Figure 14-1. Lighting Geometric and Operational Factors Form No. 750-020-20



Form 750-020-20
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

LIGHTING GEOMETRIC AND OPERATIONAL FACTORS

Item No.	Classification Factor	Rating Factor "R"					Weigh t "W"	Enter "R" Here	Score "R"x"W"	
		1	2	3	4	5				
	Geometric Factors (See Note 6)									
1	Number of Lanes	≤4	5	6	7	≥8	0.15	3	0.45	
2	Lane Width (ft.)	>11.8	11.2 to 11.8	10.5 to 11.2	9.8 to 10.5	<9.8	0.35	2	0.7	
3	Median Openings/mile	<4 or 1-way	4 to 8	8 to 12	12 to 15	>15 or No Median	1.40	2	2.8	
4	Driveways and Entrances/mile	<32	32 to 64	64 to 97	97 to 129	>129	1.40	2	2.8	
5	Horizontal Curve Radius (ft.)	>1969	1476 to 1969	738 to 1476	574 to 738	<574	5.90	5	29.5	
6	Vertical Grades (%)	<3	3 to 4	4 to 5	5 to 7	>7	0.35	1	0.35	
7	Sight Distance (ft.)	>689	492 to 689	295 to 492	197 to 295	<197	0.15	4	0.6	
8	Parking	Prohibited	Loading	Off Peak	One Side	Both Sides	0.10	1	0.1	
								Subtotal Geometric Factors	37.3	G
	Operational Factors									
9	Signalized Intersections (%)	80 to 100	70 to 80	60 to 70	50 to 60	0 to 50	0.15	2	0.3	
10	Left Turn Lane	All Major Intersections or 1-way	Substantial Number of Major Intersections	Most Major Intersections	Half of the Intersections	Infrequent Number or TWTL (See Notes 1 & 3)	0.70	3	2.1	
11	Median Width (ft.)	> 32	20 to 32	10 to 20	4 to 10	0 to 4	0.35	3	1.05	
12	Operating or Posted Speed (mph) (See Note 5)	≤ 25	30	35	45	≥50	0.60	4	2.4	
13	Pedestrian Activity Level (See Note 2)			Low	Medium	High	3.15	3	9.45	
								Subtotal Environmental Factors	15.3	O
	Environmental Factors									
14	Percentage of Development Adjacent to Road (%) (See Note 4)	nil	nil to 30	30 to 60	60 to 90	>90	0.15	4	0.6	
15	Area Classification	Rural	Industrial	Residential	Commercial	Downtown	0.15	4	0.6	
16	Distance from Development to Roadway (ft) (See Note 4)	>200	150 to 200	100 to 150	50 to 100	<50	0.15	100	15	
17	Ambient (off Roadway) Lighting	Nil	Sparse	Moderate	Distracting	Intense	1.38	3	4.14	
18	Raised Curb Median	None	Continuous	At All Intersections (100%)	At Most Intersections (51% to 99%)	At Few Intersections (≤50%) (See Note 7)	0.35	4	1.4	
								Subtotal Environmental Factors	21.74	E
	Collision Factors									
19	Night-to-Day Collision Ratio	<1	1.0 to 1.2	1.2 to 1.5	1.5 to 2.0	>2.0 (See Note 1)	5.55	3	16.65	
								Subtotal Collision Factors	16.65	A

Notes: 1 Lighting Warranted
2 Pedestrian Activity Level
3 Two Way Left Turn Lane
4 Development defined as Commercial, Industrial or Residential Buildings
5 85th Percentile night speed should be used if available, otherwise posted Speed Limit shall be used
6 Worst case geometric factors for a segment of roadway shall apply
7 Also includes isolated medians (non-continuous) between intersections

G + O + E + A = Total Warranting Points 90.99
Warranting Condition 60.00
Difference ± 30.99 D

14.3 STEP 2: NET PRESENT VALUE ANALYSIS

(1) The purpose of this step in the roadway lighting justification procedure is to determine if the project is justified based on its NPV. If the total crash cost is equal to or greater than cost of construction, maintenance, and operation of the lighting project, then lighting is justified for high crash locations (HCL) as identified by the State Safety Office's annual HCL list. This list may be obtained directly from the State Safety Office or downloaded from the FDOT CAR system. At other locations, the NPV should be used to rank projects according to their value in benefit to the public. Those with a higher NPV offer more value than those with a lower NPV when the cost of construction, maintenance, and operation are comparable. The procedure can be used to analyze either an existing or proposed lighting system. There are two primary differences between the two analyses.

(2) The first difference is that, for an existing lighting system, the HSM Predictive Method can be used to determine crash impacts of the system without lighting. For a proposed system, the night unlighted crash rate is based on actual crash data collected at the site. In cases when the HSM methodology is not applicable or reliable crash data are not available, a minimum unlighted crash rate of 3.0 crashes per million vehicle miles has been determined to be a reasonable "default" value for conditions in Florida.

(3) The second difference between the analyses is that if an existing lighting system is being evaluated to determine if it should continue to operate, the cost of the installation is not considered because it is a sunk cost. This recognizes that the initial investment in lighting hardware has already been made.

14.3.1 Net Present Value Computations using the HSM Methodology

(1) The NPV computations when the HSM methodology is applicable can be computed using the procedure outlined in this section. The use of a spreadsheet is required. Example spreadsheets can be downloaded from the MUTS website for the application of the HSM Methodology NPV calculations. NPV computations can be conducted using a six step process, outlined as follows:

- Step 1: Identify or compute crash frequencies for NO LIGHTING CONDITIONS
- Step 2: Quantify monetary cost of crashes for NO LIGHTING CONDITIONS
- Step 3: Identify or compute crash frequencies for LIGHTED CONDITIONS

- Step 4: Quantify monetary cost of crashes for LIGHTED CONDITIONS
- Step 5: Compute difference: BENEFIT = Monetary cost of crashes for NO LIGHTING CONDITIONS – Monetary cost of crashes for LIGHTED CONDITIONS
- Step 6: Next steps: Compute NPV

(2) It should be noted that the crashes predicted using HSM methodologies are not nighttime-only crashes, but rather a compilation of all day and night crashes. However when modifying the lighting parameter in the methodology (unlighted to lighted), the methodology automatically adjusts for the impact of lighting to nighttime crashes only.

(3) A sample illustration of the application of the six-step process is presented in the following section. Note that the sample has been developed using only two years of analysis. In reality, the calculations shown below would be conducted for the each year in the design life of the project. The analysis steps are outlined as follows:

(a) **Step 1:** Crashes are predicted for the Roadway with NO LIGHTING using HSM methodologies as outlined in Chapter 5 of the MUTS. Crashes are then distributed by severity using the default severity distributions found in the HSM. The table below illustrates an $N_{predicted}$ value being the predicted number of crashes computed using the HSM Predictive Method. This value is then distributed by severity per the KABCO scale using HSM default severity distribution values.

Year	AADT	TOTAL	K	A	B	C	O
		$N_{predicted}$ (crashes/year)	Fatal	Inc. Injury	Non Inc. Injury	Pos. Injury	PDO
2012	17300	3.15	0.041	0.170	0.343	0.457	2.139
2013	17676	3.22	0.042	0.174	0.351	0.467	2.186

Repeat for all years being analyzed, the number of years analyzed will depend on the design life of the lighting project.

Computed using HSM Default Distributions

(b) **Step 2:** Quantify the monetary cost of crashes for the NO LIGHTING condition.

(c) **Step 2A:** Compute the annual costs using FDOT costs contained in Chapter 23 of the Plans Preparation Manual (PPM) and shown in the table below. The following tables below illustrate the computation for two years of data, 2012 and 2013. This process is repeated for each year in the design life of the project.

Crash Severity	Comprehensive Crash Cost
Fatal (K)	$10,100,000
Severe Injury (A)	$818,636
Moderate Injury (B)	$163,254
Minor Injury (C)	$99,645
Property Damage Only (O)	$6,500

Year		K	A	B	C	O	TOTAL
		Fatal	Inc. Injury	Non Inc. Injury	Pos. Injury	PDO	$N_{predicted}$ (crashes/ year)
2012	Crashes	0.041	0.170	0.343	0.457	2.139	3.15
	Cost per Crash Type	$10,100,000	$818,636	$163,254	$99,645	$6,500	
	Total Cost per Crash Type	$414,100	$139,168	$55,996	$45,538	$13,904	
	Total Cost for 2012	**$668,706**					

Year		**K**	**A**	**B**	**C**	**O**	**TOTAL**
		Fatal	**Inc. Injury**	**Non Inc. Injury**	**Pos. Injury**	**PDO**	**$N_{predicted}$ (crashes/ year)**
2013	Crashes	0.042	0.174	0.351	0.467	2.186	3.22
	Cost per Crash Type	$10,100,000	$818,636	$163,254	$99,645	$6,500	
	Total Cost per Crash Type	$424,200	$142,443	$57,302	$46,534	$14,209	
	Total Cost for 2013	**$684,688**					

Repeat for all years being analyzed

(d) **Step 2B:** Compute the present worth for each year using the equation shown below. This process is repeated for each year in the design life of the project. Add up all the present worth of costs. The example below illustrates a computation for year 2013 assuming the present year is 2012. The Discount (interest) rate to be utilized in benefit/cost analysis is 4% per PPM Section 23.5 paragraph y.

$$Present\ worth = \frac{Final\ Value}{(1+0.04)^{years}}$$

$$For\ 2013\ Present\ Worth = \frac{\$\ 684{,}688}{(1+0.04)^{2}} = \$\ 633{,}033$$

Year	**AADT**	**$N_{predicted}$ (crashes/year)**	**Total Cost**	**Present Worth of Cost**
2012	17300	3.15	$668,706	$668,706
2013	17676	3.22	$684,688	$633,033
Total Present Worth of Cost				$1,301,738

(e) **Step 3 and 4:** Repeat the entire process for the LIGHTED conditions.

(f) **Step 5:** Compute the difference (Savings) between the NO LIGHTING and LIGHTED conditions. Assuming that the entire process for LIGHTED conditions yields a Total Present Worth of Cost of $702,000, the table below illustrates the monetary savings the lighted project yields.

Scenario	Present Worth
NO-BUILD	$1,301,738
BUILD	$702,000
Savings for LIGHTED conditions	$599,738

(g) **Step 6:** Compare the present value of the lighting project costs (i.e., construction, maintenance, and operation) to the monetary savings. Note that to determine if lighting should be maintained for existing lighting infrastructure where an evaluation is being conducted, the construction cost is considered a sunk cost and should not be included in the computations. The equation presented in Step 2 can be used to determine the present value of annual costs. Assuming for this example that the total project cost (i.e., construction, maintenance, and operation) is $250,000, yielding a NPV of $349,738.

(4) Examples of Present Worth Analysis for ***Rural-Two Lane Road (Form 750-020-21-a)***, ***Present Worth Analysis for Rural-Multilane Road (Form 750-020-21-b)***, and ***Present Worth Analysis for Urban/Suburban Arterial (Form 750-020-21-c)*** completed spreadsheets providing crash cost calculations are shown in ***Figure 14-2***, ***Figure 14-3*** and ***Figure 14-4***, respectively.

Figure 14-2. Rural Two-Lane Road Example (Form No. 750-020-21-a)

State of Florida Department of Transportation

Present Worth Analysis
Rural Two Lane Road
No Build Alternative

General Information

Analyst: JFR
Date: 9/1/2014
Agency or Company: FDOT

Site Information

Location ID: N/A
County: Miami-Dade
City: Miami
M.P. - M.P.:

Manual Input from Analysis

Growth Rate = 1.0%
Opening Year AADT = 12,000
Segment Length = 0.11
Opening Year = 2012
Rate of Return = 4.0%
Segment = Segment1

Default Distribution for Crash Severity Level (2008-2012 Florida HSM Crash Distribution)

Fatality = 3.7%
Incapacitating = 14.2%
Non-Incapacitating = 20.6%
Possible Injury = 20.6%
Property Damage Only = 40.9%
100.0%

	Year	AADT	Annual Number of Crashes						Annual Cost						
			Site Specific ($N_{predicted-rs}$)	Fatality	Incap.	Non-Inc.	Possible Injury	PDO	Fatality	Incap.	Non-Inc.	Possible Injury	PDO	Total Cost*	Present Value
0	2012	12,000	0.5	0.018	0.070	0.102	0.102	0.202	$184,624	$57,431	$16,615	$10,141	$1,313	$268,810	$268,810
1	2013	12,120	0.5	0.018	0.071	0.102	0.102	0.203	$185,711	$57,769	$16,713	$10,201	$1,321	$270,394	$259,994
2	2014	12,241	0.5	0.018	0.071	0.103	0.103	0.204	$186,801	$58,108	$16,811	$10,261	$1,329	$271,980	$251,461
3	2015	12,364	0.5	0.019	0.071	0.104	0.104	0.206	$187,892	$58,447	$16,909	$10,321	$1,337	$273,569	$243,202
4	2016	12,487	0.5	0.019	0.072	0.104	0.104	0.207	$188,986	$58,787	$17,007	$10,381	$1,344	$275,161	$235,209
5	2017	12,612	0.5	0.019	0.072	0.105	0.105	0.208	$190,081	$59,128	$17,106	$10,441	$1,352	$276,756	$227,473
6	2018	12,738	0.5	0.019	0.073	0.105	0.105	0.209	$191,178	$59,470	$17,205	$10,501	$1,360	$278,354	$219,987
7	2019	12,866	0.5	0.019	0.073	0.106	0.106	0.210	$192,277	$59,811	$17,304	$10,562	$1,368	$279,954	$212,742
8	2020	12,994	0.5	0.019	0.073	0.107	0.107	0.212	$193,378	$60,154	$17,403	$10,622	$1,376	$281,556	$205,731
9	2021	13,124	0.5	0.019	0.074	0.107	0.107	0.213	$194,480	$60,497	$17,502	$10,683	$1,384	$283,161	$198,945
10	2022	13,255	0.5	0.019	0.074	0.108	0.108	0.214	$195,584	$60,840	$17,601	$10,743	$1,391	$284,768	$192,379
11	2023	13,388	0.5	0.019	0.075	0.108	0.108	0.215	$196,689	$61,184	$17,701	$10,804	$1,399	$286,377	$186,025
12	2024	13,522	0.5	0.020	0.075	0.109	0.109	0.216	$197,795	$61,528	$17,800	$10,865	$1,407	$287,988	$179,876
13	2025	13,657	0.5	0.020	0.076	0.110	0.110	0.218	$198,903	$61,872	$17,900	$10,925	$1,415	$289,600	$173,926
14	2026	13,794	0.5	0.020	0.076	0.110	0.110	0.219	$200,011	$62,217	$18,000	$10,986	$1,423	$291,214	$168,169
15	2027	13,932	0.5	0.020	0.076	0.111	0.111	0.220	$201,120	$62,562	$18,099	$11,047	$1,431	$292,829	$162,598
16	2028	14,071	0.5	0.020	0.077	0.111	0.111	0.221	$202,231	$62,908	$18,199	$11,108	$1,439	$294,446	$157,207
17	2029	14,212	0.5	0.020	0.077	0.112	0.112	0.223	$203,342	$63,253	$18,299	$11,169	$1,447	$296,064	$151,991
18	2030	14,354	0.5	0.020	0.078	0.113	0.113	0.224	$204,453	$63,599	$18,399	$11,230	$1,454	$297,682	$146,944
19	2031	14,497	0.6	0.020	0.078	0.113	0.113	0.225	$205,566	$63,945	$18,499	$11,291	$1,462	$299,301	$142,061
20	2032	14,642	0.6	0.020	0.079	0.114	0.114	0.226	$206,678	$64,291	$18,600	$11,353	$1,470	$300,921	$137,337
														Total Present Value	$4,122,068

* PDO not included in Total Cost

Shaded cell indicates the AADT is outside the limits

NOTES:

1. Present Value = Future Cash Flow / (1 + Required Rate of Return)$^{\text{Number of Years You Have To Wait For The Cash Flow}}$
2. Traffic Growth Rate = $[((ADT_f / ADT_i)^{(1/(F-I))}-1] \times 100$

where ADT_f = Average Daily Traffic for Future Year
ADT_i = Average Daily Traffic for Initial Year
I = Initial Year for ADT
F = Future Year for ADT

Figure 14-3. Rural-Multilane Road Example (Form No. 750-020-21-b)

State of Florida Department of Transportation

Present Worth Analysis
Rural Multilane Arterial
No Build Alternative

General Information

Analyst: JFR
Date: 9/1/2014
Agency or Company: FDOT

Site Information

Location ID: N/A
County: Miami-Dade
City: Miami
M.P. - M.P.:

Manual Input from Analysis

Growth Rate = 1.0%
Opening Year AADT = 26,500
Segment Length = 1.50
Opening Year = 2010
Rate of Return = 4.0%
Segment = Rural Undivided Multilane S

Default Distribution for Crash Severity Level (2008-2012 Florida HSM Crash Distribution)

Fatality = 2.3%
Incapacitating = 13.1%
Non-Incapacitating = 22.4%
Possible Injury = 24.5%
Property Damage Only = 37.8%
100.1%

			Annual Number of Crashes						Annual Cost						
	Year	AADT	Site Specific ($N_{predicted-rs}$)	Fatality	Incap.	Non-Inc.	Possible Injury	PDO	Fatality	Incap.	Non-Inc.	Possible Injury	PDO	Total Cost*	Present Value
0	2010	26,500	11.0	0.252	1.436	2.456	2.686	4.145	$2,547,119	$1,175,878	$400,970	$267,683	$26,940	$4,391,650	$4,391,650
1	2011	26,765	11.1	0.255	1.453	2.485	2.718	4.193	$2,577,099	$1,189,718	$405,690	$270,834	$27,258	$4,443,341	$4,272,443
2	2012	27,033	11.2	0.258	1.470	2.514	2.750	4.243	$2,607,433	$1,203,721	$410,465	$274,022	$27,578	$4,495,641	$4,156,473
3	2013	27,303	11.4	0.261	1.488	2.544	2.782	4.293	$2,638,123	$1,217,890	$415,296	$277,247	$27,903	$4,548,556	$4,043,650
4	2014	27,576	11.5	0.264	1.505	2.574	2.815	4.343	$2,669,174	$1,232,225	$420,184	$280,511	$28,231	$4,602,094	$3,933,889
5	2015	27,852	11.6	0.267	1.523	2.604	2.848	4.394	$2,700,591	$1,246,728	$425,130	$283,812	$28,564	$4,656,262	$3,827,108
6	2016	28,130	11.8	0.271	1.541	2.635	2.882	4.446	$2,732,378	$1,261,403	$430,134	$287,153	$28,900	$4,711,068	$3,723,225
7	2017	28,412	11.9	0.274	1.559	2.666	2.916	4.498	$2,764,539	$1,276,250	$435,197	$290,533	$29,240	$4,766,518	$3,622,162
8	2018	28,696	12.0	0.277	1.577	2.697	2.950	4.551	$2,797,079	$1,291,272	$440,319	$293,952	$29,584	$4,822,622	$3,523,843
9	2019	28,983	12.2	0.280	1.596	2.729	2.985	4.605	$2,830,001	$1,306,470	$445,502	$297,412	$29,932	$4,879,386	$3,428,192
10	2020	29,272	12.3	0.283	1.615	2.761	3.020	4.659	$2,863,311	$1,321,848	$450,745	$300,913	$30,285	$4,936,818	$3,335,137
11	2021	29,565	12.5	0.287	1.634	2.794	3.055	4.714	$2,897,013	$1,337,406	$456,051	$304,455	$30,641	$4,994,925	$3,244,608
12	2022	29,861	12.6	0.290	1.653	2.826	3.091	4.770	$2,931,112	$1,353,148	$461,419	$308,038	$31,002	$5,053,717	$3,156,537
13	2023	30,159	12.8	0.294	1.672	2.860	3.128	4.826	$2,965,612	$1,369,075	$466,850	$311,664	$31,367	$5,113,201	$3,070,856
14	2024	30,461	12.9	0.297	1.692	2.893	3.165	4.882	$3,000,519	$1,385,190	$472,345	$315,332	$31,736	$5,173,385	$2,987,501
15	2025	30,766	13.1	0.301	1.712	2.927	3.202	4.940	$3,035,836	$1,401,494	$477,904	$319,044	$32,110	$5,234,278	$2,906,409
16	2026	31,073	13.2	0.304	1.732	2.962	3.239	4.998	$3,071,568	$1,417,990	$483,529	$322,799	$32,487	$5,295,887	$2,827,517
17	2027	31,384	13.4	0.308	1.753	2.997	3.278	5.057	$3,107,722	$1,434,680	$489,221	$326,599	$32,870	$5,358,221	$2,750,767
18	2028	31,698	13.5	0.311	1.773	3.032	3.316	5.116	$3,144,301	$1,451,567	$494,979	$330,443	$33,257	$5,421,289	$2,676,101
19	2029	32,015	13.7	0.315	1.794	3.068	3.355	5.177	$3,181,310	$1,468,652	$500,805	$334,332	$33,648	$5,485,099	$2,603,461
20	2030	32,335	13.9	0.319	1.815	3.104	3.395	5.238	$3,218,755	$1,485,939	$506,700	$338,268	$34,044	$5,549,661	$2,532,793
														Total Present Value	$71,014,321

* PDO not included in Total Cost

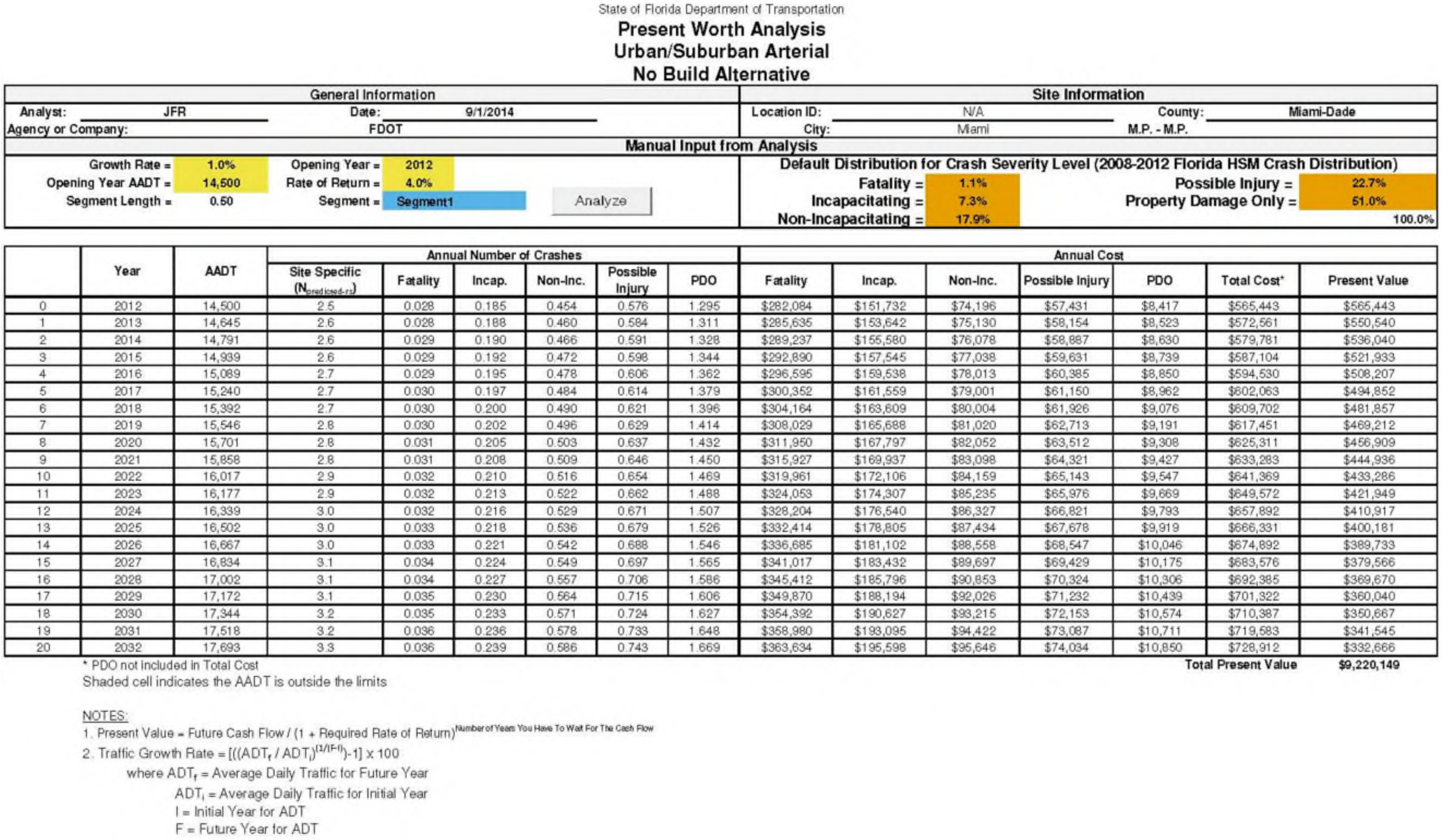
Shaded cell indicates the AADT is outside the limits

NOTES:

1. Present Value = Future Cash Flow / (1 + Required Rate of Return)$^{\text{Number of Years You Have To Wait For The Cash Flow}}$
2. Traffic Growth Rate = $[((ADT_f / ADT_i)^{(1/(F-I))}-1] \times 100$

where ADT_f = Average Daily Traffic for Future Year
ADT_i = Average Daily Traffic for Initial Year
I = Initial Year for ADT
F = Future Year for ADT

Figure 14-4. Urban/Suburban Arterial Example (Form No. 750-020-21-c)



State of Florida Department of Transportation

Present Worth Analysis
Urban/Suburban Arterial
No Build Alternative

General Information				Site Information			
Analyst:	JFR	**Date:**	9/1/2014	**Location ID:**	N/A	**County:**	Miami-Dade
Agency or Company:			FDOT	**City:**	Miami	**M.P. - M.P.**	

Manual Input from Analysis

Growth Rate = 1.0%
Opening Year AADT = 14,500
Segment Length = 0.50
Opening Year = 2012
Rate of Return = 4.0%
Segment = Segment1

☐ Analyze

Default Distribution for Crash Severity Level (2008-2012 Florida HSM Crash Distribution)

Fatality = 1.1%
Incapacitating = 7.3%
Non-Incapacitating = 17.9%
Possible Injury = 22.7%
Property Damage Only = 51.0%
100.0%

	Year	AADT	Annual Number of Crashes						Annual Cost						
			Site Specific ($N_{predicted-rs}$)	Fatality	Incap.	Non-Inc.	Possible Injury	PDO	Fatality	Incap.	Non-Inc.	Possible Injury	PDO	Total Cost*	Present Value
0	2012	14,500	2.5	0.028	0.185	0.454	0.576	1.295	$282,084	$151,732	$74,196	$57,431	$8,417	$565,443	$565,443
1	2013	14,645	2.6	0.028	0.188	0.460	0.584	1.311	$285,635	$153,642	$75,130	$58,154	$8,523	$572,561	$550,540
2	2014	14,791	2.6	0.029	0.190	0.466	0.591	1.328	$289,237	$155,580	$76,078	$58,887	$8,630	$579,781	$536,040
3	2015	14,939	2.6	0.029	0.192	0.472	0.598	1.344	$292,890	$157,545	$77,038	$59,631	$8,739	$587,104	$521,933
4	2016	15,089	2.7	0.029	0.195	0.478	0.606	1.362	$296,595	$159,538	$78,013	$60,385	$8,850	$594,530	$508,207
5	2017	15,240	2.7	0.030	0.197	0.484	0.614	1.379	$300,352	$161,559	$79,001	$61,150	$8,962	$602,063	$494,852
6	2018	15,392	2.7	0.030	0.200	0.490	0.621	1.396	$304,164	$163,609	$80,004	$61,926	$9,076	$609,702	$481,857
7	2019	15,546	2.8	0.030	0.202	0.496	0.629	1.414	$308,029	$165,688	$81,020	$62,713	$9,191	$617,451	$469,212
8	2020	15,701	2.8	0.031	0.205	0.503	0.637	1.432	$311,950	$167,797	$82,052	$63,512	$9,308	$625,311	$456,909
9	2021	15,858	2.8	0.031	0.208	0.509	0.646	1.450	$315,927	$169,937	$83,098	$64,321	$9,427	$633,283	$444,936
10	2022	16,017	2.9	0.032	0.210	0.516	0.654	1.469	$319,961	$172,106	$84,159	$65,143	$9,547	$641,369	$433,286
11	2023	16,177	2.9	0.032	0.213	0.522	0.662	1.488	$324,053	$174,307	$85,235	$65,976	$9,669	$649,572	$421,949
12	2024	16,339	3.0	0.032	0.216	0.529	0.671	1.507	$328,204	$176,540	$86,327	$66,821	$9,793	$657,892	$410,917
13	2025	16,502	3.0	0.033	0.218	0.536	0.679	1.526	$332,414	$178,805	$87,434	$67,678	$9,919	$666,331	$400,181
14	2026	16,667	3.0	0.033	0.221	0.542	0.688	1.546	$336,685	$181,102	$88,558	$68,547	$10,046	$674,892	$389,733
15	2027	16,834	3.1	0.034	0.224	0.549	0.697	1.565	$341,017	$183,432	$89,697	$69,429	$10,175	$683,576	$379,566
16	2028	17,002	3.1	0.034	0.227	0.557	0.706	1.586	$345,412	$185,796	$90,853	$70,324	$10,306	$692,385	$369,670
17	2029	17,172	3.1	0.035	0.230	0.564	0.715	1.606	$349,870	$188,194	$92,026	$71,232	$10,439	$701,322	$360,040
18	2030	17,344	3.2	0.035	0.233	0.571	0.724	1.627	$354,392	$190,627	$93,215	$72,153	$10,574	$710,387	$350,667
19	2031	17,518	3.2	0.036	0.236	0.578	0.733	1.648	$358,980	$193,095	$94,422	$73,087	$10,711	$719,583	$341,545
20	2032	17,693	3.3	0.036	0.239	0.586	0.743	1.669	$363,634	$195,598	$95,646	$74,034	$10,850	$728,912	$332,666
														Total Present Value	**$9,220,149**

* PDO not included in Total Cost
Shaded cell indicates the AADT is outside the limits

NOTES:

1. Present Value = Future Cash Flow / (1 + Required Rate of Return)$^{\text{Number of Years You Have To Wait For The Cash Flow}}$
2. Traffic Growth Rate = $[((ADT_f / ADT_i)^{(1/(F-I))})-1] \times 100$

where ADT_f = Average Daily Traffic for Future Year
ADT_i = Average Daily Traffic for Initial Year
I = Initial Year for ADT
F = Future Year for ADT

14.3.2 Net Present Value Computations when the HSM Part C Methodology is Not Applicable

(1) The procedure to conduct a NPV computation when the HSM Part C Methodology is not applicable follows the same general concept as the procedure when the HSM is applicable. However provided the crash frequency cannot be predicted, it is estimated using an observed field crash rate, or a minimum unlighted crash rate of 3.0 crashes per million vehicle miles.

(2) The procedure follows a similar six-step process as the HSM with some modifications as noted below:

- Step 1: Identify or compute crash frequencies for NO LIGHTING CONDITIONS
- Step 2: Quantify monetary cost of crashes for NO LIGHTING CONDITIONS
- Step 3: Identify or compute crash frequencies for LIGHTED CONDITIONS
- Step 4: Quantify monetary cost of crashes for LIGHTED CONDITIONS
- Step 5: Compute difference: BENEFIT = Monetary cost of crashes for NO LIGHTING CONDITIONS – Monetary cost of crashes for LIGHTED CONDITIONS
- Step 6: Next steps: Compute NPV

(a) **Step 1:** Crash frequency is computed using the ADT, percent of the ADT at night, and a nighttime crash rate value for unlighted conditions (NRU, see next section for detailed description of this variable). Note that crash frequency is computed for every year in the analysis period. If sufficient information is known to identify a severity distribution, then a table similar to the one shown in Step 1 for the HSM procedure should be produced. If severity distribution is unknown, then a similar table should be produced with the exception of the KABCO distribution columns.

$$N_{unlighted}\left(\frac{crash}{year}\right) = \frac{(ADT * \%ADTn * 365 * NRU)}{1{,}000{,}000}$$

(b) **Step 2:** Quantify the monetary cost of the UNLIGHTED CONDITIONS crash frequency. If the crash distribution is known or can be estimated, then a similar table to that shown in Step 2 of the HSM procedure must be produced and the formula below computed for every year and crash severity. If the distribution is unknown, then the formula shown below is computed once for every year in the analysis period using the total crash number, and a similar table to that shown in Step 2 of the HSM procedure is produced with the difference being that a single cost will be computed for each year.

When the distribution of crashes is unavailable, the average crash cost should be used; this value can be obtained from the Historical Crash Method discussion for all state roads found in the FDOT PPM Chapter 23. Finally, the present value of the crash costs for each year in the analysis period must be computed, as shown in Step 2B of the HSM procedure.

$$Present\ Worth\ of\ Cost\ UNLIGHTED\ =\ N_{unlighted} * CC$$

(c) **Step 3:** Crash frequency is computed using the ADT value, percent of the ADT at night, nighttime crash rate value (NRU), and a crash modification factor (CMF) for lighted conditions. Note that this value is computed for every year in the analysis period. If sufficient information is known to identify a severity distribution, then a table similar to the one shown in Step 1 for the HSM procedure should be produced. If severity distribution is unknown, then a similar table should be produced with the exception of the KABCO distribution columns.

$$N_{lighted}\ \left(\frac{crash}{year}\right) = \frac{(ADT * \%ADTn * 365 * NRU * CMF)}{1{,}000{,}000}$$

Net Present Value for Lighting Retention

$$NPV = (ADT * \%ADTn * 365 * NRU * CFR * ACC) - [(TMC + AEC) * 1{,}000{,}000]$$

(d) **Step 4:** Quantify the monetary cost of the LIGHTED CONDITIONS crash frequency. If the crash distribution is known or can be estimated, then a similar table to that shown in Step 2 of the HSM procedure must be produced and the formula below computed for every year and crash severity. If the distribution is unknown, then the formula shown below is computed once for every year in the analysis period using the total crash number, and a similar table to that shown in Step 2 of the HSM procedure is produced with the difference being that a single cost will be computed for each year.

When the distribution of crashes is unavailable, the average crash cost should be used, this value can be obtained from the Historical Crash Method discussion for all state roads found in the ***FDOT PPM Chapter 23***. Finally, the present value of the crash costs for each year in the analysis period must be computed, as show in Step 2B of the HSM procedure.

$$Present\ Worth\ of\ Cost\ LIGHTED = N_{unlighted} * CC$$

(e) **Step 5:** Compute the difference in cost between lighted and unlighted conditions.

$$Cost\ Difference = Present\ Worth\ of\ Cost\ UNLIGHTED - Present\ Worth\ of\ Cost\ LIGHTED$$

(f) **Step 6:** Compute the Net Present Value.

For New Roadway Lighting Systems (Lighting Installation)

$$NPV = Cost\ Difference - (IC + PVMC + PVEC)$$

For Existing Roadway Lighting Systems (Lighting Retention)

$$NPV = Cost\ Difference - (PVMC + PVEC)$$

Where:

$N_{unlighted}$ = Crash frequency for unlighted conditions, this value may represent all crashes or a specific severity type.

$N_{lighted}$ = Crash frequency for lighted conditions, this value may represent all crashes or a specific severity type.

ADT = Average Daily Traffic (Existing or Projected)

$\%ADTn$ = Percent of ADT at night

NRU = Night crash rate unlighted (see description below)

CMF = Crash modification factor

CC = Crash cost (U.S. dollars per crash from Chap 23 of PPM)

IC = Installation cost

$PVMC$ = Present value of annual maintenance cost

$PVEC$ = Present value of annual electric costs

14.3.2.1 Description of Key Variables

(1) NRU is expressed as nighttime crashes per million vehicle miles for mainline sections or crashes per million entering vehicles for interchanges. The NRU is obtained by searching crash records.

(2) The percent of ADT at night ($\%ADTn$) can be determined by examining traffic data.

(3) Crash modification factors ($CMFs$) are based on an estimate of the crash reduction potential due to the installation of lighting. These values may be obtained from a variety of sources including the Highway Safety Manual or the CMF Clearinghouse.

14.4 DETERMINING OPERATIONAL STATUS OF EXISTING LIGHTING: FREEWAYS

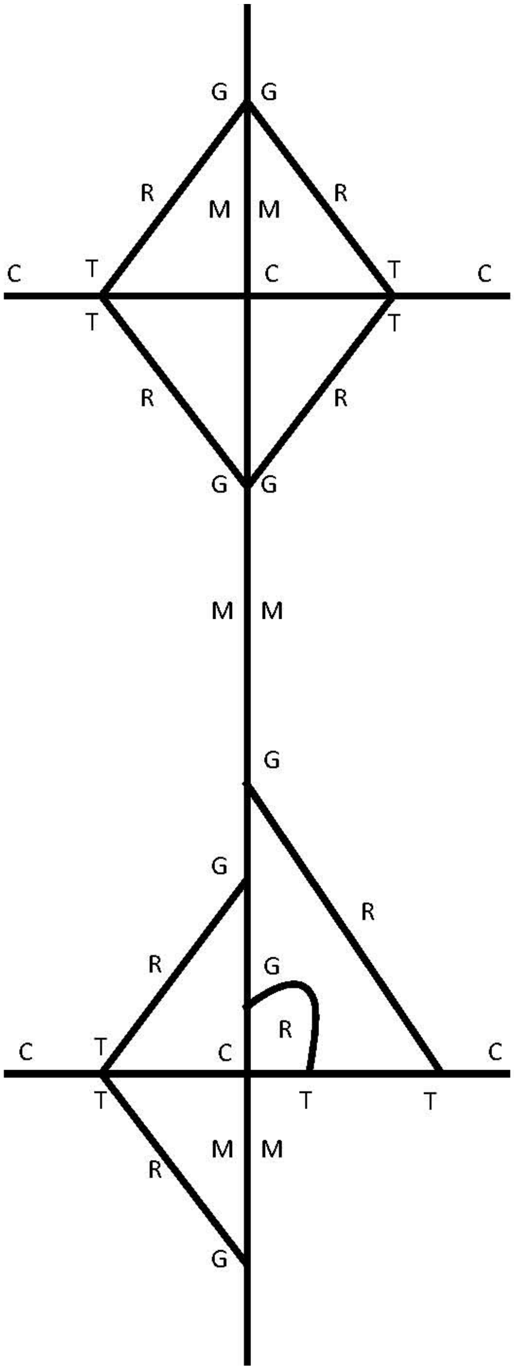
(1) Existing highway lighting systems are subject to various causes of electrical or mechanical malfunction. Pole knockdowns, lightning strikes, damaged-circuits, blown fuses, burned-out bulbs, and other causes result in an operational status almost always less than 100 percent.

(2) This guideline sets forth a procedure that can assist the engineer in determining when a certain section of existing lighting is operating below an acceptable level. The procedure calculates an “operational ratio” of the actual lighting operation level to the base lighting operation level. An acceptable range of operational ratio is between 0.90 and 1.00 for interchanges and for the total lighting system. However, a range between 0.75 and 1.00 is acceptable for mainline systems.

(3) This technique should only be used as a guideline and should not form the basis in all cases for determining when corrective repair work is scheduled for a highway lighting system. The procedure does, however, recognize that cost-effective management of lighting system maintenance involves a value judgment relating to the seriousness of various types, patterns, locations, and the number of failed fixtures.

(4) ***Figure 14-5*** and ***Figure 14-6*** include a graphical presentation of the procedure. Unacceptable levels of operation are defined in ***Table 14-2.***

Figure 14-5. Example Application of Procedure



Gore Areas		G
Terminal Areas	T	
Mainline Segments		M
Crossroads Segments	C	
Ramp Segments		R

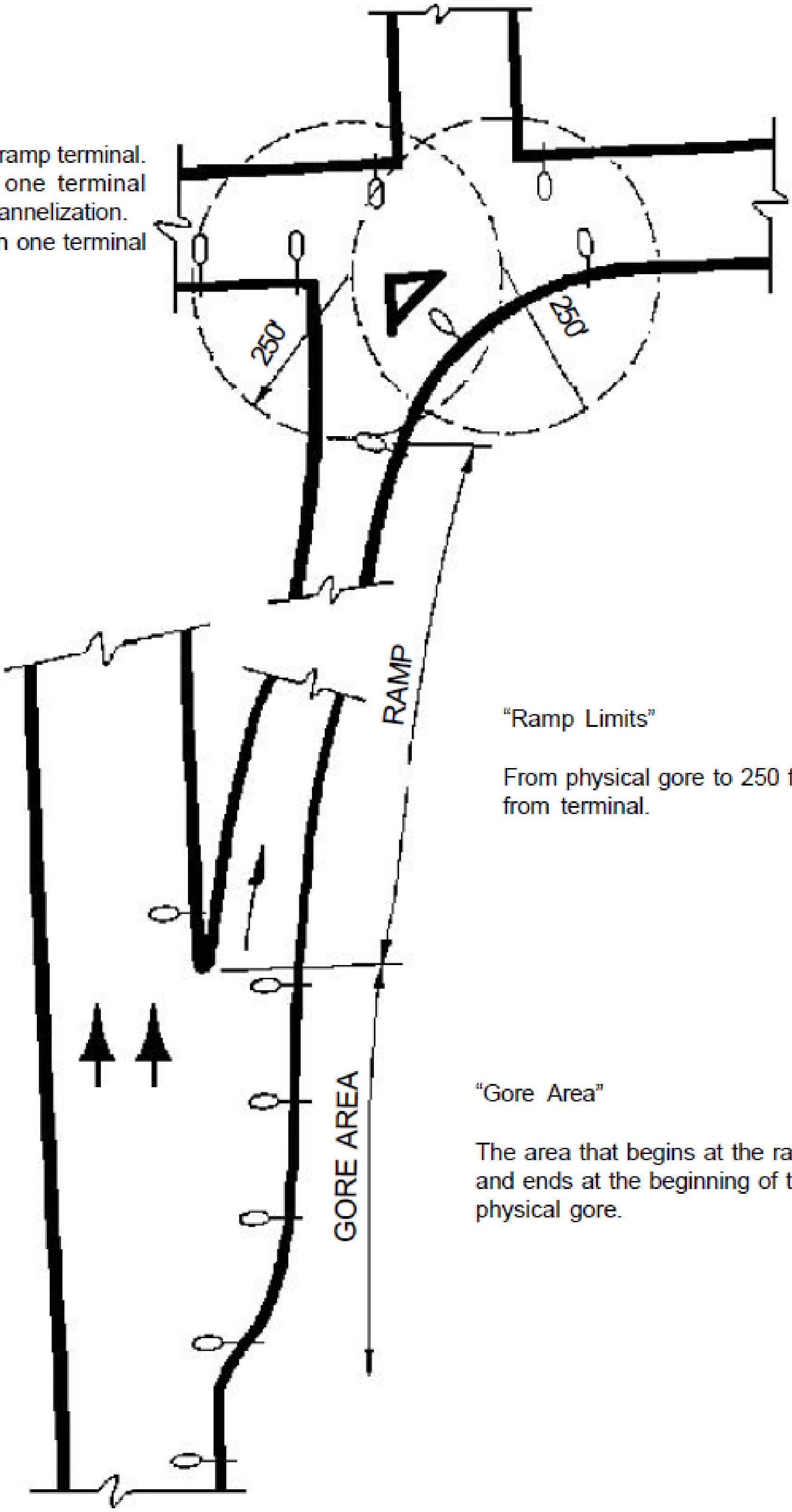
Example Calculation of Numerical Base Lighting Operational Level for configuration shown at left:

	#	Points	Total
Gore Areas	8	(30)	240
Terminal Areas	8	(20)	160
Mainline Segments	6	(10)	60
Crossroads Segments	6	(15)	30
Ramp Segments	8	(15)	120
			610

NOTE: In instances where underdeck lighting is present, all underdeck luminaires per directions, per structure are considered as a single pole for this analysis. If 50% of the underdeck luminaires are inoperative, the ”pole” is inoperative.

ALL CONVENTIONAL LIGHTING

Figure 14-6. Graphical Representation



"Terminal Area"

Area within 250 feet of ramp terminal. Each ramp has only one terminal area, regardless of channelization. There are six fixtures in one terminal area shown at right.

"Ramp Limits"

From physical gore to 250 feet from terminal.

"Gore Area"

The area that begins at the ramp taper and ends at the beginning of the physical gore.

Table 14-2. Guidelines for Assessing Operational Level of Highway Lighting

Type Area	Description	Operational Points For Each Area/Section	Minimum Unacceptable Operating Condition
Gore Area	The area that begins at the ramp taper and ends at the beginning of the physical gore.	30	Two inoperative fixtures within the gore area.
Terminal Area	The area (or groups of areas) within a 250 foot radius, measured from the center of the ramp pavement where it joins the edge of a crossroad.	20	Twenty-five percent of the fixtures inoperative within the terminal area.
Ramp Area	Any section of ramp roadway not considered in a gore or terminal area.	15	Three consecutive fixtures or 50 percent of the total fixtures inoperative along the ramp section.
Mainline Section	Any section of one-way mainline roadway between gore areas.	10	If a mainline section has one or more groups with three or more consecutive luminaires inoperative, the sum of the numbers in the groups is multiplied by two and added to the remaining number of inoperative luminaires.*
Crossroad Section	The two-way traffic section between terminal areas or from terminal areas to the ends of the lighting maintenance.	5	Three consecutive fixtures inoperative along the one side of the crossroad or two consecutive fixtures inoperative along one side of the crossroad opposite two consecutive inoperative fixtures.
High Mast Interchange	When high lighting towers are involved, none of the above sub-areas shall be identified within the interchange. The interchange is defined as the limits of the interchange high mast lighting.	30	Twenty-five percent of the fixtures inoperative or two adjacent towers with all fixtures inoperative.
High Mast Mainline	Mainline high mast lighting shall only apply when towers exist for at least one mile continuously between the end of ramp tapers at successive interchanges.	10	Twenty-five percent of the fixtures inoperative or two adjacent towers with all fixtures inoperative.

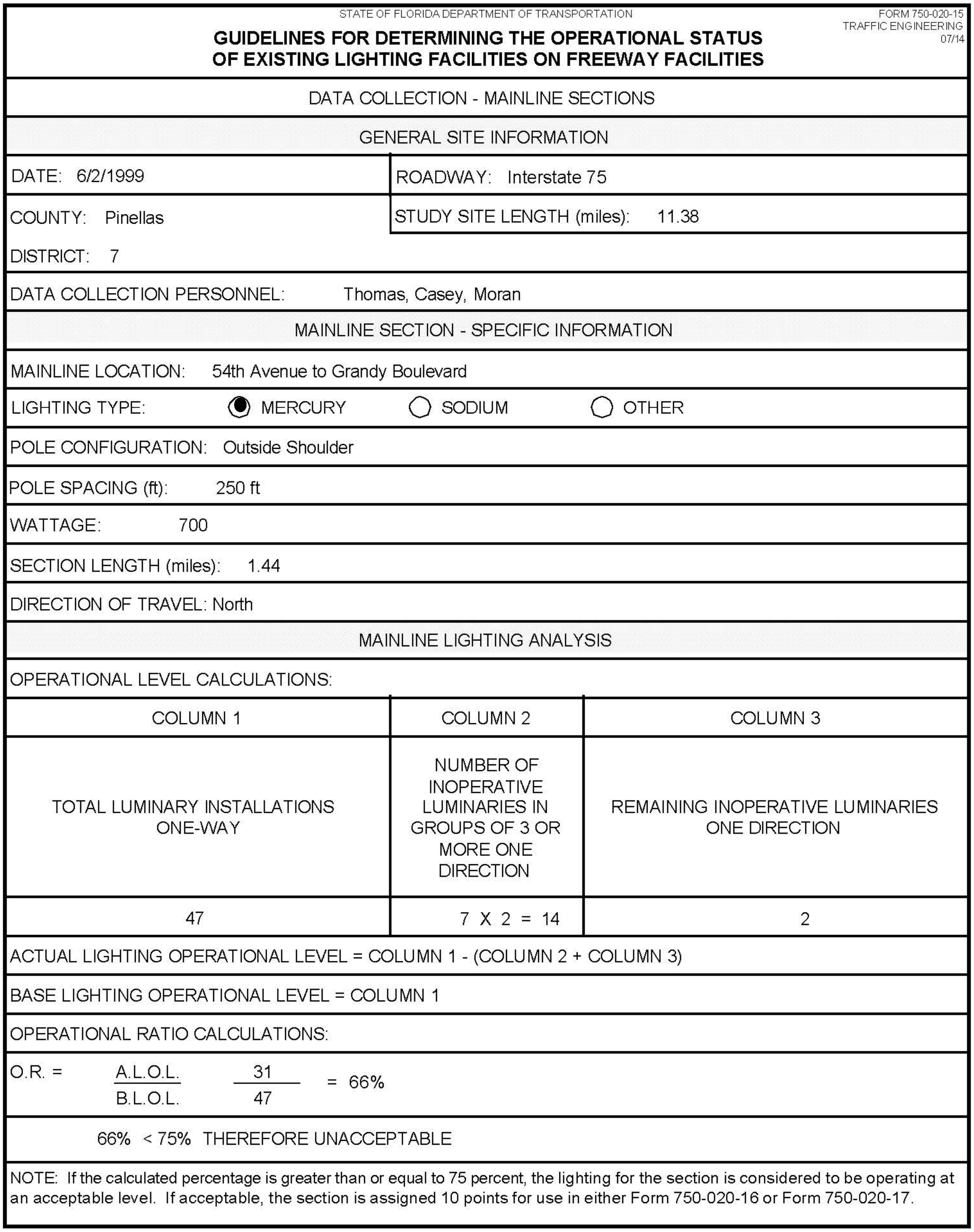
*If the sum is greater than 25 percent of the total number of luminaires, then the section is unacceptable.

(5) It is estimated that approximately 0.6 hour of data collection team time is needed for each mile of the study site. Approximately one-fourth of the inspection time should be spent during daylight hours, during which time the number of installations and knockdowns should be counted. The remaining three-fourths of the inspection time should be spent during nighttime hours, counting burned out luminaires and tabulating data. Examples of completed tables and calculation techniques are provided in ***Figure 14-7***, ***Figure 14-8*****,** and ***Figure 14-9****.*

14.5 FORMS ACCESS

(1) Example crash cost spreadsheets for the HSM application can be downloaded from the MUTS website. Reproducible copies of the ***Present Worth Analysis Spreadsheets (Form No. 750-020-21-a*****,** ***750-020-21-b*****,** ***and 750-020-21-c)*** and ***Guidelines for Determining the Operational Status of Existing Lighting Systems on Freeway Facilities (Form Nos. 750-020-15*****,** ***750-020-16*****,** ***and 750-020-17)*** are available in the Department's Forms Library.

Figure 14-7. Operational Status of Existing Lighting for Mainline Sections (Form No. 750-020-15)



STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

FORM 750-020-15
TRAFFIC ENGINEERING
07/14

GUIDELINES FOR DETERMINING THE OPERATIONAL STATUS OF EXISTING LIGHTING FACILITIES ON FREEWAY FACILITIES

DATA COLLECTION - MAINLINE SECTIONS

GENERAL SITE INFORMATION

DATE: 6/2/1999

ROADWAY: Interstate 75

COUNTY: Pinellas

STUDY SITE LENGTH (miles): 11.38

DISTRICT: 7

DATA COLLECTION PERSONNEL: Thomas, Casey, Moran

MAINLINE SECTION - SPECIFIC INFORMATION

MAINLINE LOCATION: 54th Avenue to Grandy Boulevard

LIGHTING TYPE: ● MERCURY ○ SODIUM ○ OTHER

POLE CONFIGURATION: Outside Shoulder

POLE SPACING (ft): 250 ft

WATTAGE: 700

SECTION LENGTH (miles): 1.44

DIRECTION OF TRAVEL: North

MAINLINE LIGHTING ANALYSIS

OPERATIONAL LEVEL CALCULATIONS:

COLUMN 1	COLUMN 2	COLUMN 3
TOTAL LUMINARY INSTALLATIONS ONE-WAY	NUMBER OF INOPERATIVE LUMINARIES IN GROUPS OF 3 OR MORE ONE DIRECTION	REMAINING INOPERATIVE LUMINARIES ONE DIRECTION
47	7 X 2 = 14	2

ACTUAL LIGHTING OPERATIONAL LEVEL = COLUMN 1 - (COLUMN 2 + COLUMN 3)

BASE LIGHTING OPERATIONAL LEVEL = COLUMN 1

OPERATIONAL RATIO CALCULATIONS:

$$\text{O.R.} = \frac{\text{A.L.O.L.}}{\text{B.L.O.L.}} \quad \frac{31}{47} = 66\%$$

66% < 75% THEREFORE UNACCEPTABLE

NOTE: If the calculated percentage is greater than or equal to 75 percent, the lighting for the section is considered to be operating at an acceptable level. If acceptable, the section is assigned 10 points for use in either Form 750-020-16 or Form 750-020-17.

Figure 14-8. Operational Status of Existing Lighting for Interchanges (Form No. 750-020-16)

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

FORM 750-020-16
TRAFFIC ENGINEERING
07/14

GUIDELINES FOR DETERMINING THE OPERATIONAL STATUS OF EXISTING LIGHTING SYSTEMS ON FREEWAY FACILITIES

DATA COLLECTION - INTERCHANGES

GENERAL SITE INFORMATION

DATE: 6/2/1999

ROADWAY: Interstate 75

COUNTY: Pinellas

STUDY SITE LENGTH (miles): 11.38

DISTRICT: 7

DATA COLLECTION PERSONNEL: Thomas, Casey, Moran

INTERCHANGE - SPECIFIC INFORMATION

INTERCHANGE LOCATION:

LIGHTING TYPE: ● MERCURY ○ SODIUM ○ OTHER

MAINLINE POLE CONFIGURATION: Outside Shoulder

MAINLINE POLE SPACING (ft): 250 ft

WATTAGE: 700

SECTION LENGTH (miles): N/A

INTERCHANGE LIGHTING ANALYSIS

BASE LIGHTING OPERATIONAL LEVEL CALCULATIONS (B.L.O.L.):

CONFIGURATION	TOTAL NUMBER	POINTS	TOTAL
GORE AREA	4	30	120
TERMINAL AREA	4	20	80
MAINLINE SEGMENTS	2	10	20
CROSSROAD SEGMENTS	3	5	15
RAMP SEGMENTS	4	15	60
TOTAL			295

ACTUAL LIGHTING OPERATIONAL LEVEL CALCULATIONS (A.L.O.L.):

CONFIGURATION	ACCEPTABLE OPERATIONS	POINTS	TOTAL
GORE AREA	2	30	60
TERMINAL AREA	3	200	60
MAINLINE SEGMENTS	2	10	20
CROSSROAD SEGMENTS	3	5	15
RAMP SEGMENTS	2	15	30
TOTAL			185

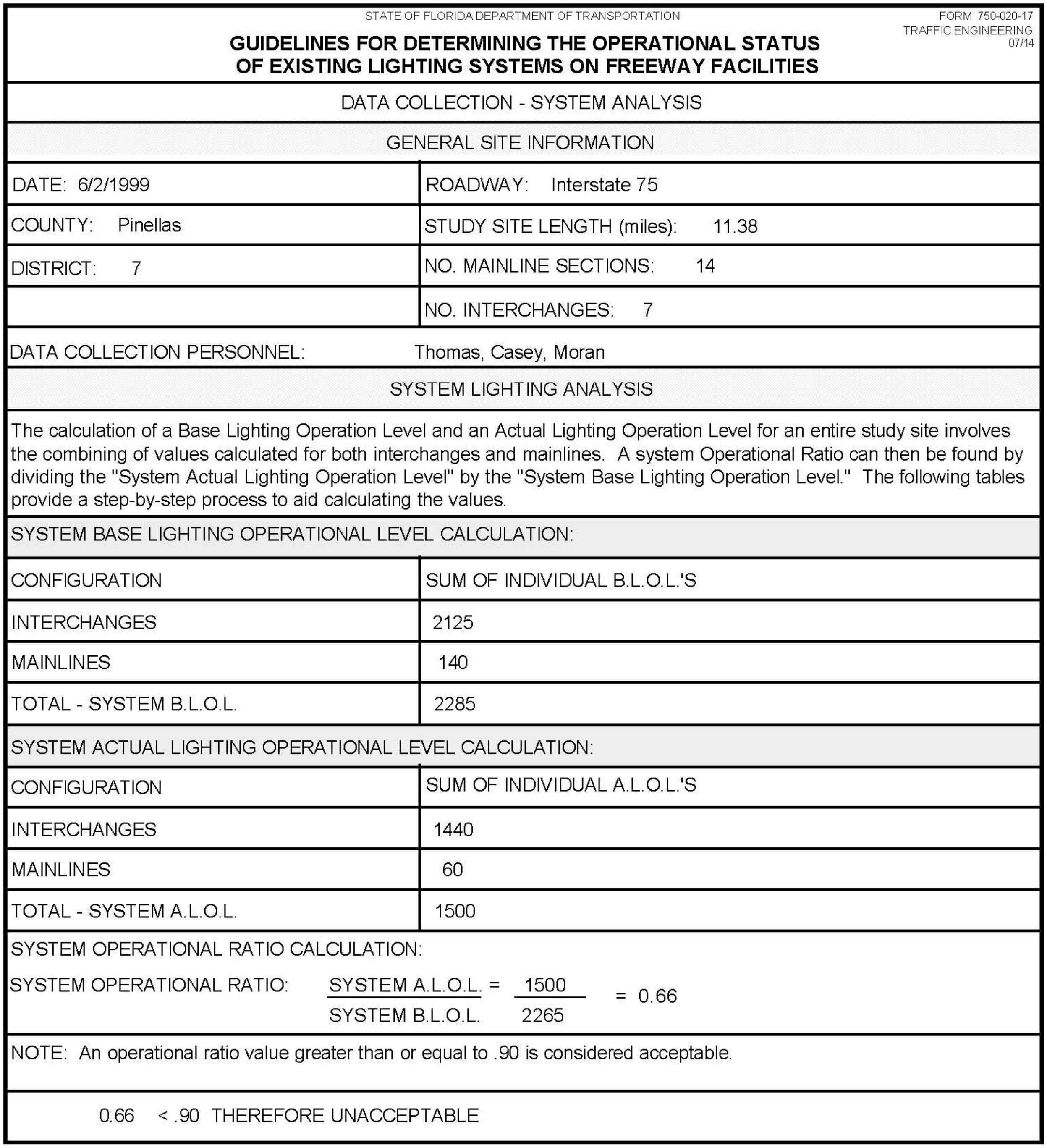
OPERATIONAL RATIO CALCULATIONS:

O.R. = $\frac{\text{A.L.O.L.}}{\text{B.L.O.L.}}$ $\frac{185}{295}$ = 0.627

0.726 < .90 THEREFORE UNACCEPTABLE

NOTE: The acceptable level for the O.R. is 0.90 or greater.

Figure 14-9. Operational Status of Existing Lighting for System Analysis (Form No. 750-020-17)



STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

FORM 750-020-17
TRAFFIC ENGINEERING
07/14

GUIDELINES FOR DETERMINING THE OPERATIONAL STATUS
OF EXISTING LIGHTING SYSTEMS ON FREEWAY FACILITIES

DATA COLLECTION - SYSTEM ANALYSIS

GENERAL SITE INFORMATION

DATE: 6/2/1999	ROADWAY: Interstate 75
COUNTY: Pinellas	STUDY SITE LENGTH (miles): 11.38
DISTRICT: 7	NO. MAINLINE SECTIONS: 14
	NO. INTERCHANGES: 7

DATA COLLECTION PERSONNEL: Thomas, Casey, Moran

SYSTEM LIGHTING ANALYSIS

The calculation of a Base Lighting Operation Level and an Actual Lighting Operation Level for an entire study site involves the combining of values calculated for both interchanges and mainlines. A system Operational Ratio can then be found by dividing the "System Actual Lighting Operation Level" by the "System Base Lighting Operation Level." The following tables provide a step-by-step process to aid calculating the values.

SYSTEM BASE LIGHTING OPERATIONAL LEVEL CALCULATION:

CONFIGURATION	SUM OF INDIVIDUAL B.L.O.L.'S
INTERCHANGES	2125
MAINLINES	140
TOTAL - SYSTEM B.L.O.L.	2285

SYSTEM ACTUAL LIGHTING OPERATIONAL LEVEL CALCULATION:

CONFIGURATION	SUM OF INDIVIDUAL A.L.O.L.'S
INTERCHANGES	1440
MAINLINES	60
TOTAL - SYSTEM A.L.O.L.	1500

SYSTEM OPERATIONAL RATIO CALCULATION:

SYSTEM OPERATIONAL RATIO: $\frac{\text{SYSTEM A.L.O.L.}}{\text{SYSTEM B.L.O.L.}} = \frac{1500}{2265} = 0.66$

NOTE: An operational ratio value greater than or equal to .90 is considered acceptable.

0.66 < .90 THEREFORE UNACCEPTABLE