MUTS

Manual on Uniform Traffic Studies

FDOT

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CHAPTER 1 MANUAL ON UNIFORM TRAFFIC STUDIES

1.1 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.

1.2 AUTHORITY

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

1.3 SCOPE

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

1.4 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.

1.5 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.fdot.gov/traffic/trafficservices/Studies/MUTS/MUTS.shtm

1.6 REVISIONS AND ADDITIONS

(1) The District Traffic Operations Engineers (DTOE) and the State Traffic Operations Engineer (STOE) or designee 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.

1.7 TRAINING

No training is required. Computer based training modules will be available through the Department's Learning Management System also known as Learning Curve.

1.8 FORMS ACCESS

All forms in this Manual have been standardized and are available in the FDOT MUTS website (https://www.fdot.gov/traffic/trafficservices/studies/muts/muts.shtm) and Forms Library (https://fms.fdot.gov). Reproducible and electronic copies of the forms are available through these links.

Chapter 3:

Form 750-020-01, Traffic Signal Warrant Summary

Chapter 4:

Form 750-020-03, Vehicle Turning Movement Counts

Form 750-020-02, Summary of Turning Movement Counts

Chapter 5:

Form 750-020-05a, Rural Two-Lane Roadway Segment Data Collection

Form 750-020-05b, Rural Multi-Lane Highway Segment Data Collection

Form 750-020-05c, Urban/Suburban Arterial Segment for 2 to 5 Lanes Data Collection

Form 750-020-05l, Urban/Suburban Arterial Segment for 6 to 8 Lanes and One-Way Roadway 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 Highway Intersection Data Collection

Form 750-020-05g, Urban/Suburban Arterial Intersection for 2 to 5 Lanes on the Major Street Data Collection

Form 750-020-05m, Urban/Suburban Roadway Intersection for 6 to 8 Lanes and One-Way on the Major Street Data Collection

Form 750-020-05n, Restricted Crossing U-Turn Data Collection

Form 750-020-05o, Roundabout Data Collection

Form 750-020-05h, Other Intersections Data Collection

Form 750-020-04, Condition Diagram

Form 750-020-05i, Collision Diagram for Segments

Form 750-020-05j, Collision Diagram for Intersections

Form 750-020-05k, Collision Summary

Chapter 6:

Form 750-020-06a, Freeway Segments Data Collection

Form 750-020-06b, Ramp Segments Data Collection

Form 750-020-06c, Ramp Terminal Data Collection

Chapter 7:

Form 750-020-07, Intersection Control Delay Study

Chapter 8:

Form 750-020-08a, Gap Study

Form 750-020-08b, Vehicular Gap Study

Chapter 9:

Form 750-020-09, Non-Motorized Volume Sheet

Form 750-020-10, Summary of Non-Motorized Movements

Form 750-020-11a, Walking Speed Study – Intersection

Form 750-020-11b, Walking Speed Study – Mid-block

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 750-020-21a, Present Worth Analysis for Rural-Two Lane Roads

Form 750-020-21b, Present Worth Analysis for Rural-Multilane Roads

Form 750-020-21c, Present Worth Analysis for Urban and Suburban Arterials (2 to 5 Lanes)

Form 750-020-21d, Present Worth Analysis for Urban and Suburban Arterials (6 to 8 Lanes and One-Way Streets)

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 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), FDOT's Intersection Control Evaluation (ICE) Manual and experiences of practicing traffic engineers.

(2) This chapter 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 sections outline the observation of problem symptoms, establishment of areas of concern, collection of data, evaluation, 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 ABOUT 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 formally defined.

(2) The engineer is required to respond to a notice regardless of its source. The 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

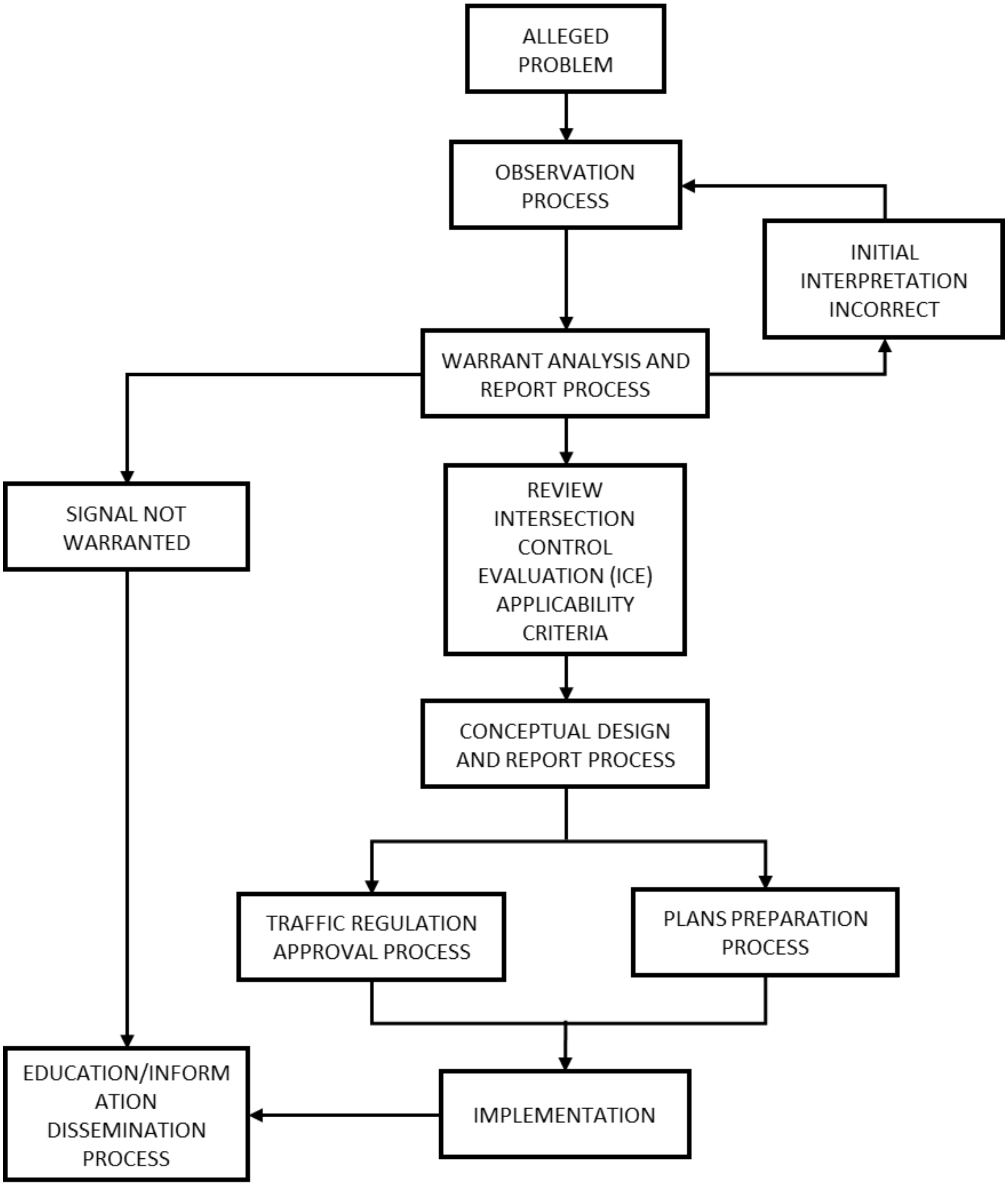
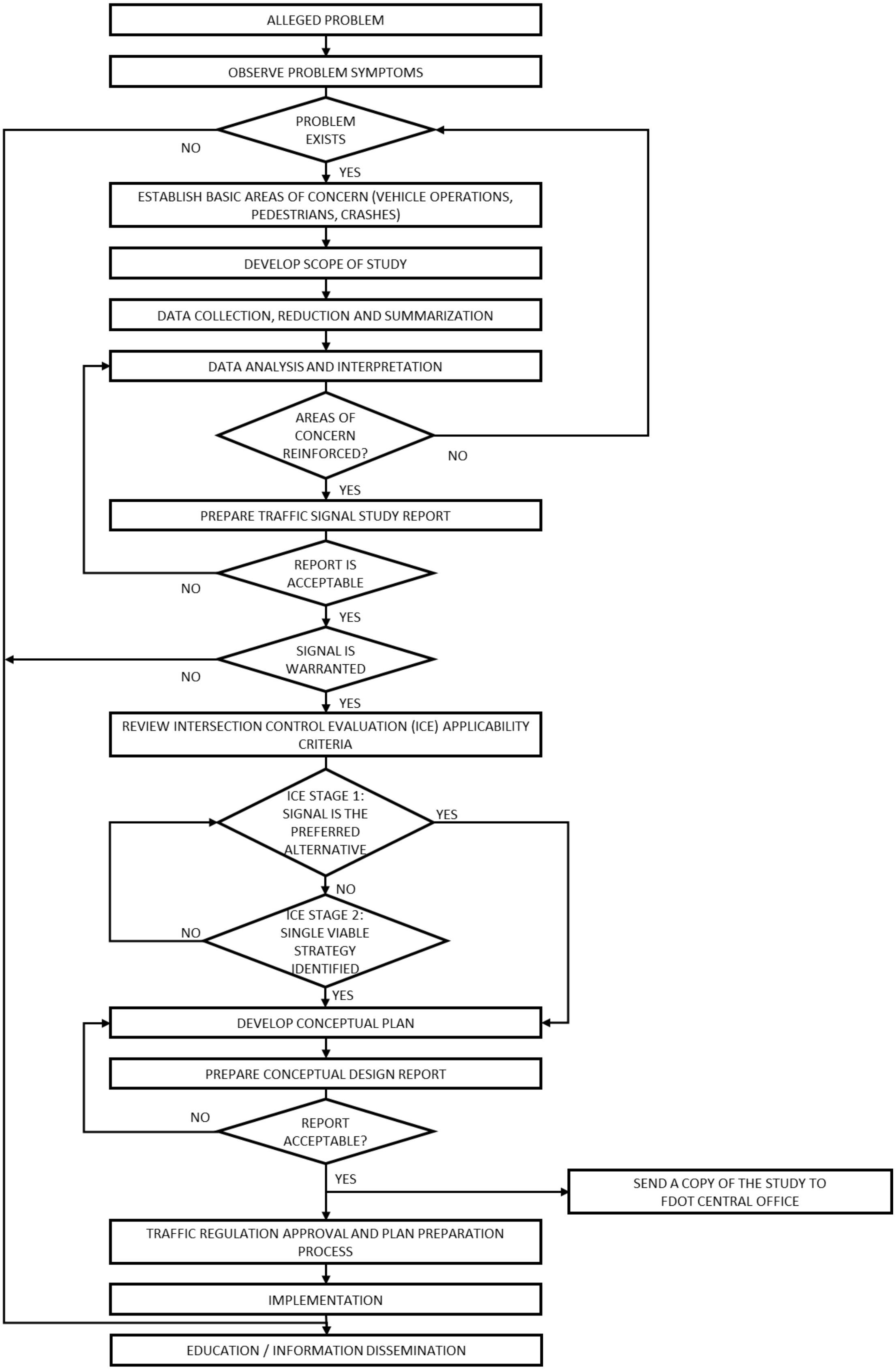


Figure 2-2. Detail of Study Procedure



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*** (see MUTS Chapter 5; Section 5.4.2) 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 as needed. 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 or other improvements 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 operations, 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 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 Operations

(1) A vehicle operations problem can normally be diagnosed during the field observation. Some of these characteristics include but are not limited to excessive queue lengths, slow queue dissipation rates, and large traffic volumes using the intersection.

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

- **(a)** Hourly approach volumes on an average day, as required for MUTCD Signal Warrants 1, 2, 3, 4, 7 and 8 (see MUTS Chapter 3). Right-turn volume reductions should be addressed per MUTS Chapter 3; Section 3.3.
- **(b)** Progressive Movement - distance to nearest signal greater than 1,000 feet as required for MUTCD Signal Warrant 6 (see MUTS Chapter 3; Section 3.10).
- **(c)** Intersection Delay Study (see MUTS Chapter 7).
- **(d)** Travel Time and Delay Study (see MUTS Chapter 13).

2.4.2 Pedestrian and/or Bicycle

(1) A pedestrian and/or bicycle problem can also be diagnosed through field observations. 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)** Non-motorized volume studies as required for MUTCD Signal Warrants 4 and 5. These studies are addressed under the MUTS Chapter 3; Sections 3.8 and 3.9, and MUTS Chapter 9 Non-Motorized Volume Studies.
- **(b)** Gap Study (see MUTS Chapter 8) as required for MUTCD Signal Warrant 4 (see MUTS Chapter 3; Section 3.8).
- **(c)** Distance to nearest crosswalk, or signalized intersection is greater than 300 feet as required for MUTCD Signal Warrant 4 (see MUTS Chapter 3; Section 3.8).
- **(d)** Pedestrians characteristics 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 historical 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. A minimum of five years of crash data should be reviewed, subject to any major changes to the site. Engineering judgment should be used to determine the required number of years to be considered if a major change to the site is reported. 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 as required for MUTCD Signal Warrants 1, 2, 3, 4, 7, and 8 (see MUTS Chapter 3)
- **(c)** Crash records/rates as required for MUTCD Signal Warrant 7 (see MUTS Chapter 3; Section 3.11)
- **(d)** Collision Diagram (see MUTS Chapter 5; Section 5.4.3.2)
- **(e)** Pedestrian Volume Counts (see MUTS Chapter 3; Sections 3.8, 3.9, and MUTS Chapter 9) as required for MUTCD Warrants 4 and 5
- **(f)** Vehicle Spot Speed Study (see MUTS Chapter 12)
- **(g)** Sight distances
- **(h)** Geometry: vertical and horizontal alignment
- **(i)** Pavement conditions for skid resistance
- **(j)** Roadside hazards
- **(k)** Existing guidance through signing and pavement 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 signal warrant analysis has been collected, it is the 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 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 MUTS Chapter 3. 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. Other 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
- **(g)** For existing signals, signal timing information should be obtained in advance of study.

(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. When a new traffic signal is considered, it is required to apply the FDOT Intersection Control Evaluation (ICE) process to evaluate alternative intersections by comparing the operations and safety performance of a standard signalized intersection to alternative intersections such as a roundabout, median U-turn (MUT) or restricted crossing U-turn (RCUT). Closely spaced intersections in high volume corridors could all meet volume warrants, but signals may not be the best solution at every cross street. For example, the engineer should consider pedestrian activity in the area as having additional signal protected pedestrian crosswalks in the area may be desirable. The benefits of these conditions need to be considered when evaluating a traffic signal applicability.

(5) Even when an intersection meets signal warrants, other intersection control alternatives may be preferred over a standard signalized intersection. The FDOT ICE Manual provides a process and the necessary tools to evaluate, compare and select the alternative intersection to best accommodate the intersection context and address the study intersection areas of concern. The ICE process follows a multi-stage approach in which Stage 1 reviews existing conditions and evaluates viable alternative intersection forms at a planning level. Stage 2 involves detailed operations and safety analysis to conduct a benefit-cost comparison of the viable alternative intersections.

(6) If the intersection is currently signalized, the signal timing information for the controller and system data should be obtained to conduct the signal modifications evaluation. Some of the signal operation and controller capabilities to pay attention to include: availability to code phasing modifications by time-of-day, protected vs protected + permitted by time-of-day, lead-lag operation, transit priority, emergency preemptions, etc.

(7) Engineering judgement should be applied when evaluating to modify an existing signalized intersection. Signal warrants may not be necessary for signal modification to existing signalized intersections.

2.7 PREPARATION AND APPROVAL OF TRAFFIC SIGNAL STUDY REPORT

(1) Proper documentation of all activities taking place from the initial allegation of a problem through the warrant analysis is required. A traffic signal study report including 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) (see MUTS Chapter 5; Section 5.4.2)

(d) Crash Analysis and Collision Diagram (see MUTS Chapter 5; Section 5.4.3.1)

(e) If applicable, discussion of Signal Warrant Analysis (may not be needed if the existing intersection is signalized)

(f) If applicable, discussion of ICE analysis to include approved Stage 1 and Stage 2 ICE Forms showing the traffic signal to be the best improvement alternative (ICE may not be needed if the existing intersection is signalized)

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

(h) Recommendations (including sketch if applicable)

(i) 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:

(a) No problem exists and therefore no traffic signal is warranted;

(b) A problem exists, but the solution is not a traffic signal;

(c) A problem exists, and a traffic signal will correct or reduce the problem; or

(d) 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 should be initiated to resolve the problem, and proper notification should be given. In the third or fourth case, the ICE process should be initiated to resolve the problem, and proper notification should be given. 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.

(4) If a new signal is warranted, the ICE procedure as described in the FDOT ICE Manual should be followed to determine if a traditional traffic signal is the preferred alternative. ICE Stage 1 should be completed to identify the viable alternatives. The ICE Stage 1 Form should be submitted for review and approval by the FDOT District Traffic Operations Engineer (DTOE) and District Design Engineer (DDE). If only one alternative is identified to be viable, the ICE procedure should terminate upon the completion of Stage 1. If multiple alternatives are determined to be viable alternatives at completion of Stage 1, Stage 2 ICE should be conducted as described in the FDOT ICE manual.

(5) Following the completion of ICE Stage 2, the ICE Stage 2 Form should be submitted for review and approval by the FDOT DTOE and DDE. For MUT and RCUT intersection forms, a separate signal warrant analysis is not required for the signalized intersections supporting the U-turn movements. These two locations are considered part of the main study intersection approval. Following the completion of Stage 2 and approval of the preferred alternative by the DTOE and DDE the remainder of this chapter should be reviewed to ensure the work completed in ICE Stage 2 meets the requirements of this chapter. If work conducted as part of ICE does not meet the requirements of this chapter, complete the necessary requirements as outlined in the remainder of the chapter.

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 existing signal operations modification is identified. 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 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 turning movement counts. An example is an update of non-motorized 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 most recent 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 with adjacent intersections. The Engineer of Record should be responsible for any analysis 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 (benefit-cost ratio and net present value) should be conducted before proceeding to the new signal implementation stage. If ICE Stage 1 selected the traffic signal as the preferred alternative, it is recommended ICE Stage 2 be done to conduct this economic analysis for the no-build and traffic signal alternatives only. If the traffic signal (or other alternative intersections having a traffic signal) was selected as the preferred alternative in Stage 2, use the Stage 2 economic analysis.

(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) If ICE was conducted as part of the analysis the approved Stage 1, and if applicable, Stage 2 ICE Forms should be included in the report.

(3) 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.

(4) Once the study has been completed, a copy should be emailed to FDOT Central Office.

2.10 IMPLEMENTATION

(1) Implementation of the improvement should take place as soon as possible after the project development and design report are completed. Conditions change with time, and if too much time lapses before implementation, it may be necessary to repeat the entire traffic signal study. 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-e 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 analysis from 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.

(2) 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 documented. Alternatives to traffic control signals should be considered. Section 4B.04 of the MUTCD provides a list of possible alternatives.

(3) 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.

(4) 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 met before a traffic signal installation is considered.

3.2 THE TRAFFIC SIGNAL WARRANT SUMMARY

(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 *Instructions & Input* tab. The data completed electronically in the *Instructions & Input* tab will be automatically carried over to the Warrant sheets, as applicable. Samples of each warrant are shown as ***Figure 3-2*** through ***Figure 3-10****.*

(3) The orange highlighted cells and checkboxes shall be completed, starting with Page 2 of the *Instructions & Input* tab. The general intersection information completed in the *Instructions & Input* tab is carried over to all warrants and the summary checklist. The volumes to be completed in the *Instructions & Input* tab are carried over to the applicable warrants only.

(4) 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 tab at the end of the form. ***Figure 3-11*** shows an example of this tab completed.

(5) 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

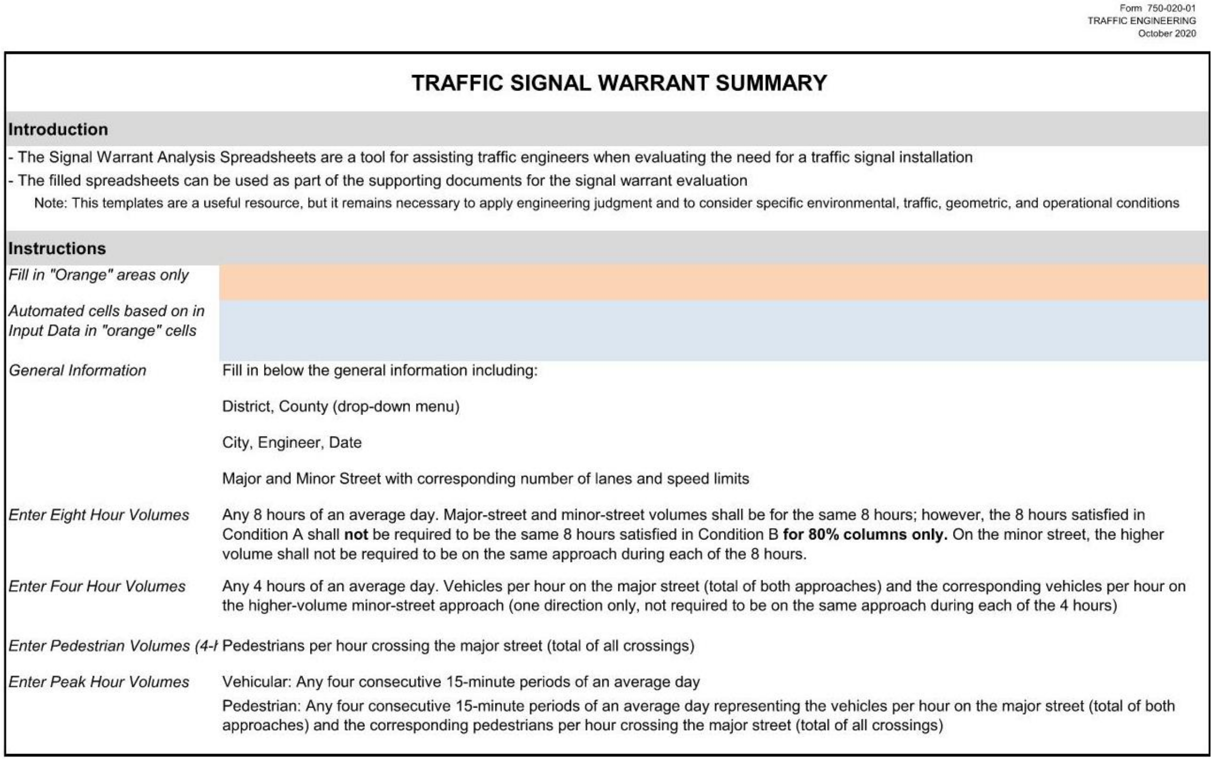
Warrant 6, Coordinated Signal System

Warrant 7, Crash Experience

Warrant 8, Roadway Network

Warrant 9, Intersection near a Grade Crossing

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



Form 750-020-01
TRAFFIC ENGINEERING
October 2020

TRAFFIC SIGNAL WARRANT SUMMARY

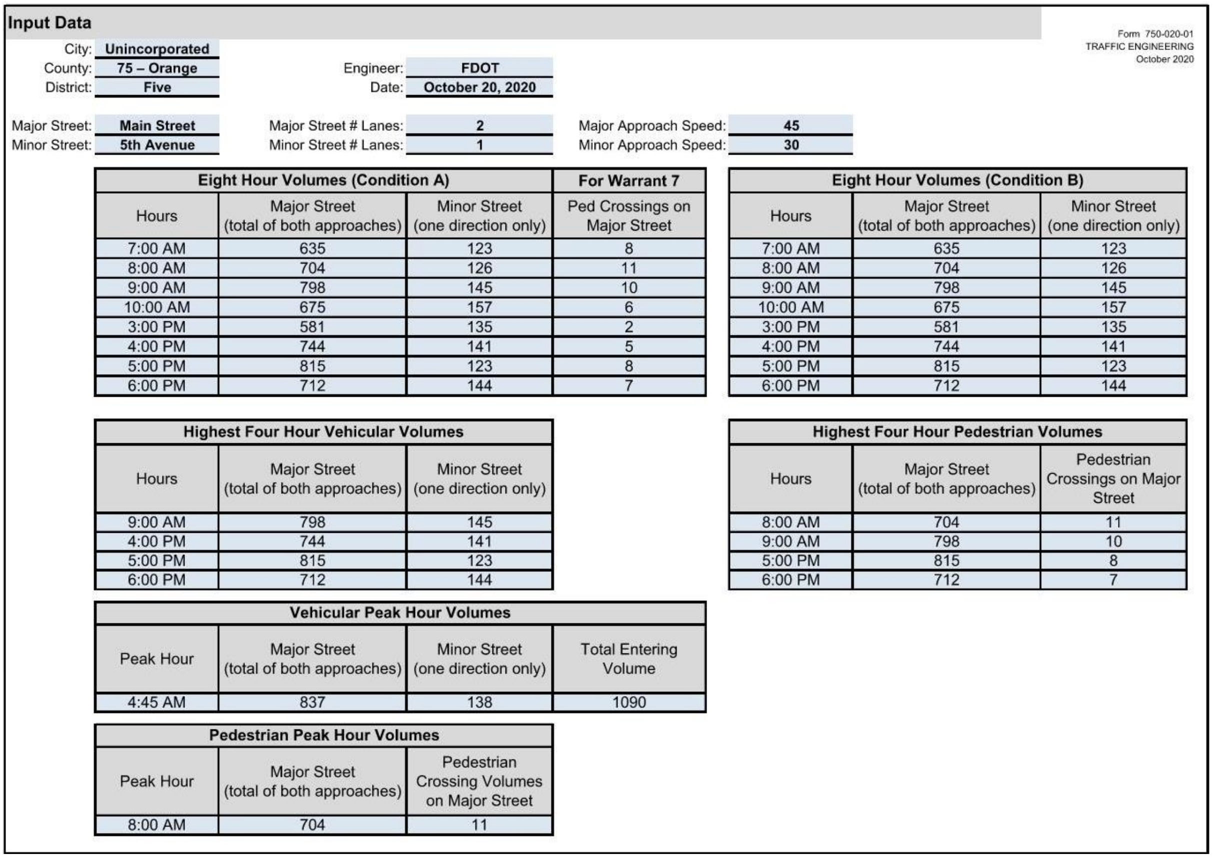
Introduction

- 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-I	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
October 2020

City: **Unincorporated**
County: **75 – Orange**
District: **Five**

Engineer: **FDOT**
Date: **October 20, 2020**

Major Street: **Main Street**
Minor Street: **5th Avenue**

Major Street # Lanes: **2**
Minor Street # Lanes: **1**

Major Approach Speed: **45**
Minor Approach Speed: **30**

Eight Hour Volumes (Condition A)			**For Warrant 7**
Hours	Major Street (total of both approaches)	Minor Street (one direction only)	Ped Crossings on Major Street
7:00 AM	635	123	8
8:00 AM	704	126	11
9:00 AM	798	145	10
10:00 AM	675	157	6
3:00 PM	581	135	2
4:00 PM	744	141	5
5:00 PM	815	123	8
6:00 PM	712	144	7

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
3:00 PM	581	135
4:00 PM	744	141
5:00 PM	815	123
6:00 PM	712	144

Highest Four Hour Vehicular Volumes		
Hours	Major Street (total of both approaches)	Minor Street (one direction only)
9:00 AM	798	145
4:00 PM	744	141
5:00 PM	815	123
6:00 PM	712	144

Highest Four Hour Pedestrian Volumes		
Hours	Major Street (total of both approaches)	Pedestrian Crossings on Major Street
8:00 AM	704	11
9:00 AM	798	10
5:00 PM	815	8
6:00 PM	712	7

Vehicular Peak Hour Volumes			
Peak Hour	Major Street (total of both approaches)	Minor Street (one direction only)	Total Entering Volume
4:45 AM	837	138	1090

Pedestrian Peak Hour Volumes		
Peak Hour	Major Street (total of both approaches)	Pedestrian Crossing Volumes on Major Street
8:00 AM	704	11

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 traffic volumes should be the actual Turning Movement Counts (TMCs) 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.

(2) If the posted, statutory, or 85th percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the 70% volumes thresholds or 70% Factor may be used for Warrants 1, 2, and 3. For Warrant 4, the criteria to use the 70% volumes thresholds should be based on the posted, statutory, or 85th percentile speed on the major street exceeding 35 mph.

Form No. 750-020-01 allows the engineer to document if these criteria are met, and automatically checks the 70% option when either criteria are marked as 'Yes'. The engineer may or may not choose to make use of the 70% reduced volume thresholds and has the flexibility to continue with the 100% and 80% thresholds where applicable. If the engineer is using the electronic form and would like to make use of the 70% reduced volumes, the *MAY* checkbox has to be checked to auto-populate the corresponding input from the *Instructions & Input* tab.

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.

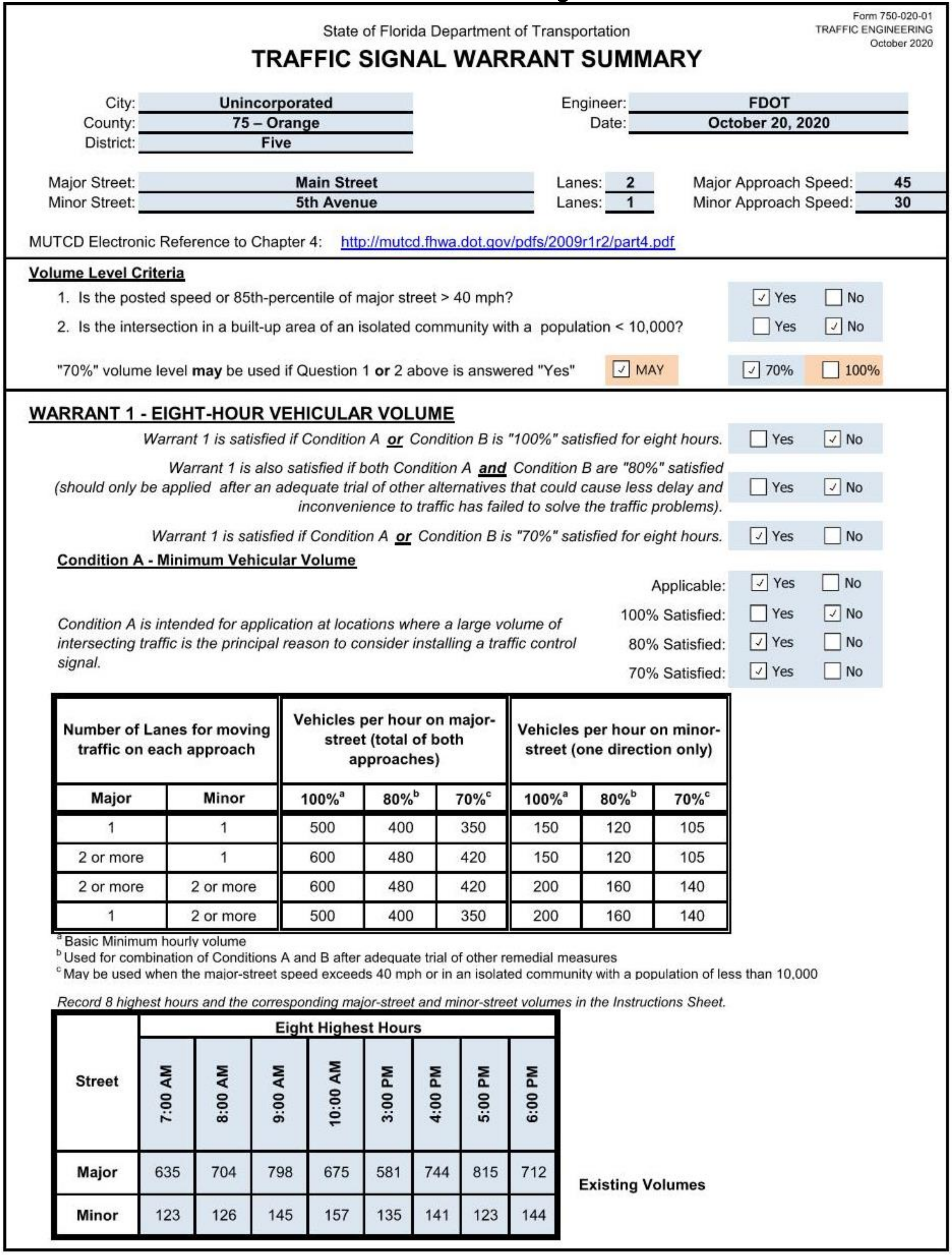
(2) Under circumstances where Conditions A or B for the 100% volume threshold columns are not satisfied for a specific location, the combination of Conditions A and B can be applied. This combination lowers the volume threshold recommended for traffic signal installation but requires both, Conditions A and B, to be met. Both volume thresholds 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 used shall be 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 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% volumes for the combination of Conditions A and B is not allowed on an intersection along the state highway system.

(4) If the posted, statutory, or 85th percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the 70% volumes thresholds may be used for this warrant.

Form No. 750-020-01 allows the engineer to document if these criteria are met, and automatically checks the 70% option when either criteria are positive. The engineer may or may not choose to make use of the 70% reduced volume thresholds and has the flexibility to remain with the 100% and 80% volume thresholds. If the engineer is using the electronic form and would like to make use of the 70% reduced volumes, the *MAY* checkbox will have to be checked to auto-populate the corresponding input from the *Instructions & Input* tab.

Figure 3-2. Eight Hour Vehicular Volume
Condition A – Page 1



Form 750-020-01
TRAFFIC ENGINEERING
October 2020

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **75 – Orange**
District: **Five**

Engineer: **FDOT**
Date: **October 20, 2020**

Major Street: **Main Street** Lanes: **2** Major Approach Speed: **45**
Minor Street: **5th Avenue** Lanes: **1** 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? ☑ 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" ☑ MAY ☑ 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

Warrant 1 is satisfied if Condition A ***or*** *Condition B is "70%" satisfied for eight hours.* ☑ 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.

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	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

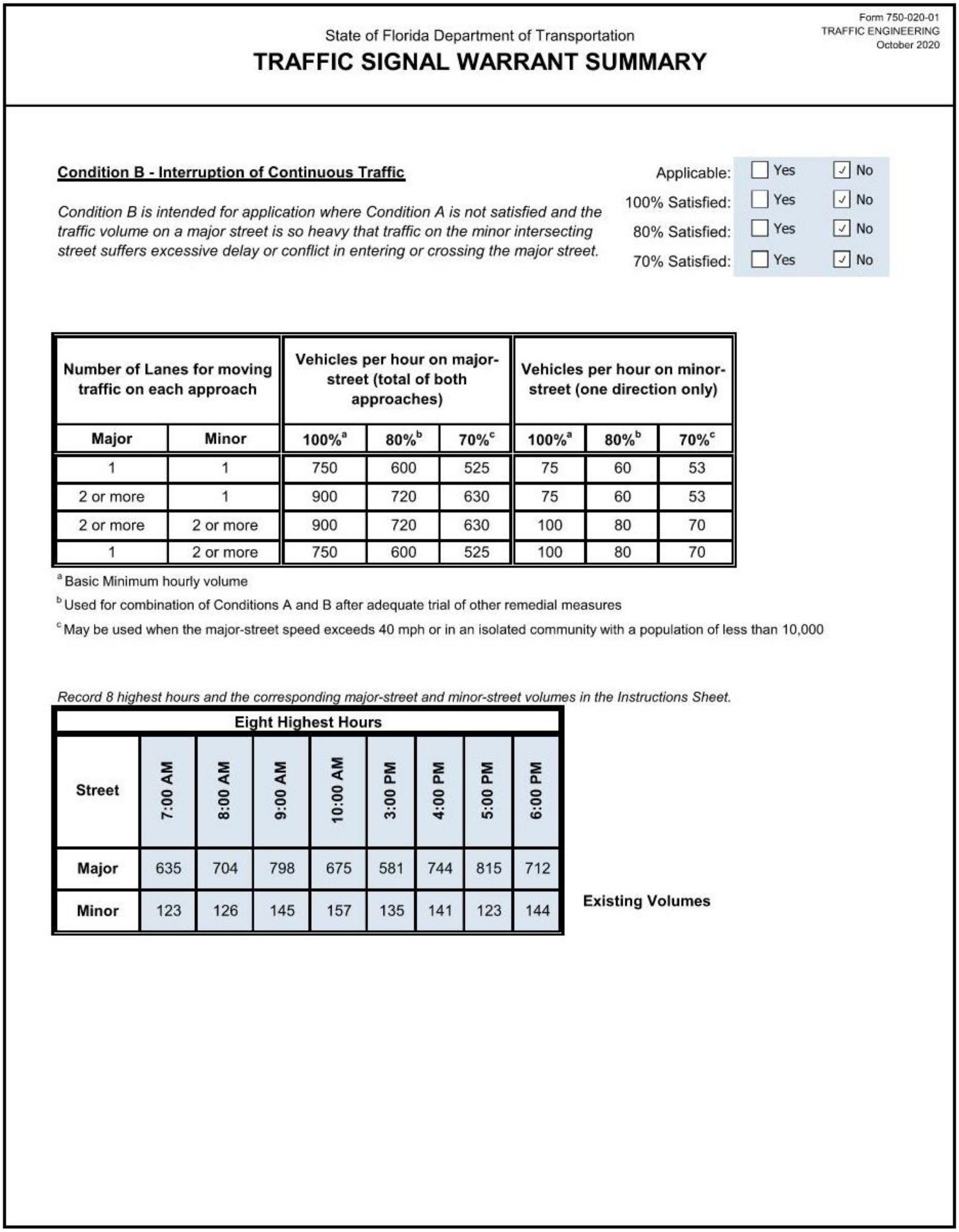
[a] Basic Minimum hourly volume
[b] Used for combination of Conditions A and B after adequate trial of other remedial measures
[c] May be used when the major-street speed exceeds 40 mph or in an isolated community with a population of less than 10,000

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	3:00 PM	4:00 PM	5:00 PM	6:00 PM
Major	635	704	798	675	581	744	815	712
Minor	123	126	145	157	135	141	123	144

Existing Volumes

Condition B – Page 2



Form 750-020-01
TRAFFIC ENGINEERING
October 2020

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

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**	**3:00 PM**	**4:00 PM**	**5:00 PM**	**6:00 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) If the posted, statutory, or 85th percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the 70% volumes thresholds or 70% Factor may be used for this warrant.

Form No. 750-020-01 allows the engineer to document if these criteria are met, and automatically checks the 70% option when either criteria are positive. The engineer may or may not choose to make use of the 70% reduced volume thresholds and has the flexibility to remain with the 100% volume thresholds. If the engineer is using the electronic form and would like to make use of the 70% reduced volumes, the *MAY* checkbox will have to be checked to auto-populate the corresponding input from the *Instructions & Input* tab.

3.7 WARRANT 3: PEAK HOUR

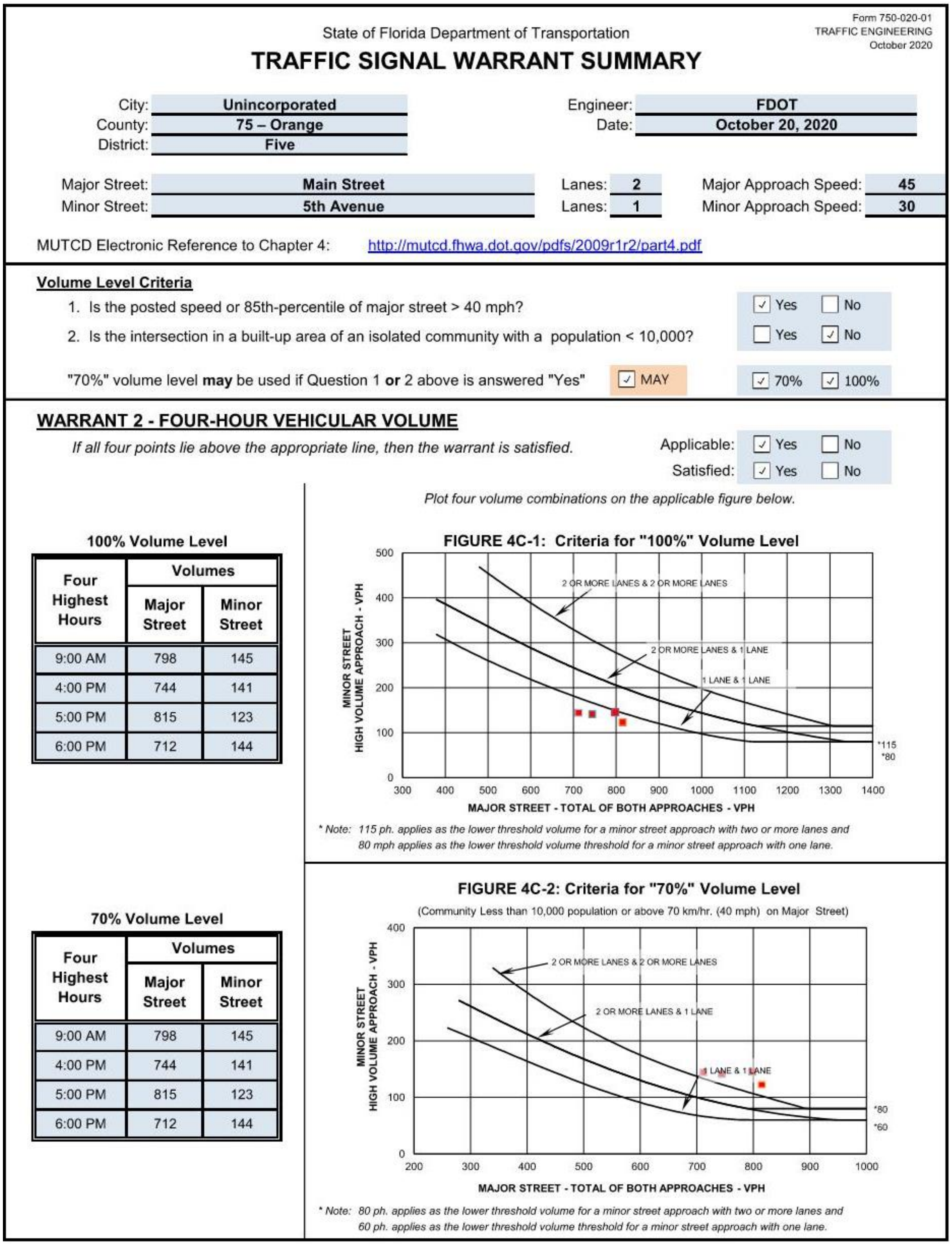
(1) The Peak Hour signal warrant is intended for use at a location where traffic conditions are such that for a minimum of 1 hour of an average day, the minor street traffic suffers undue delay when entering or crossing the major street. This signal warrant shall be applied only in unusual cases, such 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.

(4) If the posted, statutory, or 85th percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the 70% volumes thresholds may be used for this warrant. If the engineer is using the electronic form and would like to make use of the 70% reduced volumes, the MAY checkbox will have to be checked to auto-populate the corresponding input from the *Instructions & Input* tab.

Figure 3-3. Four-Hour Vehicular Volume



Form 750-020-01
TRAFFIC ENGINEERING
October 2020

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **75 – Orange**
District: **Five**
Engineer: **FDOT**
Date: **October 20, 2020**

Major Street: **Main Street** Lanes: **2** Major Approach Speed: **45**
Minor Street: **5th Avenue** Lanes: **1** 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? ☑ 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" ☑ MAY ☑ 70% ☑ 100%

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
9:00 AM	798	145
4:00 PM	744	141
5:00 PM	815	123
6:00 PM	712	144

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

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

70% Volume Level

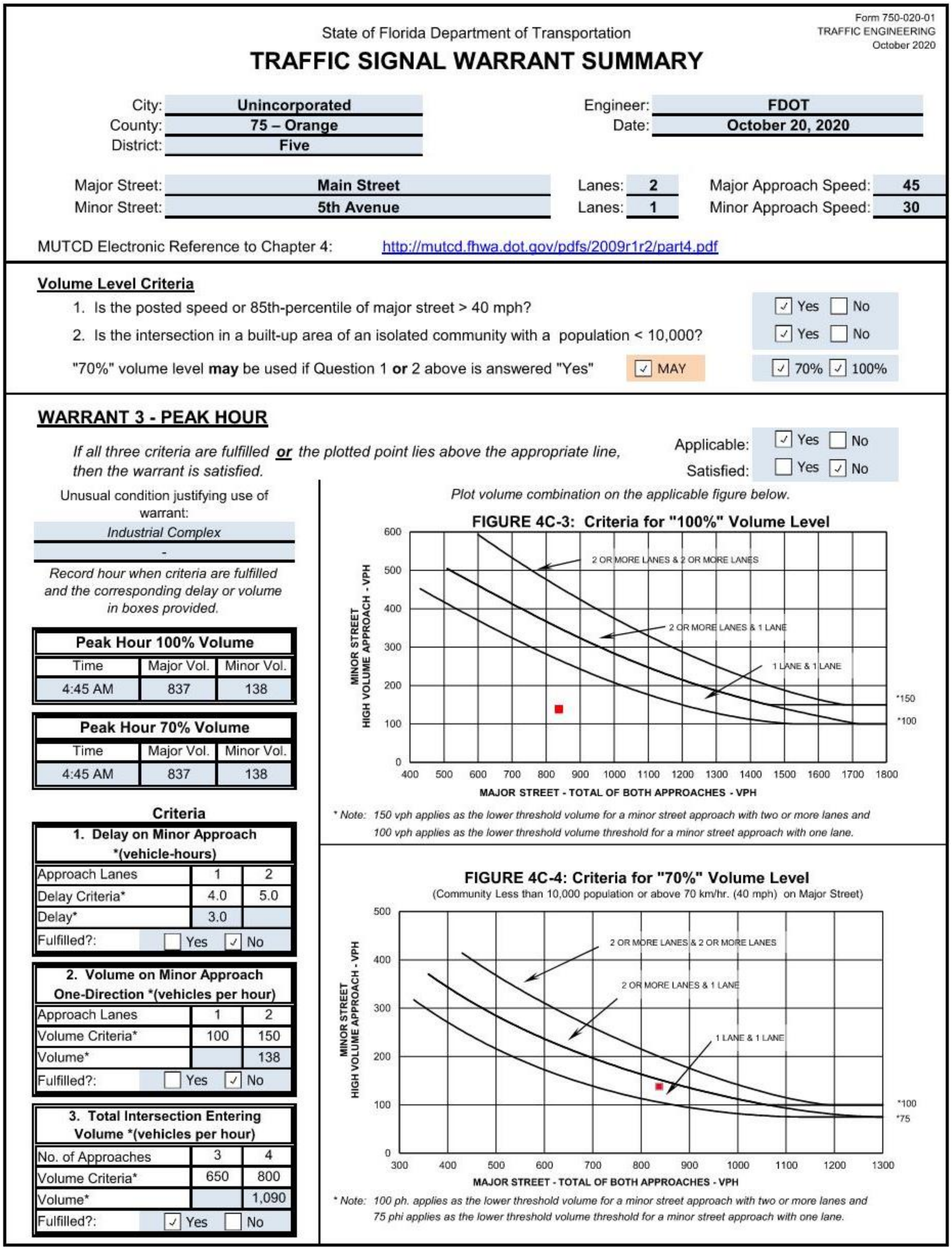
Four Highest Hours	Volumes	
	Major Street	Minor Street
9:00 AM	798	145
4:00 PM	744	141
5:00 PM	815	123
6:00 PM	712	144

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 ph. applies as the lower threshold volume for a minor street approach with two or more lanes and 60 ph. applies as the lower threshold volume threshold for a minor street approach with one lane.*

Figure 3-4. Peak Hour



Form 750-020-01
TRAFFIC ENGINEERING
October 2020

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **75 – Orange**
District: **Five**
Engineer: **FDOT**
Date: **October 20, 2020**

Major Street: **Main Street** Lanes: **2** Major Approach Speed: **45**
Minor Street: **5th Avenue** Lanes: **1** 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? ☑ 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" ☑ MAY ☑ 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.
4:45 AM	837	138

Peak Hour 70% Volume		
Time	Major Vol.	Minor Vol.
4:45 AM	837	138

Criteria

1. Delay on Minor Approach *(vehicle-hours)		
Approach Lanes	1	2
Delay Criteria*	4.0	5.0
Delay*	3.0	
Fulfilled?:	☐ Yes	☑ No

2. Volume on Minor Approach One-Direction *(vehicles per hour)		
Approach Lanes	1	2
Volume Criteria*	100	150
Volume*		138
Fulfilled?:	☐ Yes	☑ No

3. Total Intersection Entering Volume *(vehicles per hour)		
No. of Approaches	3	4
Volume Criteria*	650	800
Volume*		1,090
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 ph. applies as the lower threshold volume for a minor street approach with two or more lanes and 75 phi 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 from the MUTCD)

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

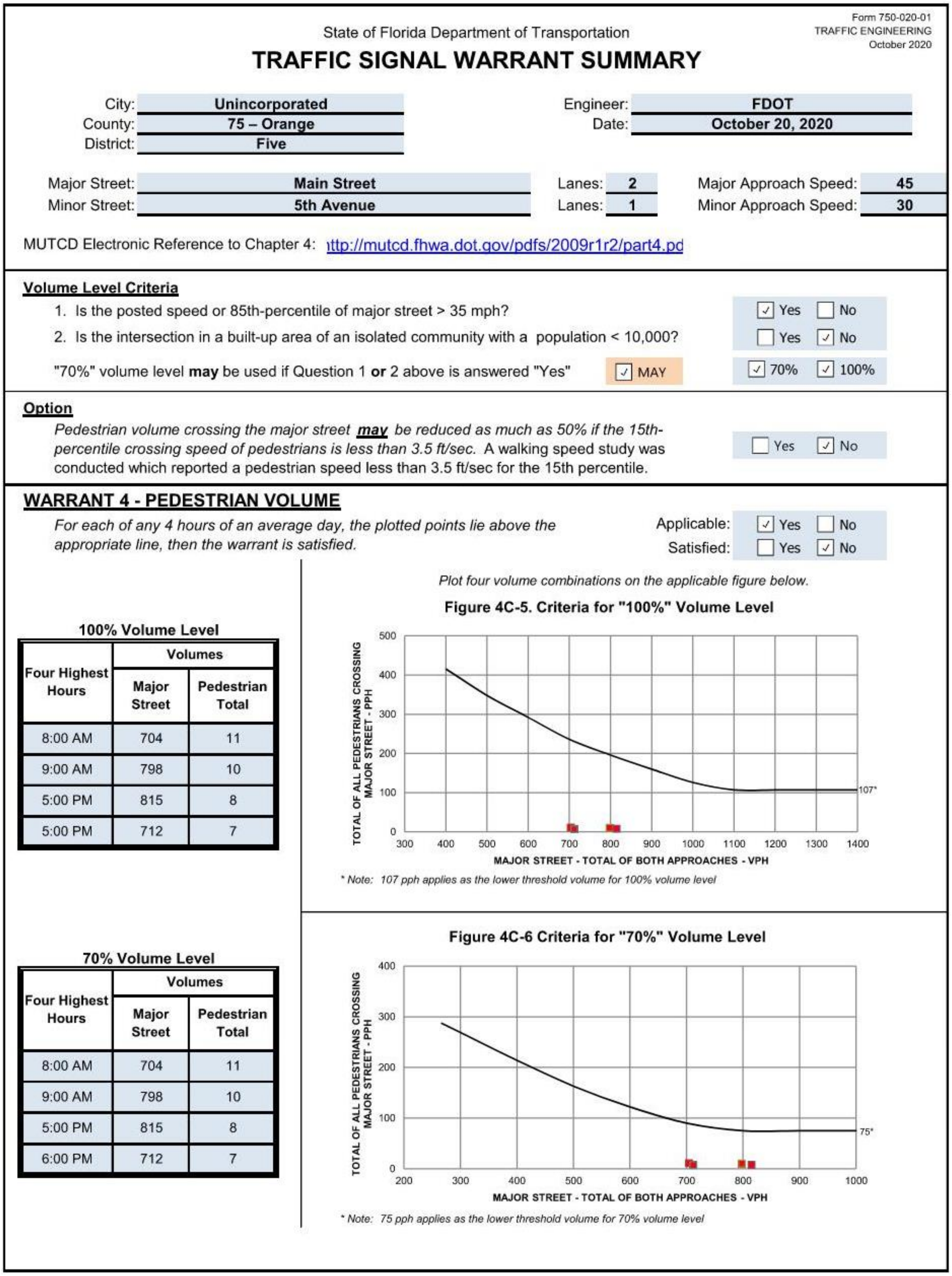
(3) The total pedestrians crossing the major street along with the major street traffic volume should be plotted on Figure 4C-5 or 4C-7 from the MUTCD, depending on the criterion being evaluated. If the posted, statutory, or 85th percentile speed on the major street exceeds 35 mph, or if the intersection 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*** 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.

(5) If the posted, statutory, or 85th percentile speed on the major street exceeds 40 mph, or if the intersection lies within the built-up area of an isolated community having a population of less than 10,000, the 70% volumes thresholds or 70% Factor may be used for this warrant.

If the engineer is using the electronic form and would like to make use of the 70% reduced volumes, the *MAY* checkbox will have to be checked to auto-populate the corresponding input from the *Instructions & Input* tab.

Figure 3-5. Pedestrian Volume
Four-Hour – Page 1



Form 750-020-01
TRAFFIC ENGINEERING
October 2020

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **75 – Orange**
District: **Five**
Engineer: **FDOT**
Date: **October 20, 2020**

Major Street: **Main Street**
Lanes: **2**
Major Approach Speed: **45**
Minor Street: **5th Avenue**
Lanes: **1**
Minor Approach Speed: **30**

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

Volume Level Criteria

1. Is the posted speed or 85th-percentile of major street > 35 mph? ☑ 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" ☑ MAY ☑ 70% ☑ 100%

Option

Pedestrian volume crossing the major street ***may*** *be reduced as much as 50% if the 15th-percentile crossing speed of pedestrians is less than 3.5 ft/sec.* A walking speed study was conducted which reported a pedestrian speed less than 3.5 ft/sec for the 15th percentile. ☐ Yes ☑ No

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
8:00 AM	704	11
9:00 AM	798	10
5:00 PM	815	8
5:00 PM	712	7

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

* *Note: 107 pph applies as the lower threshold volume for 100% volume level*

70% Volume Level

Four Highest Hours	Volumes	
	Major Street	Pedestrian Total
8:00 AM	704	11
9:00 AM	798	10
5:00 PM	815	8
6:00 PM	712	7

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

* *Note: 75 pph applies as the lower threshold volume for 70% volume level*

One-Hour – Page 2

Form 750-020-01
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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
8:00 AM	704	11

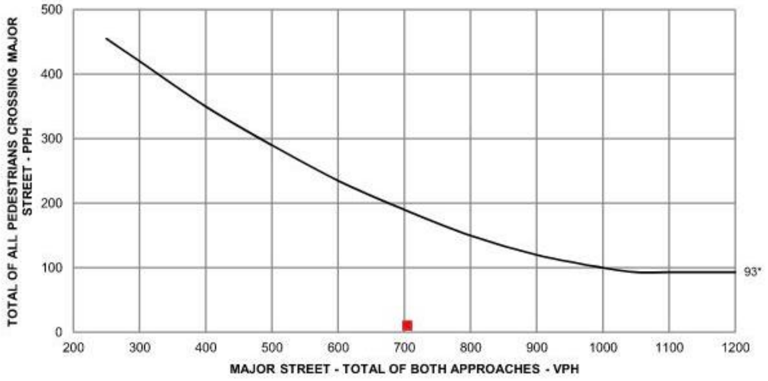
Figure 4C-7. Criteria for "100%" Volume Level - Peak Hour

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

70% Volume Level

Peak Hour	Volumes	
	Major Street	Pedestrian Total
8:00 AM	704	11

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



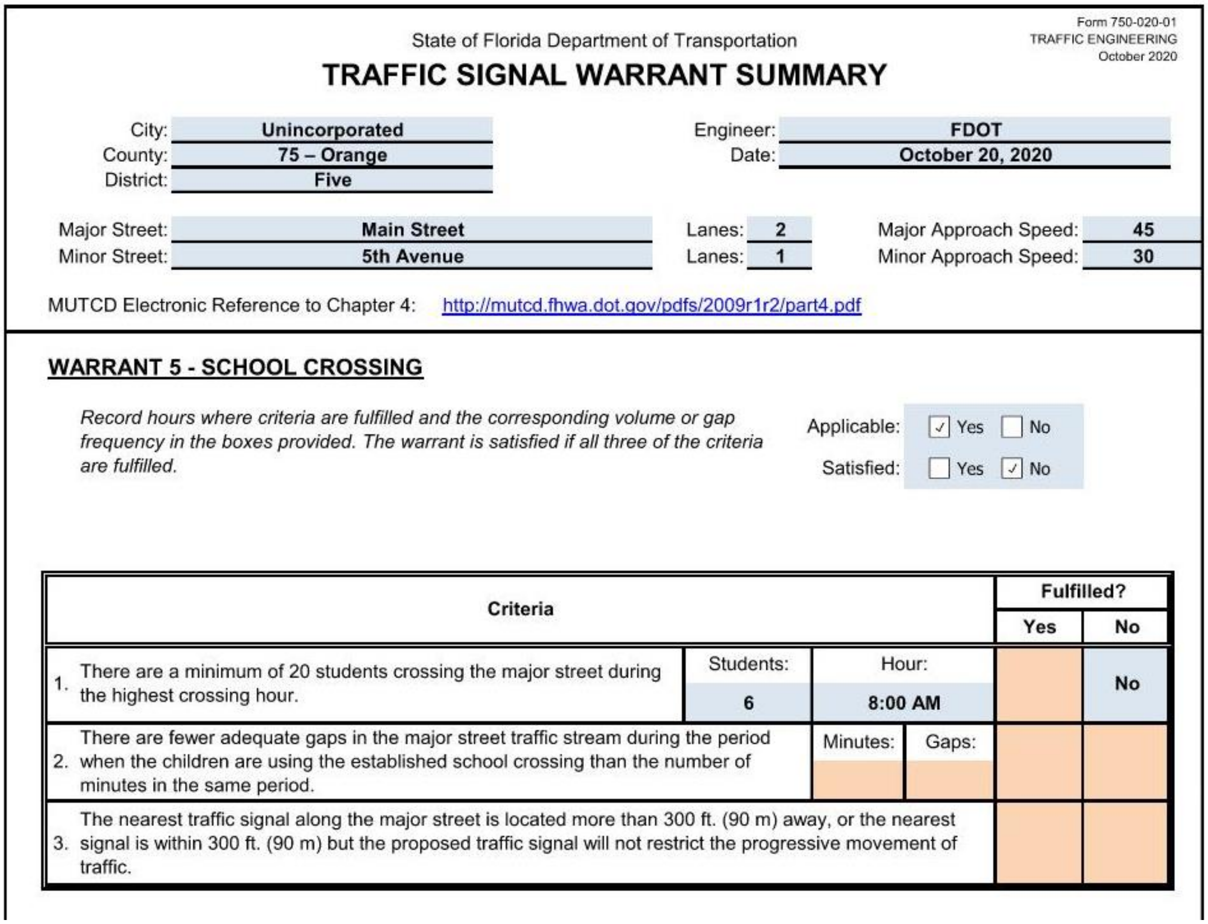
* *Note: 93 pph applies as the lower threshold volume*

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 3-6*** shows the portion of Form No. 750-020-01 that must be completed to satisfy this warrant.

Figure 3-6. School Crossing



Form 750-020-01
TRAFFIC ENGINEERING
October 2020

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **75 – Orange**
District: **Five**

Engineer: **FDOT**
Date: **October 20, 2020**

Major Street: **Main Street** Lanes: **2** Major Approach Speed: **45**
Minor Street: **5th Avenue** Lanes: **1** 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

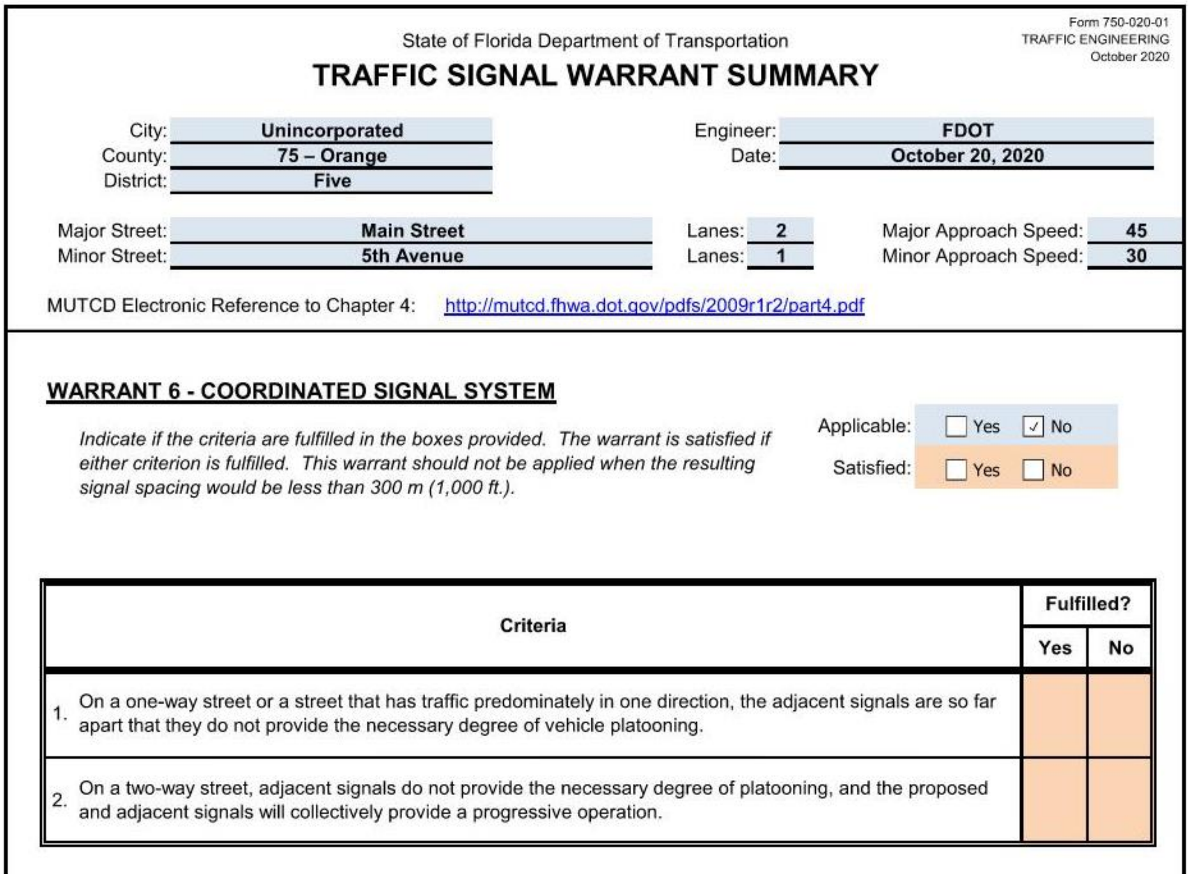
	Criteria			**Fulfilled?**	
				Yes	**No**
1.	There are a minimum of 20 students crossing the major street during the highest crossing hour.	Students: **6**	Hour: **8:00 AM**		**No**
2.	There are fewer adequate gaps in the major street traffic stream during the period when the children are using the established school crossing than the number of minutes in the same period.	Minutes:	Gaps:		
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.				

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

Figure 3-7. Coordinated Signal System



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October 2020

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **75 – Orange**
District: **Five**

Engineer: **FDOT**
Date: **October 20, 2020**

Major Street: **Main Street** Lanes: **2** Major Approach Speed: **45**
Minor Street: **5th Avenue** Lanes: **1** 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: ☐ Yes ☑ No
Satisfied: ☐ Yes ☐ 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.		
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.		

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

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

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***.***

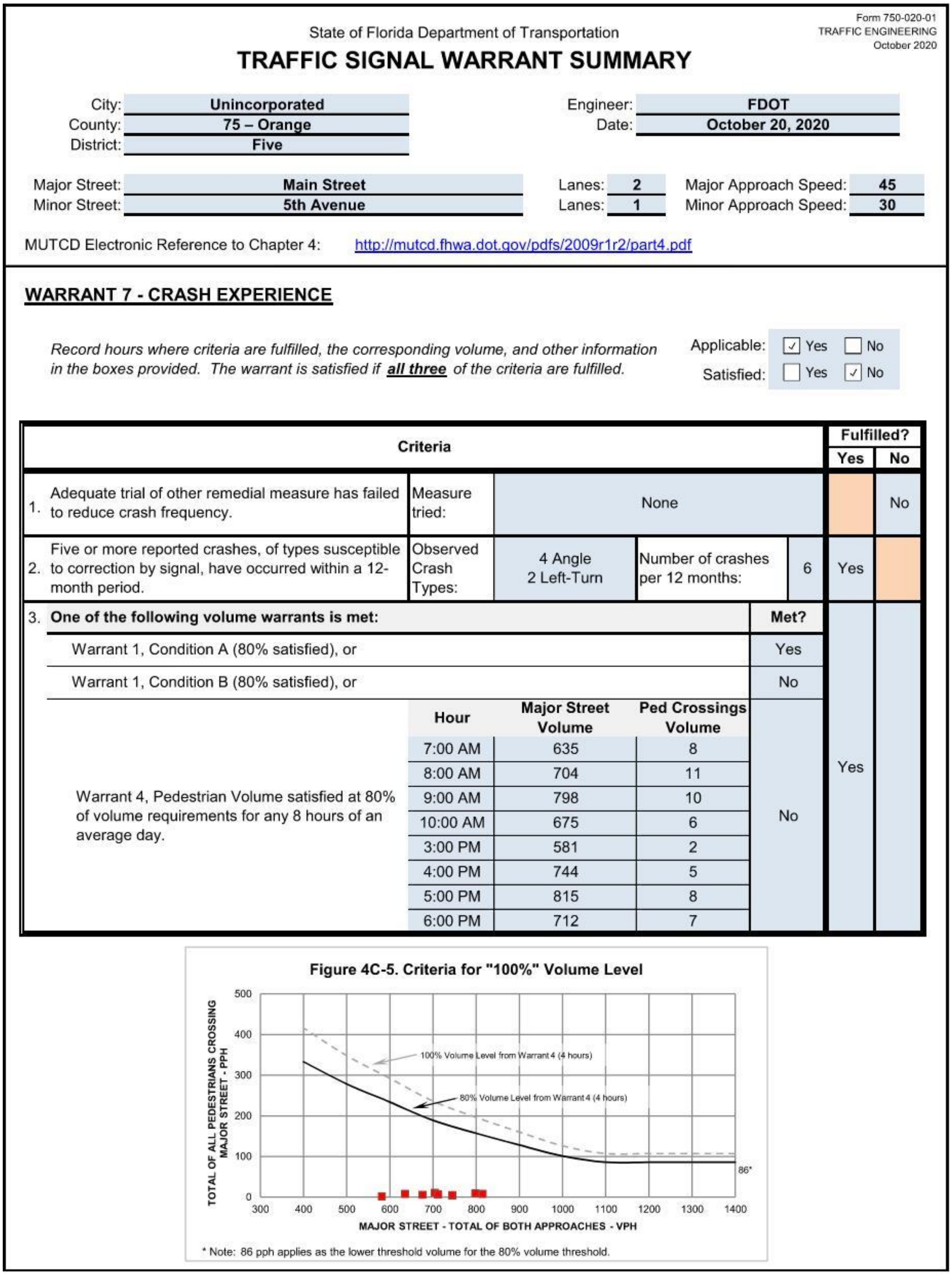
(2) ***Figure 3-10*** shows the portion of Form No. 750-020-01 that must be completed to satisfy this warrant.

(3) ***Figure 3-11*** 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 allows 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 3-8. Crash Experience



Form 750-020-01
TRAFFIC ENGINEERING
October 2020

State of Florida Department of Transportation

TRAFFIC SIGNAL WARRANT SUMMARY

City: **Unincorporated**
County: **75 – Orange**
District: **Five**
Engineer: **FDOT**
Date: **October 20, 2020**

Major Street: **Main Street** Lanes: **2** Major Approach Speed: **45**
Minor Street: **5th Avenue** Lanes: **1** 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

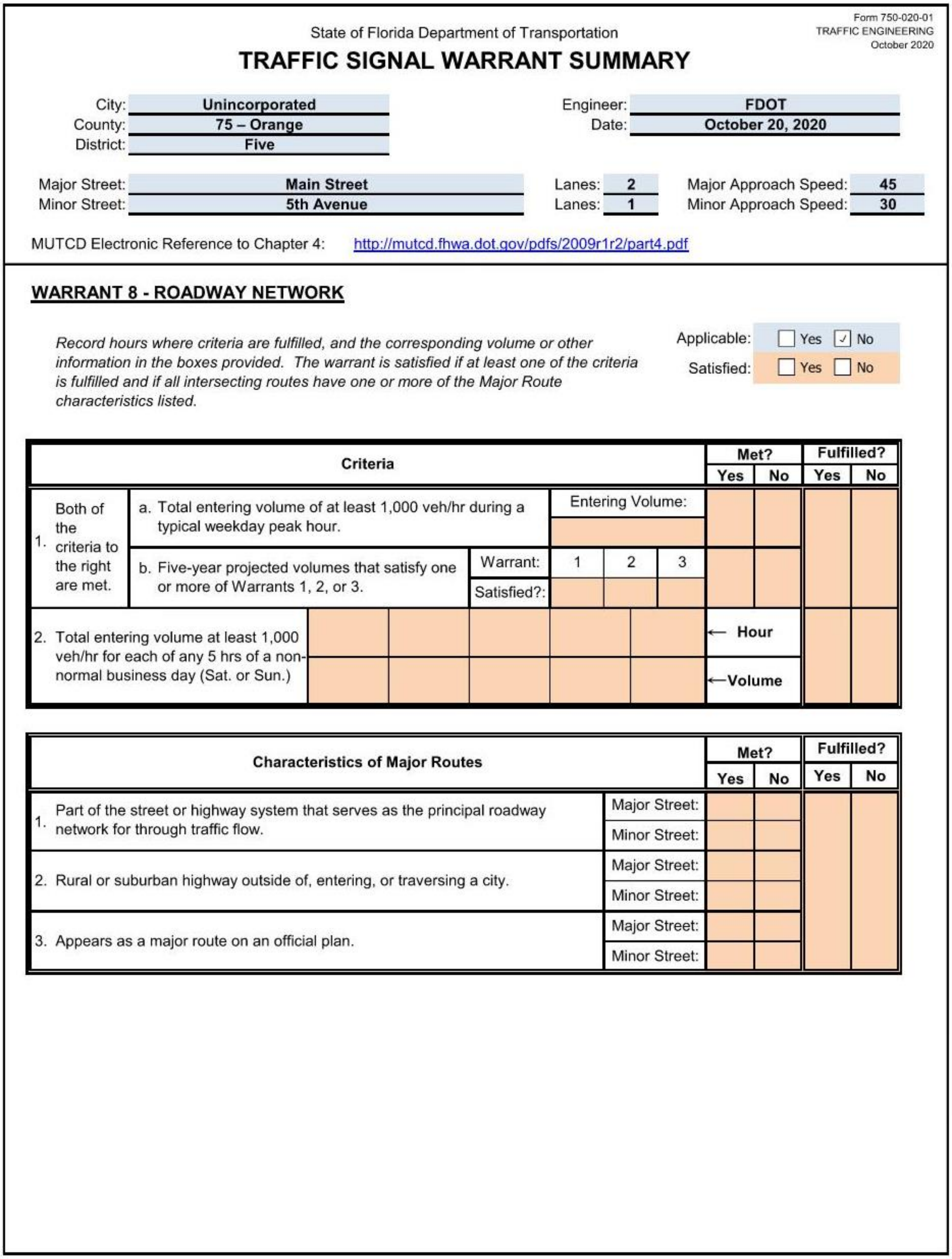
	Criteria					**Fulfilled? Yes**	**No**
1.	Adequate trial of other remedial measure has failed to reduce crash frequency.	Measure tried:	None				No
2.	Five or more reported crashes, of types susceptible to correction by signal, have occurred within a 12-month period.	Observed Crash Types:	4 Angle 2 Left-Turn	Number of crashes per 12 months:	6	Yes	
3.	**One of the following volume warrants is met:**				**Met?**	Yes	
	Warrant 1, Condition A (80% satisfied), or				Yes		
	Warrant 1, Condition B (80% satisfied), or				No		
	Warrant 4, Pedestrian Volume satisfied at 80% of volume requirements for any 8 hours of an average day.				No		

Hour	**Major Street Volume**	**Ped Crossings Volume**
7:00 AM	635	8
8:00 AM	704	11
9:00 AM	798	10
10:00 AM	675	6
3:00 PM	581	2
4:00 PM	744	5
5:00 PM	815	8
6:00 PM	712	7

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

* Note: 86 pph applies as the lower threshold volume for the 80% volume threshold.

Figure 3-9. Roadway Network



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WARRANT 8 - ROADWAY NETWORK

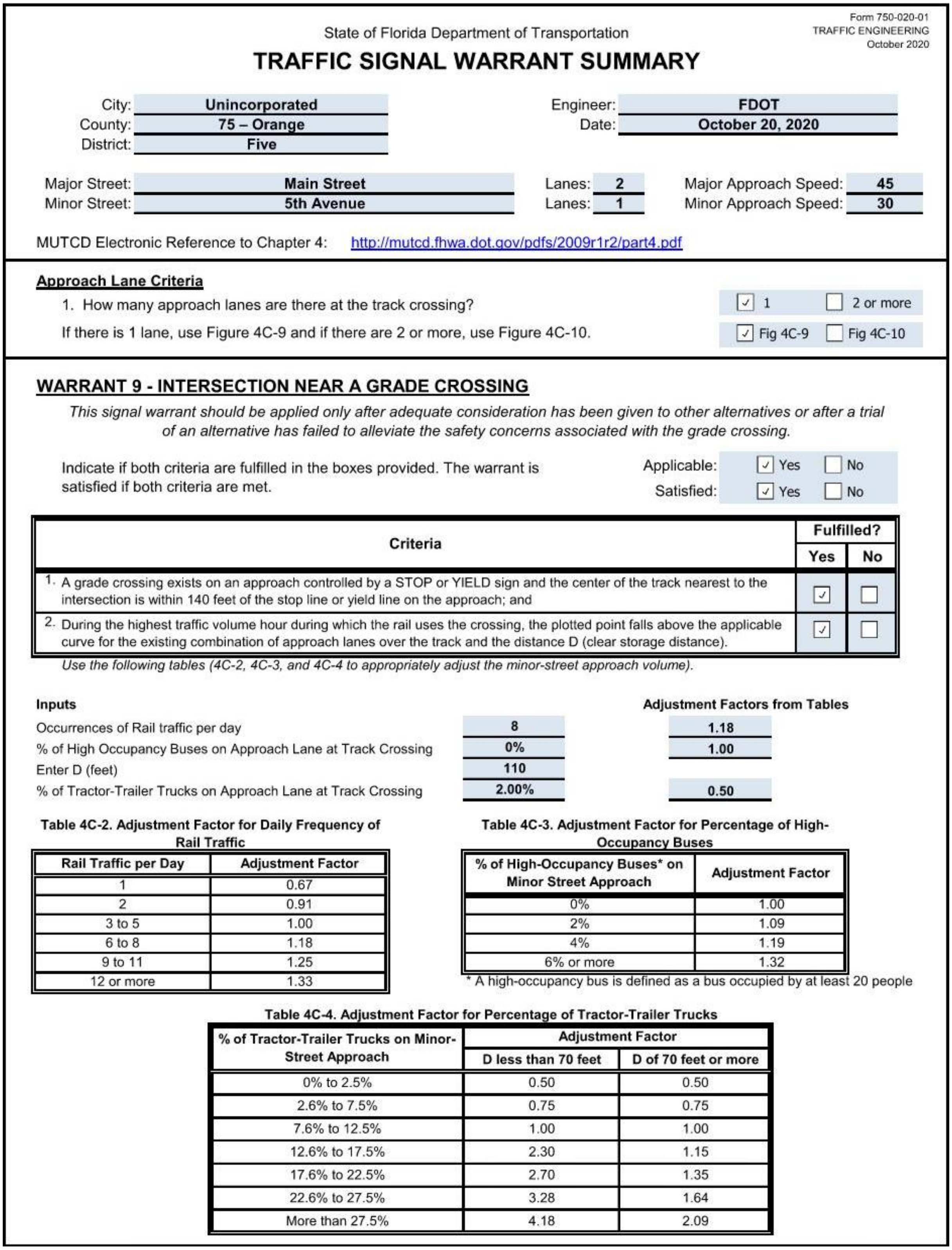
Record hours where criteria are fulfilled, and the corresponding volume or other information in the boxes provided. The warrant is satisfied if at least one of the criteria is fulfilled and if all intersecting routes have one or more of the Major Route characteristics listed.

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:									
	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**				
							←**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:				
	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:				

Figure 3-10. Intersection Near Grade Crossing
Page 1



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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 more

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	8	1.18
% of High Occupancy Buses on Approach Lane at Track Crossing	0%	1.00
Enter D (feet)	110	
% of Tractor-Trailer Trucks on Approach Lane at Track Crossing	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

Page 2

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TRAFFIC ENGINEERING
October 2020

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

1 Approach Lane		
110	815	123
D (ft)	Major Vol.	Minor Vol.

After adjustment factors are applied

1 Approach Lane w/Factors		
110	815	73
D (ft)	Major Vol.	Minor Vol.

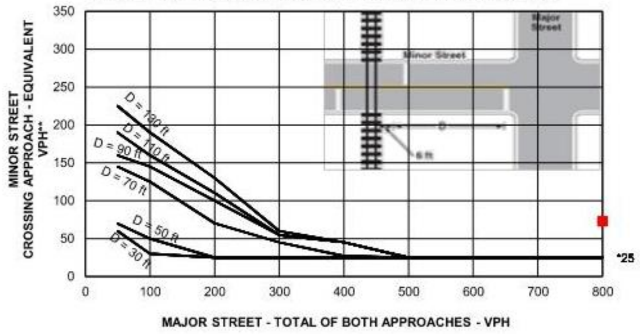
Input D and the major and minor street volumes before adjustment factors are applied

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

After adjustment factors are applied

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

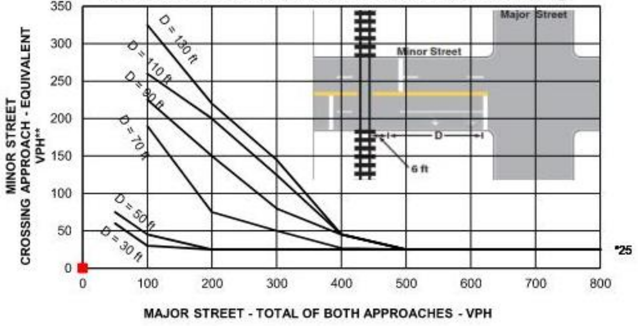
FIGURE 4C-9: Criteria for 1 Approach Lane at the Track Crossing



** 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*

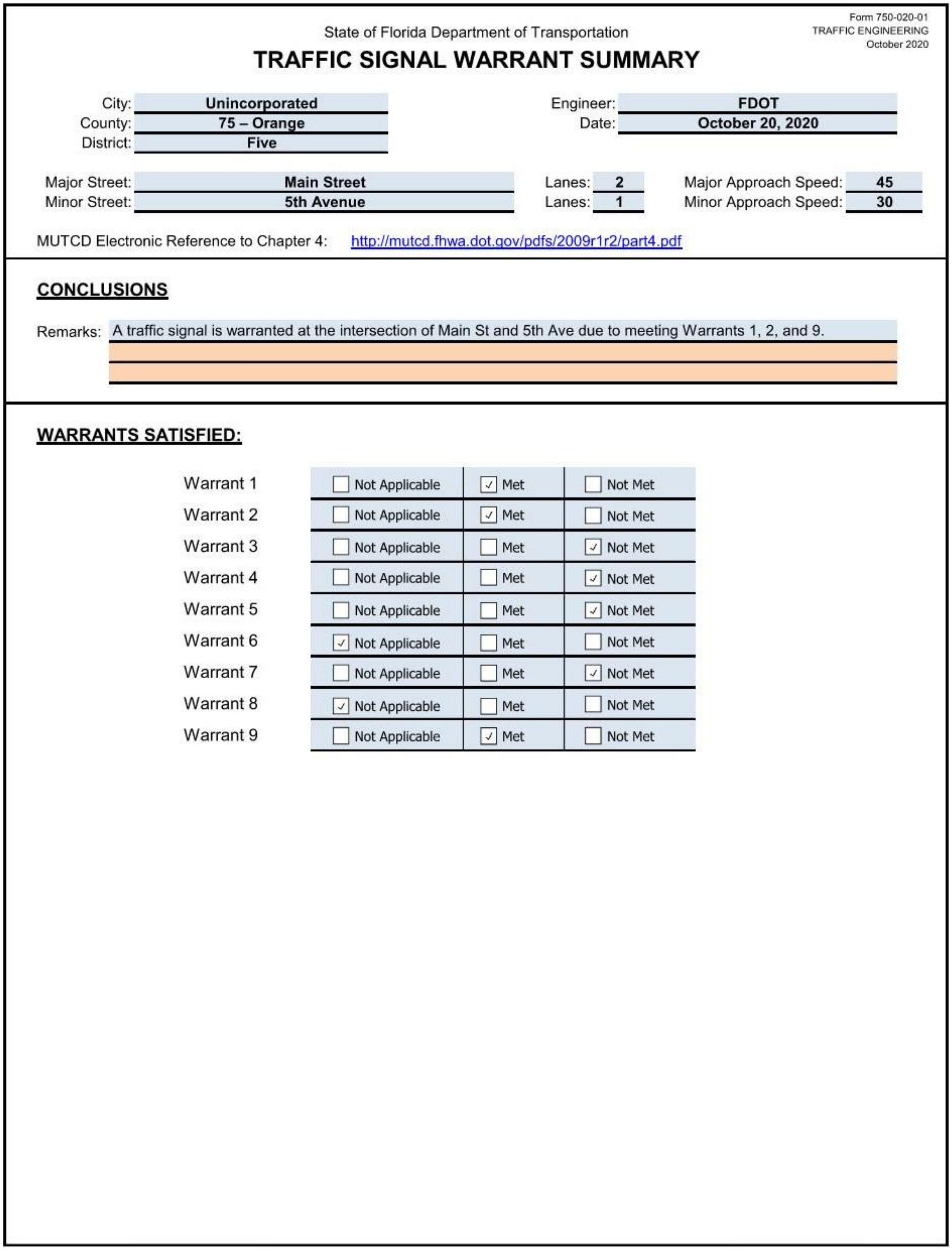
FIGURE 4C-10: Criteria for 2+ Approach Lanes at Track Crossing



** 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 3-11. Warrant Summary Checklist



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TRAFFIC SIGNAL WARRANT SUMMARY

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Lanes: **1**
Minor Approach Speed: **30**

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CONCLUSIONS

Remarks: A traffic signal is warranted at the intersection of Main St and 5th Ave due to meeting Warrants 1, 2, and 9.

WARRANTS SATISFIED:

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

CHAPTER 4 INTERSECTION TURNING MOVEMENT COUNTS

4.1 PURPOSE

(1) The purpose of collecting intersection Turning Movement Counts (TMC) is to summarize the counts of vehicle movements through an intersection during certain time periods. This type of volume summary is typically used in making decisions regarding the:

(a) geometric design of the roadway,

(b) capacity analysis,

(c) intersection control type,

(d) sign and signal installation,

(e) signal phasing and timing,

(f) pavement markings installation,

(g) traffic circulation patterns,

(h) parking and loading zones, and

(i) vehicle classification (e.g., single-unit trucks, buses, motorcycles, etc.).

(2) 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 should be recorded as they are also intersection users. For additional guidance on non-motorized volume studies, see MUTS Chapter 9.

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, geometric design, and size of the intersection. Most likely, several observers will be necessary to perform 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 will depend on the geometric design and size of the intersection. In the most recent technology applications, drones have been used to collect the video for post processing at the office.

(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 (generally 15-minute intervals). The maximum cycle length should be used if the signal is actuated.

(3) Potential challenges conducting turning movement counts at signalized intersections during actuated phasing include:

- **(a)** permissive turning movements, as they do not move consistently during their green phase, and
- **(b)** right-turn / 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; departure volumes should be recorded as vehicles cross the stop bar.

(2) Arrival volumes may extend beyond the observer's line of vision. For manual counts, a primary observer should record the departure volumes and an additional observer counts arrival volumes. Time-synchronized video cameras or drone recordings 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 ***ITE Manual of Transportation Engineering Studies, 2nd Edition Chapter 4: Volume Studies page 45**, **Exhibit 4-1***.

4.2.2 Pedestrian and Bicycle Counts

(1) MUTS Chapter 9 describes the procedures for performing non-motorized volume counts.

(2) Information for e-scooters data collection is provided in MUTS Chapter 9.

4.2.3 Path Based Counts

(1) Some intersection configurations combine multiple movements into shared lanes, and the traffic count is dependent on the origin and destination of vehicles, commonly defined as the vehicle path. This is also the case with some alternative intersection designs such as roundabouts, jug-handles, quadrant roadways, displaced left turn, restricted crossing U-turn or median U-turn intersections. At these types of intersections, it is not possible to observe individual turning movements in isolation.

(2) Video recordings can be collected by drones. Guidance regarding drone application will be forthcoming as research is completed.

4.2.3.1 Roundabouts

(1) At roundabouts, entering traffic mixes with circulating traffic and exits at different destination points. Many data collection methods 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:

- **(a)** manual counts
- **(b)** video-image processing counts with vehicle tracking (e.g., drone footage or computer vision techniques)
- **(c)** sampling method

(3) The manual technique can be used at low-traffic roundabouts and has large error potential as the observer must 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 (see MUTS Chapter 4; Section 4.2.3.3). Guidance regarding drone application will be forthcoming as research is completed.

4.2.3.2 Restricted Crossing U-Turn and Median U-Turn Intersections

(1) Restricted Crossing U-turn (RCUT) and Median U-turn (MUT) intersections may require path-based volume counts as both of these alternative intersections restrict movements by diverting drivers to a U-turn opening on the mainline. Path-based counts are relevant in studies that seek to understand turning demand at the intersection (e.g., an analysis evaluating a conversion to a conventional signalized intersection).

(2) Time-synchronized video observations may be necessary when greater volumes are present or when the U-turn opening is beyond sight distance of the intersection. Drone technology can be used to collect the necessary footage which can cover the aerial view of the intersection. 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 requiring 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 complement approach counts with an O-D matrix based on probe data. Probe data may be obtained using Bluetooth readers or be purchased from commercial vendors that aggregate GPS and cell phone location data (e.g., INRIX, HERE, StreetLight Data, etc.). Due to the low sample sizes in most probe datasets, a long data collection period is required to develop the O-D matrix. The minimum data collection period should be determined based on the volume of intersecting roadways and the data source being used. See MUTS Chapter 7 for guidance on selecting a data collection period based on the confidence level needed for the study.

(3) Finally, a license plate matching approach may be used to create the O-D matrix. If data collection is conducted manually, 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. 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.

Video observations can be used to improve the accuracy of this technique and potentially to automate the license plate recognition process using computer vision. This process uses equipment known as Automated License Plate Readers (ALPRs). ALPRs capture the license plate numbers within the view of the camera along with additional information like location, date, time, and images of the vehicles.

4.2.4 Other Alternative Intersections and Interchanges

(1) Other alternative intersection and interchange designs include but are not limited to displaced left-turn intersections, single-point urban interchanges and diverging diamond interchanges. These alternative intersection and interchange designs generally do not require path-based counts and each movement can be observed in isolation. Therefore, a volume study at these intersections is done in a similar manner to a conventional intersection. The observer should be familiar with the flow patterns before conducting the study.

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. Observers performing manual counts may use technology such as count boards or mobile devices to aid them in counting. Automated counts reduce observer workload by using technology to perform the tallying without human input, although a person must still perform quality checks, review, and reporting.

4.3.1 Manual Observation Counts

(1) During this procedure, the observer manually records each vehicle as it proceeds through the point of interest. Field-based manual counts minimize equipment cost and set-up time; however, they can become inefficient the longer the observer stays in the field and cannot be reviewed after they have been completed. Most turning movement counts focus on peak-hour conditions and the set-up time and removal of automated equipment should be accounted or considered when deciding on the method.

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. 750-020-03. Non-motorized volumes may be recorded in the same form, however, if the volumes are high, they may require separate sheets (see MUTS Chapter 9 for additional guidance on Non-Motorized Volume Studies). 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 that it is difficult to retrieve disaggregated data from electronic count boards.

(3) ***Mobile Devices:*** Laptop computers, tablets, and mobile phones can be used in place of electronic count boards. On computers, macro-enabled spreadsheets can be used to record time stamps of different events. The benefit of using these 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.

Commercial tablet and mobile applications are available that mimic the functionality of a count board but with improved data input and export capabilities. On the data input side, the touchscreen on commercial tablets enables new functionalities such as finger-tracing the vehicle movements on the screen or double-tapping to denote truck movements. On the data export side, the Internet connectivity of mobile devices can be used to email counts as they are completed.

(4) ***Video Cameras:*** Manual counts can be conducted as a post-processing operation from video recordings. 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 from the same recording. In addition, the video recordings can usually be slowed down to facilitate the manual count recording – this is particularly helpful at intersection with high volume levels.

Automated processing of video images, through use of tools including computer vision and machine learning, is discussed in Section 4.3.2.

(5) Guidance regarding drone application will be forthcoming as research is completed.

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 traffic volume levels. A single observer can count turning movements at a low volume signalized or four-way intersection with one-lane approaches if no special classifications or vehicle occupancy is needed. If additional data is required, additional observers will be needed.

(3) Drone video collection requires special personnel, including having Federal Aviation Administration-licensed drone pilot(s). For short-duration counts using a single drone, a single drone pilot may be sufficient. Additional crew members and pilots may be necessary to count multiple locations and to ensure continuity in the video footage as drones are recharged or have batteries swapped.

(4) A tethered drone may be a desired alternative to conduct the data collection (i.e., extended period of data collection). A tethered drone enables data collection for extended periods of time by being connected to a power station on the ground. Additional guidance on personnel and equipment requirements will be forthcoming as research in drone technology is completed.

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) Counts collected via drone entail additional preparation. The Federal Aviation Administration regulates the operation of drones in specific controlled airspace. These regulations can include height restrictions for drone operation or restrict operation completely. All data collection locations should be researched in advance to ensure compliance with Federal regulations and to ensure collection using a drone is feasible.

(3) ***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. 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 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.

(4) ***Data Recording:*** Organization and correct labeling of the forms and files is key for successfully performing the 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.

(5) 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 documented as they may lead to unusual traffic counts.

(6) If the ***Summary of Turning Movement Counts*** (Form No. 750-020-02) form 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 approach direction in the appropriate intersection diagram box. In the box behind the movement indications, enter the number of lanes for each movement.

(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.

(7) In instances where the ***Vehicle Turning Movement Counts*** (Form No. 750-020-03) form 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 No. 750-020-02*)

Form 750-020-02
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

SUMMARY OF TURNING MOVEMENT COUNTS

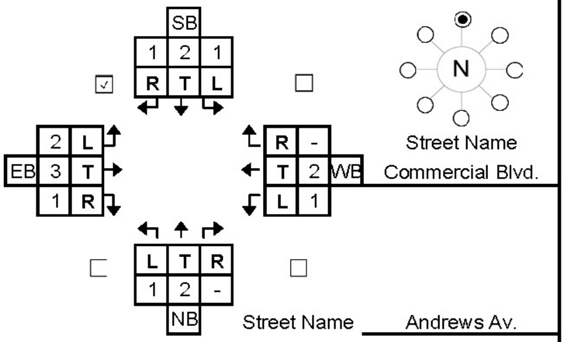
General Information

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 Counts
(*Form No. 750-020-03*)

Form 750-020-03
TRAFFIC ENGINEERING
February 2015

State of Florida Department of Transportation

VEHICLE TURNING MOVEMENT COUNTS

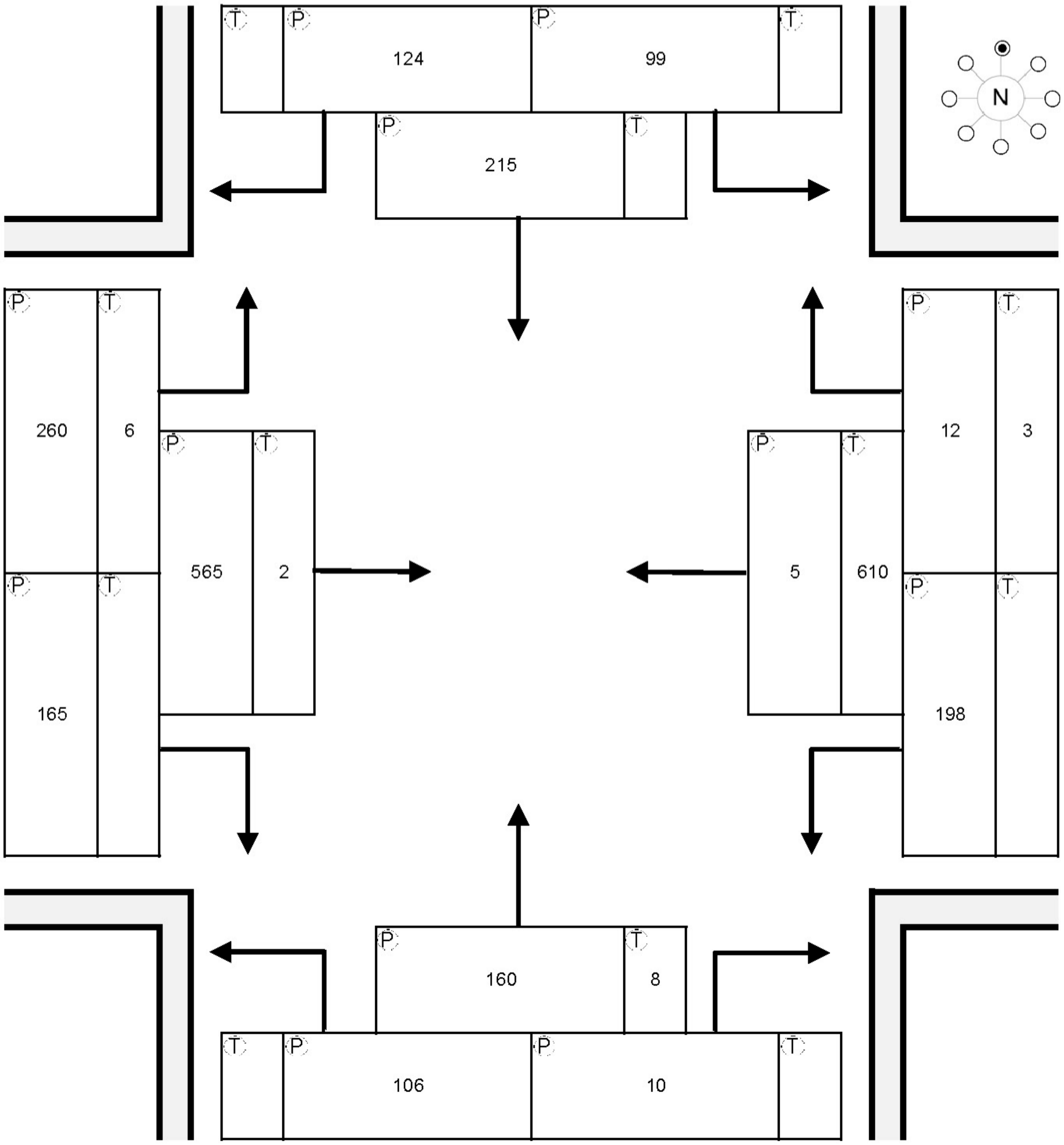
General Information

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
Remarks: Stalled vehicle on northen EB left turn lane

Site Information

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

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 Automated Counts

(1) Automated counts used to be primarily limited to in-road counts across a roadway or intersection approach, such as those using pneumatic tubes. More recently, video imaging processing has become a common way to obtain turning movement counts. This technology is available from commercial vendors. Emerging automated methods not yet used widely in practice involve analysis of trajectory data from GPS or cell phone probes, automated license plate matching, and analysis of high-resolution signal loop detector data.

(2) ***In-road Count Technologies:*** In-road count technologies are generally unable to count turning movements, pedestrians, or bicycles. For additional guidance on non-motorized traffic data collection see the Statewide Non-Motorized Traffic Monitoring Program. 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 are able to capture turning movement volumes and pedestrian/bicycle movements from video recordings by using technologies including computer vision and machine learning. Computerized measurement of lighting changes in pixels on the video are typically involved in the analysis process, but the algorithms vary among different manufacturers. When using video imaging processing, analysts must understand technology limitations, prepare contingency plans in case of equipment failure, and spot check the counts for accuracy.

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

(4) ***Automated License Plate Readers (ALPRs):*** ALPRs are usually installed in a fixed location – typically mounted on fixed objects like street poles, streetlights, or highway overpass structures. This technology can also be installed in semi-stationary or mobile settings including surveillance vans or truck trailers. While ALPRs are not commonly used for TMCs data collection, they have been used in to collect path-based information between data collection points. In addition to license plate numbers and location, ALPRs can typically record direction, travel speed and a time stamp, and store the information in a database for extended periods of time. Accuracy and penetration rate vary among the available technology and should be considered prior the selection of the equipment to be used for the studies.

4.3.2.1 Personnel Required

(1) The only personnel required to collect automated 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 automated counts (i.e., quality control), 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.

(2) ***Selecting the Count Location for In-Road Counters:*** 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) 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 condition diagram the exact location of sensor placement

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

(f) Avoid placing equipment at 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
  - **(f)** Visit the FDOT Traffic Monitoring Handbook for additional guidance.

- **(4)** ***Installation and Retrieval:*** Installation and retrieval operations should be accomplished during low-traffic-volume periods for safety reasons. Traffic control measures should be implemented to maintain a safe work zone whenever work is conducted on the roadway itself or when the field personnel’s vehicle is interacting with a travel lane or shoulder. Field personnel should adhere to a strict Personal Protective Equipment protocol (PPE) including:
  - **(a)** ANSI Class II reflective clothing
  - **(b)** ID badges
  - **(c)** Safety glasses
  - **(d)** Gloves
  - **(e)** Hard hats (as required)
  - **(f)** Headlamps for night work
  - **(g)** Closed-toe shoes

  Additional safety indications for the installation and retrieval of data equipment can be found in the Manual on Uniform Traffic Control Devices (MUTCD) and Occupational Safety and Health Administration (OSHA) guidelines. The FDOT Interim Standard Index IR102-600: General Information for Traffic Control Through Work Zones also contains relevant information.

4.4 ROADWAY DATABASE

(1) Where available, information should be pulled from the corresponding FDOT 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
- **(g)** The following resources may include some of the desired roadway information:
- **(h)** Roadway Characteristics Inventory (RCI) database
- **(i)** Florida Transportation Information (FTI)
- **(j)** Florida Traffic Online Web Application (eTraffic)

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) forms 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 ***Transportation 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)*** and Safety Performance for Intersection Control Evaluation (SPICE) tool. The SPICE tool is available on the FDOT Intersection Operations and Safety website.

(2) 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.

(3) However, for analysis purposes this chapter will follow the classification guidance consistent with the HSM. The ***HSM, Part C – Introduction and Application Guidance (Section C.6.1.)*** provides guidance on urban and rural classification by population which is based on the Federal Highway Administration (FHWA) guidelines. The guidance directs that places inside urban boundaries with population greater than 5,000 is considered urban, and places outside the urban areas with population less than 5,000 are considered rural.

5.2 SAFETY STUDY BASICS

(1) In broad terms, transportation 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 at a given location. The identification and economic justification for treatments can be supplemented by applying the ***HSM Part C – 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 ***HSM Part C***. The procedure allows the user to compute two values: Predicted Average Crash Frequency (computed from safety performance functions (SPFs) 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***.

$$N_{predicted} = N_{spf}(CMF_1 * CMF_2 * \ldots * CMF_s)C_s$$

where,

$N_{predicted}$ = predicted crash frequency

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

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

C_s = local calibration factor.

(3) Additional detail on the application of the Predictive Method can be found in ***HSM Chapter 3 – Fundamentals*** and ***HSM 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. Data collection 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 (*Highway Safety Manual*, 2010, Table 3-2, *NCHRP 17-70*, *NCHRP 17-68*, and *NCHRP 17-58*)

HSM 2010 Chapter	Undivided Roadway Segments	Divided Roadway Segments	Intersections					
			Stop Control on Minor Legs		Signalized		Restricted Crossing U-Turn [3] (RCUT)	Roundabout[3]
			3-Leg	4-Leg	3-Leg	4-Leg		
10. Rural Two-Lane Roads	✓		✓	✓	✓[3]	✓		✓
11. Rural Multi-Lane Highways[1]	✓	✓	✓	✓	✓[3]	✓	✓	✓
12. Urban and Suburban Arterials[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-, four-, and six-lane undivided arterials, four-, six-, and eight-lane divided arterials, three-, five, and seven-lane arterials with a center two-way left-turn lane, and one-way arterials with two, three, and four lanes.

3. Methodology only available in the SPICE tool.

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

(a) Traffic Volume and Geometric Data Collection (see MUTS Chapter 5; Section 5.4.1)

(b) Existing Conditions Data Collection (see MUTS Chapter 5; Section 5.4.2) and Condition Diagram development (Form No. 750-020-04)

(c) Historical Crash Data (see MUTS Chapter 5; Section 5.4.3) and Collision Diagram development (Form No. 750-020-05i and Form No. 750-020-05j)

5.4.1 Traffic Volume and Geometric 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

Crash Cost Calculation spreadsheets, which are available online from the FDOT Traffic Engineering and Operations Office's website for the Manual on Uniform Traffic Studies. These spreadsheets facilitate the HSM Predictive Method analysis and include crash cost estimates.

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

(3) Before proceeding, the analyst should determine if the HSM methodologies are applicable by referring to ***HSM 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 Roads, Rural Multi-Lane Highways, and Urban/Suburban Arterials having the characteristics required for ***HSM Part C – Predictive Method Application***. Data collection requirements for Urban/Suburban Arterials are dependent on the facility type, with two-lane, four-lane, and five-lane facilities included in crash prediction equations presented in ***HSM Part C – Predictive Method Application***, and six-lane, seven-lane, eight-lane, and one-way facilities included in ***NCHRP 17-58*** (available on the FDOT MUTS website). A "generic" data collection requirement list for locations not having the characteristics required for ***HSM Part C – Predictive Method Application*** is provided at the end of this section.

Rural Two-Lane Roads

(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*** (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 ***HSM Chapter 10, Section 10.6.1***. AADT may be existing or future AADT.
- **(b)** Homogenous roadway segment length (in miles, see guidelines in the **HSM 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 twelve crash modification factors for rural two-lane roads. 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 ***HSM Chapter 10, Section 10.7.1***.

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

(b) Shoulder width in feet and shoulder type, paved, gravel, composite, or turf (use equation found in ***HSM Chapter 10***, 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 (CMF3r).

(d) Horizontal curve superelevation as a percentage (CMF4r).

(e) Grade level as a percentage (CMF5r).

(f) Driveway Density in driveways per mile. This CMF also requires the AADT (CMF6r).

(g) Presence of center rumble strips, present or not (CMF7r).

(h) Presence of passing lanes, present or not (CMF8r).

(i) Presence of two-way left turn lanes, present or not (CMF9r).

(j) Roadside design as a function of Roadside Hazard Rating (RHR) measured from 1 through 7 (CMF10r).

(k) Presence of lighting, present or not (CMF11r).

(l) Presence of automated speed enforcement, present or not (CMF12r).

Rural Multi-Lane Highways

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on a four-lane rural multi-lane highway. Currently no methodology exists for six-lane rural multi-lane highways. ***Rural Multi-Lane Highway Segment Data Collection*** (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 HSM Chapter 11, (Sections 11.6.1,11.6.2) for undivided and divided roadway segments, respectively. AADT may be existing or future AADT.

(c) Homogenous roadway segment length (miles, see guidelines in the ***HSM 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 rural multi-lane highways. 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 ***HSM Chapter 11, Section 11.7.1*** for undivided roadway segments and ***HSM Chapter 11, Section 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}).
- Side slopes 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 (HSM)

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on urban/suburban arterials from two up to five lanes, including three and five lanes having a two-way left turn lane. One-way roadways and facilities with six through eight lanes are included under methodologies developed in ***NCHRP 17-58*** and are available in the next section. Currently no methodology exists for arterials with more than eight lanes. ***Urban/Suburban Arterial Segment for 2 to 5 Lanes Data Collection*** (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 – two-lane undivided, 3T – two-lane with center traversable two-way left-turn lane, 4U – four-lane undivided, 4D – four-lane divided, 5T – four-lane with center traversable two-way left-turn lane).
- **(b)** Roadway AADT. Guidelines regarding maximum/minimum AADT values and roadway length can be found in ***HSM Chapter 12, Section 12.6.1***. AADT may be existing or future AADT.
- **(c)** Homogenous Roadway Segment Length (miles, see guidelines in the ***HSM 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 crash modification factors for urban/suburban arterials between two and five lanes. Guidelines for the parameters used to compute CMFs can be found in ***HSM 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 (CMF1r).
- **(c)** Roadside fixed object density, fixed objects per mile (CMF2r).
- **(d)** Offset to roadside fixed objects in feet, if greater than 30 feet or not present, assume 30 feet (CMF2r).
- **(e)** Median width in feet - for divided only (CMF3r).
- **(f)** Lighting, present or not (CMF4r).
- **(g)** Auto speed enforcement, present or not (CMF5r).

Urban/Suburban Arterials (NCHRP 17-58)

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on urban/suburban arterials from six up to eight lanes, including seven lanes having a two-way left turn lane, and one-way roadways with two to four lanes. Currently no methodology exists for arterials with more than eight lanes. ***Urban/Suburban Arterial Segment for 6 to 8 Lanes and One-Way Roadway Data Collection*** (Form No. 750-020-05l) may be used to collect this data. An example of this form completed is shown in ***Figure 5-4***.

(2) Data Required to Compute Base Crash Prediction

- **(a)** Roadway type (6U, 6D, 7T, 8D, 2O, 3O, 4O).
- **(b)** Roadway AADT. Guidelines regarding maximum/minimum AADT values and roadway length (and all other data collection elements) can be found in ***NCHRP 17-58*** Table 25 and Table 26. AADT may be existing or future AADT.
- **(c)** Homogenous Roadway Segment Length (miles, see guidelines in the ***HSM 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 crash modification factors for urban/suburban arterials with six lanes or more and one-way roadways. Guidelines for the parameters used to compute CMFs can be found in ***NCHRP 17-58;*** MUTS Chapter 5 and MUTS Chapter 7.

- **(a)** Lane width in feet (CMFlw).
- **(b)** Outside shoulder width in feet, or right-shoulder for one-way facilities (CMFosw).
- **(c)** Median width in feet (CMFmw).
- **(d)** Median barriers, present or not (CMFbar,mv / bar,sv).
- **(e)** Highway-rail grade crossings, number present (CMFrhx).
- **(f)** Major commercial driveways, number present (CMFdwc_mj).
- **(g)** Major industrial driveways, number present (CMFdwi_mj).
- **(h)** Minor driveways, number present (CMFdw_mn).
- **(i)** Roadside fixed object density, fixed objects per mile (CMFfo).

- **(j)** Offset to roadside fixed objects in feet (CMFfo).
- **(k)** On-street parking, not applicable for six to eight lane roadways (CMFpk).

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*** (Form No. 750-020-05d) may be used to collect this data. An example of this form completed is shown in ***Figure 5-5***.

(2) Essential Elements

- **(a)** Urban context (urban, suburban, transitioning, or rural).
- **(b)** Homogenous roadway segment length (miles, see guidelines in the HSM Part C - Introduction and Applications Guidance on the selection of homogeneous roadway segments).
- **(c)** Roadway design: divided or undivided and number of lanes.
- **(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)** Posted speed limit (mph).
- **(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 and context 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)** Side slopes 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

(1) The following sections present data collection requirements for intersections. Intersection analysis can be performed using Crash Cost Calculation spreadsheets, which are available online from the FDOT Traffic Engineering and Operations Office's website for the ***Manual on Uniform Traffic Studies***, or the ***Safety Performance for Intersection Control Evaluation Tool (SPICE),*** incorporating ***NCHRP 17-58***, ***NCHRP 17-70*** (roundabout), and RCUT SPF crash prediction methodologies.

(2) Data collection requirements for Urban/Suburban Arterials are dependent on the facility type, with two-lane, four-lane, and five-lane facilities included in crash prediction equations presented in ***HSM Part C – Predictive Method Application***, and six-lane, seven-lane, eight-lane, and one-way facilities included in ***NCHRP 17-58***.

(3) Analysis for additional intersection types are included in ***SPICE***, including restricted crossing U-turn (RCUT) intersections, roundabouts, and other alternative intersections. A "generic" data collection requirement list for locations not having the characteristics required for ***HSM Part C – Predictive Method Application*** is provided at the end of this section.

Rural Two-Lane Roads – 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 road segment. Figure 10-2 in ***HSM Chapter 10*** provides guidance on the definition of intersections and segments. ***Rural Two-Lane Road Intersection Data Collection*** (Form No. 750-020-05e) 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 HSM 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 roads. 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 ***HSM Chapter 10, Section 10.7.2***.

(a) Intersection skew angle as an offset away from 90 degrees (CMF1i).

(b) Intersection approaches with left-turn lanes, number of approaches (CMF2i).

(c) Intersection approaches with right-turn lanes, number of approaches (CMF3i).

(d) Intersection lighting, present or not (CMF4i).

Rural Multi-Lane Highways – 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 highway. ***HSM Chapter 11***, Figure 11-2 provides guidance on the definition of intersections and segments. ***Rural Multi-Lane Highway Intersection Data Collection*** (Form No. 750-020-05f) 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), 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 **HSM 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 highways. 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 ***HSM Chapter 11, Section 11.7.3***.

(a) Intersection skew angle as an offset away from 90 degrees (CMF1i).

(b) Intersection non-stop controlled approaches with left-turn lanes, number of approaches (CMF2i).

(c) Intersection non-stop controlled approaches with right-turn lanes, number of approaches (CMF3i).

(d) Intersection lighting, present or not (CMF4i).

Urban/Suburban Arterials – Intersections (HSM)

(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 arterial. ***HSM Chapter 12, Figure 12-2*** provides guidance on the definition of intersections and segments. ***Urban/Suburban Arterial Intersection for 2 to 5 Lanes on the Major Street Data Collection*** (Form No. 750-020-05g) may be used to collect this data. An example of this form completed is shown in ***Figure 5-8***.

(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 ***HSM Chapter 12, Section 12.6.2***. AADT may be existing or future AADT.

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

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

(3) Data required to Compute Crash Modification Factors.

The parameters noted below are used to compute crash modification factors for intersections on urban-suburban arterials. These are numbered from CMF_{1i} to CMF_{6i} and from CMF_{1p} to CMF_{3p} in the HSM for data related to signalized and stop-controlled intersections. Guidelines for the parameters used to compute CMFs can be found in ***HSM Chapter 12, Section 12.7.2***.

(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 (CMF1i).

  (b) Type of left-turn signal phasing at each approach, permissive, protected/permissive, or protected (CMF2i).

  (c) Number of approaches with right-turn lanes, 0, 1, 2, 3, or 4 (CMF3i).

  (d) Number of approaches with right-turn-on-red prohibited, 0, 1, 2, 3, or 4 (CMF4i).

  (e) Intersection lighting, presence or absence (CMF5i).

  (f) Intersection red light cameras, presence or absence (CMF6i).

(6) Data for vehicle/pedestrian collisions:

  (a) Number of bus stops within 1,000 ft. of the intersection (CMF1p).

  (b) Schools within 1,000 ft. of the intersection, presence or absence (CMF2p).

  (c) Number of alcohol sales establishments within 1,000 ft. of the intersection (CMF3p).

Urban/Suburban Arterials – Intersections (NCHRP 17-58)

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on an intersection located on urban / suburban arterials with six or more lanes or on one-way. ***HSM Chapter 12, Figure 12-2*** provides guidance on the definition of intersections and segments. ***Urban/Suburban Arterial Intersection for 6 to 8 Lanes and One-Way on the Major Street Data Collection*** (Form No. 750-020-05m) may be used to collect this data. An example of this form completed is shown in ***Figure 5-9***.

(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 HSM Chapter 12, Section 12.6.2. AADT may be existing or future AADT.

(c) Sum of all pedestrian crossing volumes per day, crossing all 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 arterials having six to eight lanes and one-way roadways. Guidelines for the parameters used to compute CMFs can be found in ***NCHRP 17-58, Chapter 6 and Chapter 8***.

(4) Data for unsignalized intersections only:

(a) Number of major-road approaches with left-turn lanes, 0, 1, or 2 (CMF1i).

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

(5) Data for signalized intersections only:

(a) Intersection lighting, presence or absence (CMF_{lg}).

(b) Left-turn signal phasing on each approach (CMF_{ltph}).

(c) Right-turn on red prohibition (CMF_{rtor}).

(d) U-turn prohibition (CMF_{ut}).

(e) Right-turn Channelization (CMF_{ch}).

An approach is considered to have right-turn channelization when a marked or raised-curb island is present separating this turn from the adjacent movements. A standard exclusive right-turn lane (bay) that does not have this separation is not considered channelized. See the following examples for a visual representation of these geometric features:

Both red boxes in this image show examples of right-turn channelization

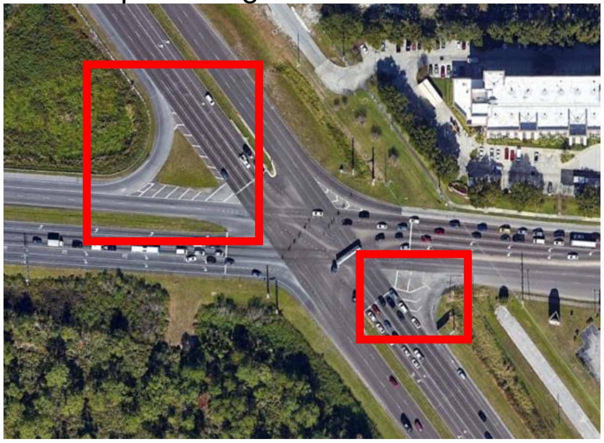


Image Source: Google Earth, 2018

The red box in this image shows a right-turn without right-turn channelization

Image Source: Google Earth, 2018

(6) Data for vehicle/pedestrian collisions:

(a) Number of lanes (CMFlanes).

(b) Number of bus stops within 1,000 ft. of the intersection (CMF1p).

(c) Schools within 1,000 ft. of the intersection, presence or absence (CMF2p).

(d) Number of alcohol sales establishments within 1,000 ft. of the intersection (CMF3p).

Intersections (SPICE)

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on an intersection using **SPICE**. The intersections previously discussed as included in the **HSM** and **NCHRP 17-58** can be analyzed using **SPICE**, as well as additional intersection types such as RCUTs, roundabouts, and additional alternative intersections. **HSM Chapter 12**, Figure 12-2 provides guidance on the definition of intersections and segments. ***Restricted Crossing U-Turn Data Collection*** (Form No. 750-020-05n) may be used to collect the required data for RCUTs. An example of this form completed is shown in ***Figure 5-10***.

(2) ***Roundabout Data Collection*** (Form No. 750-020-05o) may be used to collect data for roundabout analysis. An example of this form completed is shown in ***Figure 5-11***. Analysis for other alternative intersections in ***SPICE*** is based on signal-controlled crash prediction, modified by a CMF. Data required for this analysis may be collected using the appropriate signalized intersection data collection form.

(3) Data Required to Compute Base Crash Prediction

- **(a)** Determine intersection configuration, three-leg single-lane roundabout (31R), four-leg single-lane roundabout (41R), three-leg two-lane roundabout (32R), four-leg two-lane roundabout (42R), or restricted crossing U-turn (RCUT).
- **(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 the SPICE tool.

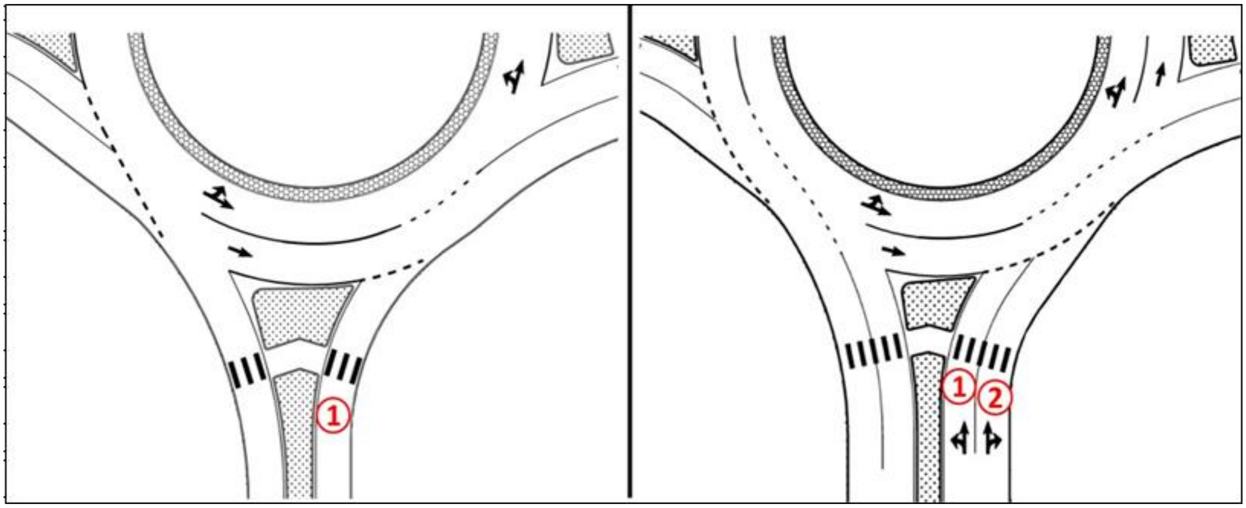
(4) Data Required to Compute Crash Modification Factors for RCUT Intersections.

- **(a)** Number of RCUT U-turns.
- **(b)** Number of major roadway lanes.
- **(c)** Number of minor roadway lanes
- **(d)** Total offset distance between center of RCUT intersection and U-turn location(s).
- **(e)** Number of driveways within RCUT footprint.
- **(f)** Total RCUT U-turn deceleration lane length.
- **(g)** Total RCUT U-turn acceleration lane length, unsignalized only.
- **(h)** Number of left-turn lanes from major approach, signalized only.
- **(i)** Major road speed limit (mph), signalized only.
- **(j)** Total median width at RCUT, signalized only.
- **(k)** Maximum median width at RCUT, unsignalized only.

(5) Data Required to Compute Crash Modification Factors for Roundabouts:

- **(a)** Inscribed circle diameter in feet (the inscribed circle describes the circle that best fits the outside edge of the circulating lanes).
- **(b)** Presence of right-turn bypass lanes.
- **(c)** Number of driveways or unsignalized access points within 250 ft. of entry point on each leg.
- **(d)** Entry width in feet on each leg.

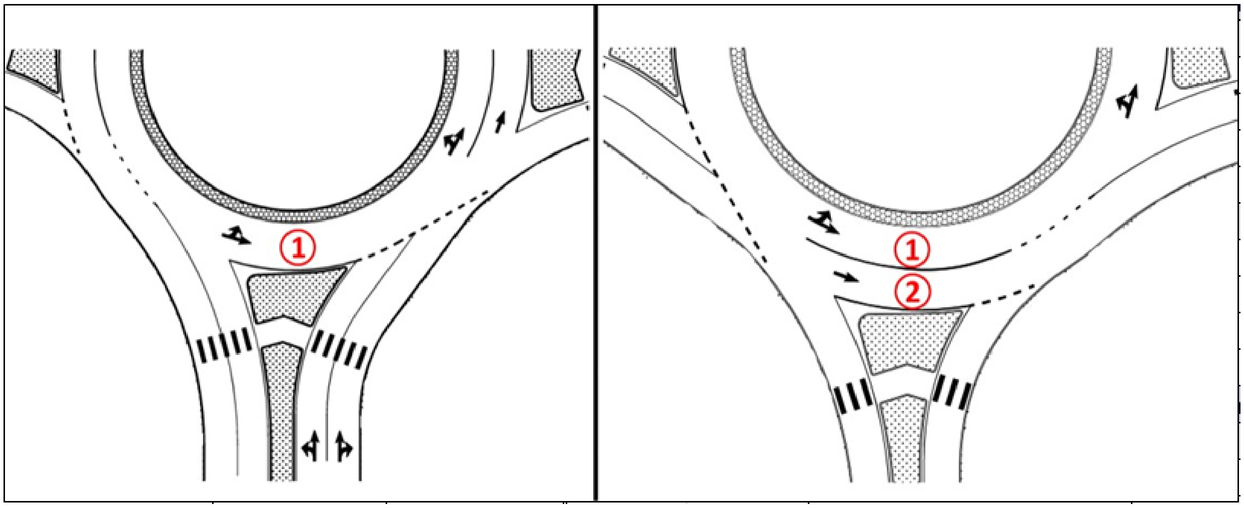
(e) Number of entering lanes. See below for example.



One entering lane

Two entering lanes

(a) Number of circulating lanes. See below for example.



One circulating lane

Two circulating lanes

Other Intersection Types

(1) The following is a list of data collection input parameters for intersections for which an ***HSM Part C – Predictive Method*** is not currently available. The ***Other Intersections Data Collection*** (Form No. 750-020-05h) may be used to collect this data. An example of this form completed is shown in ***Figure 5-12***.

(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 Condition Diagrams

(1) Condition diagrams are necessary to capture field conditions and can be helpful correlating existing conditions 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) The **Condition Diagram** (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 Standard Plans Index No. 002. An example of this form is shown in ***Figure 5-13***. Annotated aerials can be used as an alternative to this form. The engineer should verify the necessary roadway and intersection features are reflected in the diagram.

(3) 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, 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. ***HSM Chapter 5, Section 5.2.2*** discusses summarizing crashes by location. ***Figure 5-14*** illustrates the sample condition diagram that is provided in the ***HSM Chapter 5, Figure 5-5***.

5.4.3 Historical Crash Data

(1) Florida historical crash data may be obtained from the FDOT Crash Analysis Reporting System (CARS). Access to the FDOT CARS 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 before 2011 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 checkmark 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.

5.4.3.1 Collision Diagrams

(1) Collision diagrams are not required for ***HSM Part C – 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 vary. The results of automated collision diagrams should be spot checked to ensure crashes have been spatially located correctly.

HSM Chapter 5, Section 5.2.2 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.

(3) Form No. 750-020-05i and Form No. 750-020-05j may be used to develop collision diagrams for segments and intersections, respectively. Completed examples for these forms are shown in ***Figure 5-15*** and ***Figure 5-16***, respectively.

5.4.3.2 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.

(a) Crash type (rear-end, angle, sideswipe, left turn, etc.).

(b) Crash severity (fatal, injury, property damage only).

(c) Lighting and day/night conditions.

(d) Weather.

(e) Road surface conditions.

(f) Date (year, month, day of the week, time of the day).

(g) First harmful event.

(h) Contributing cause.

(2) The ***Collision Summary*** (Form No. 750-020-05k) 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 5-17***.

(3) Number the crashes (as they correspond with those represented on the Collision Diagram) on the Collision 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 CARS to automatically summarize the data into collision summary tables and histograms. These spreadsheets should be used when available to maintain consistency and meet the FDOT District's specific requirements.

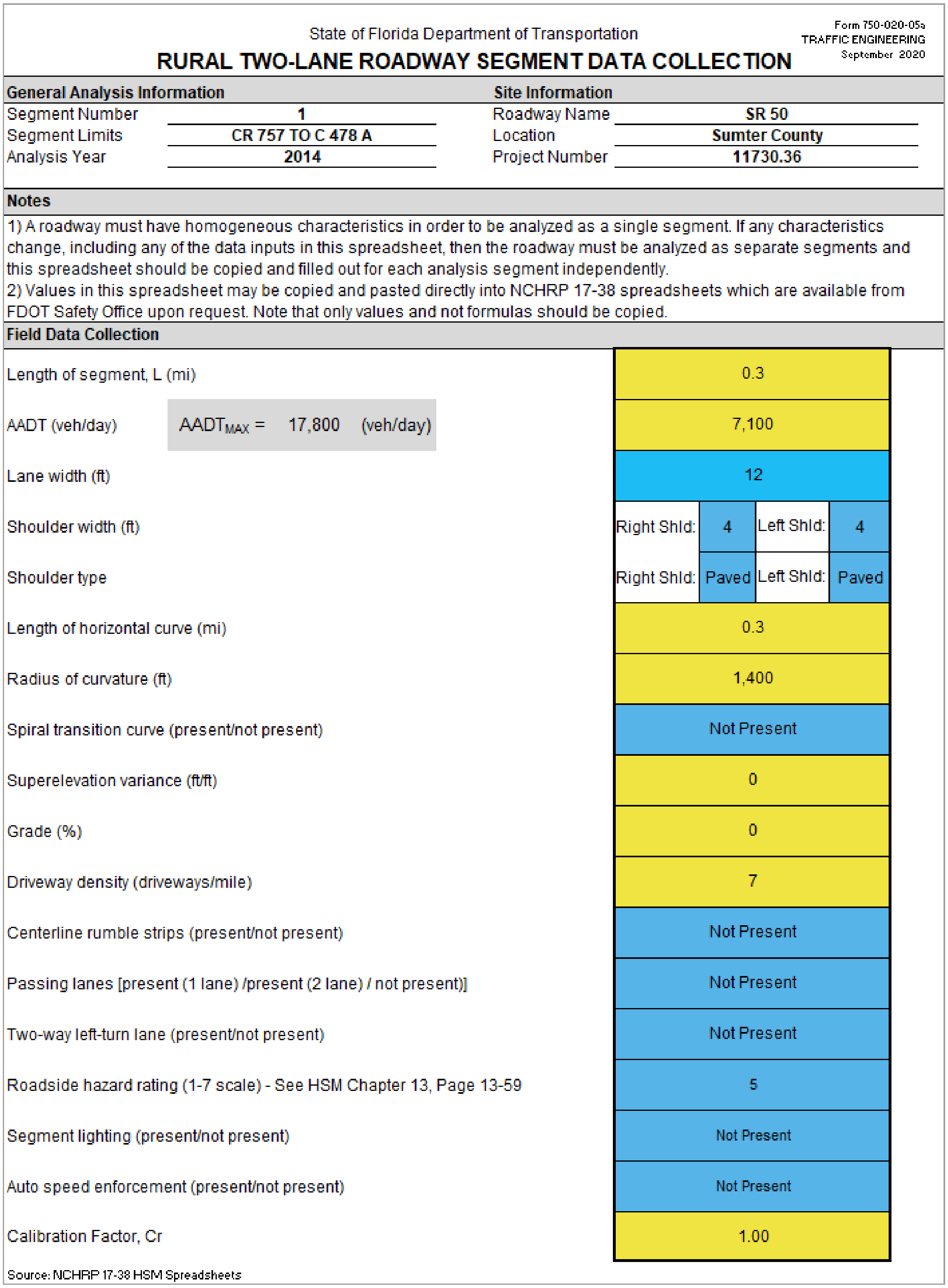
5.4.3.3 Empirical Bayes and Historical Crash Data

(1) Historical crash data of a minimum of 5 years shall be used to compute the Expected Average Crash Frequency by applying the Empirical Bayes Methodology. The methodology is explained in the Appendix of the **HSM Part C**.

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 750-020-05a
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

RURAL TWO-LANE ROADWAY SEGMENT DATA COLLECTION

General Analysis Information

Segment Number **1**
Segment Limits **CR 757 TO C 478 A**
Analysis Year **2014**

Site Information

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

Notes

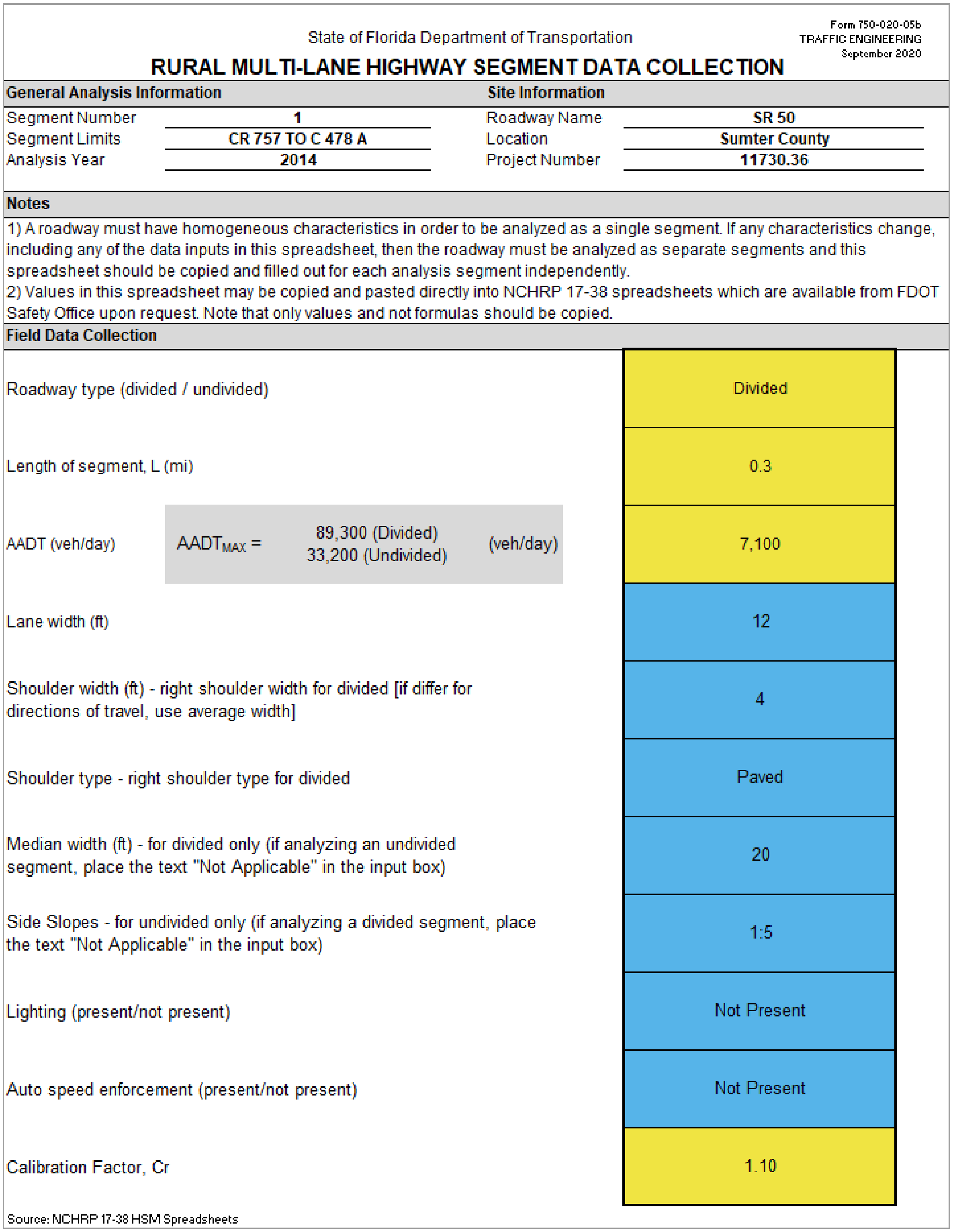
1) A roadway must have homogeneous characteristics in order to be analyzed as a single segment. If any characteristics change, including any of the data inputs in this spreadsheet, then the roadway must be analyzed as separate segments and this spreadsheet should be copied and filled out for each analysis segment 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 Highway Segment Data Collection (*Form No. 750-020-05b*)



Form 750-020-05b
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

RURAL MULTI-LANE HIGHWAY SEGMENT DATA COLLECTION

General 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

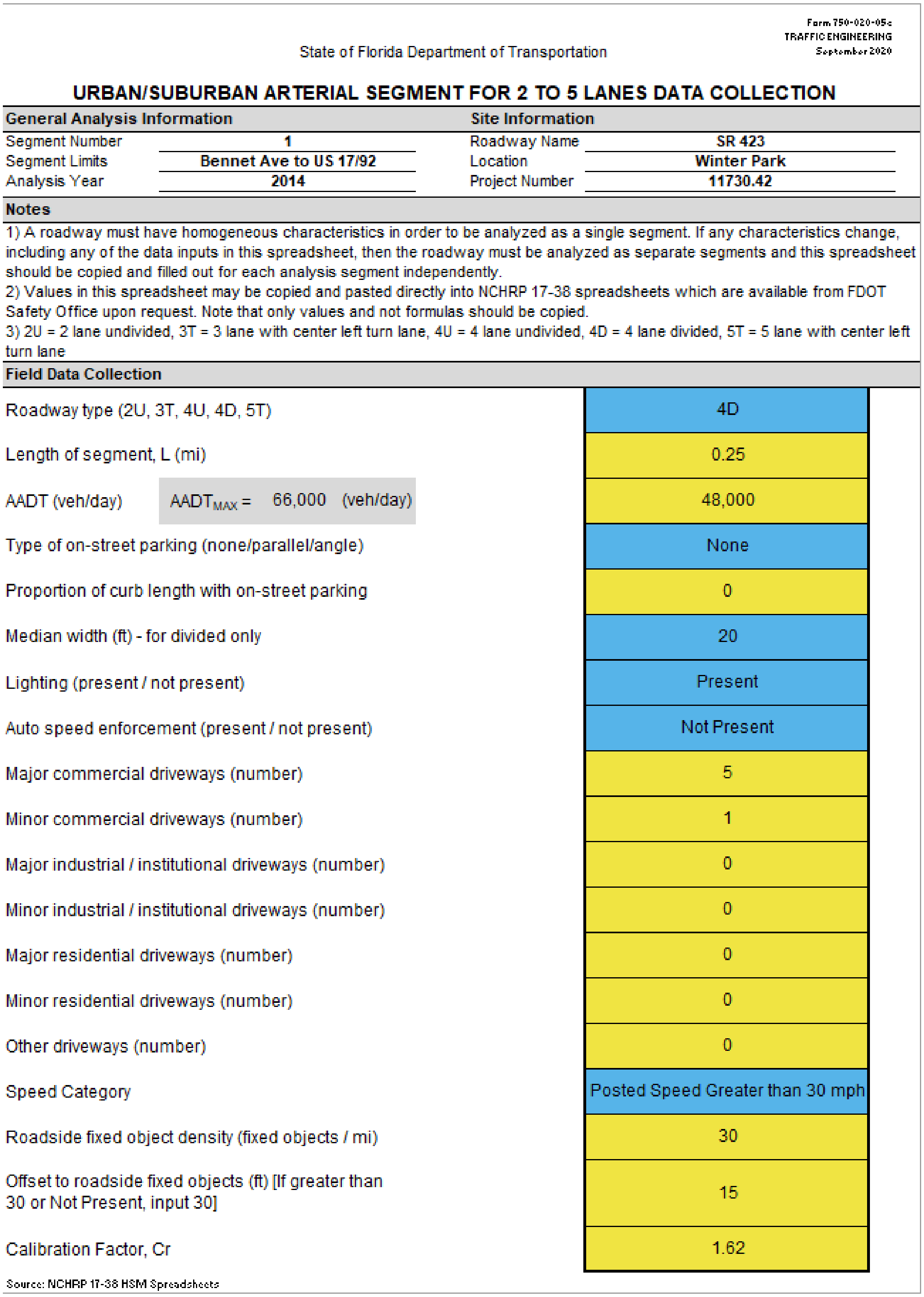
1) A roadway must have homogeneous characteristics in order to be analyzed as a single segment. If any characteristics change, including any of the data inputs in this spreadsheet, then the roadway must be analyzed as separate segments and this spreadsheet should be copied and filled out for each analysis segment 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 (Undivided) (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 for 2 to 5 Lanes Data Collection (*Form No. 750-020-05c*)



Form 750-020-05c
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

URBAN/SUBURBAN ARTERIAL SEGMENT FOR 2 TO 5 LANES DATA COLLECTION

General Analysis Information		**Site Information**	
Segment Number	1	Roadway Name	SR 423
Segment Limits	Bennet Ave to US 17/92	Location	Winter Park
Analysis Year	2014	Project Number	11730.42

Notes

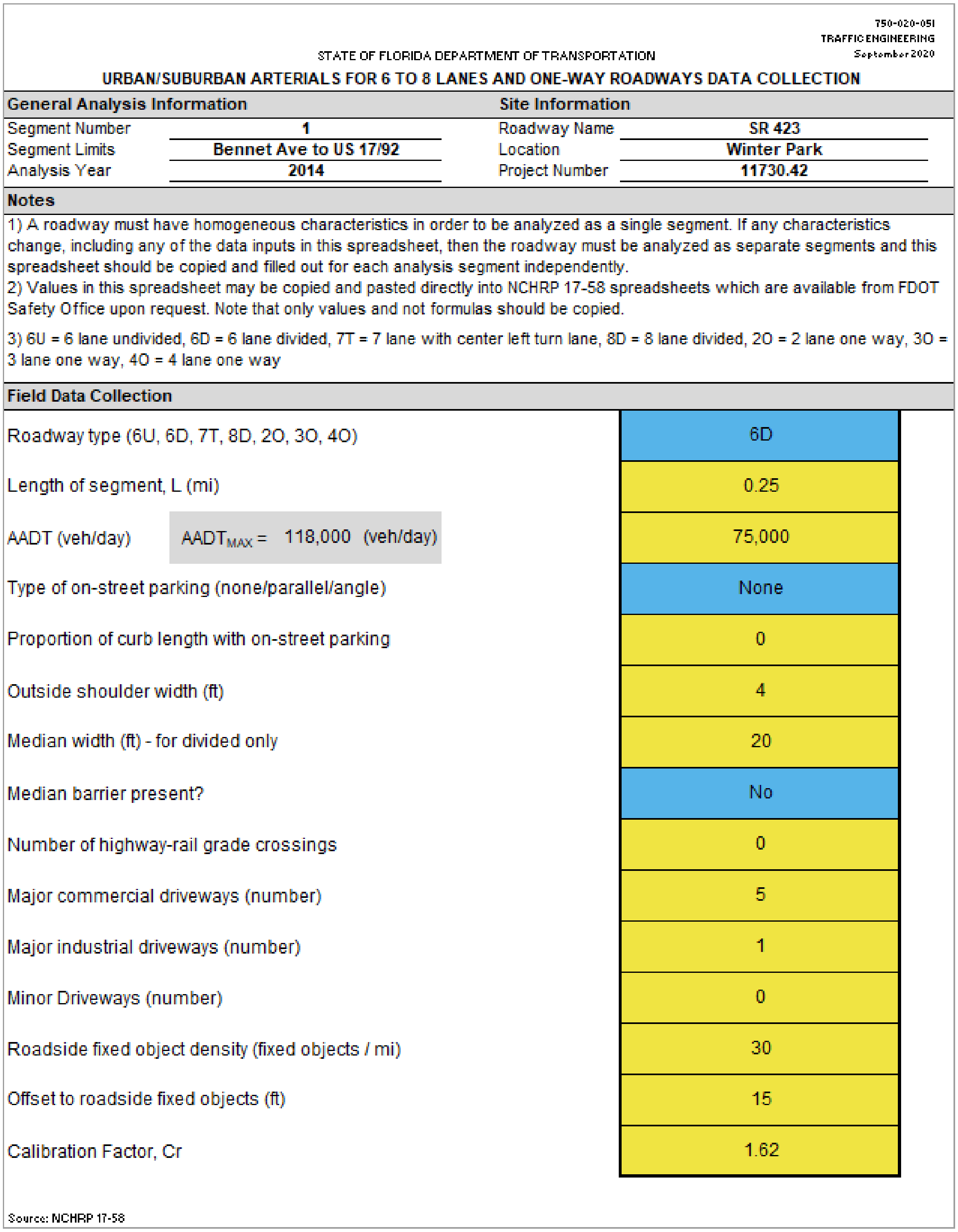
1) A roadway must have homogeneous characteristics in order to be analyzed as a single segment. If any characteristics change, including any of the data inputs in this spreadsheet, then the roadway must be analyzed as separate segments and this spreadsheet should be copied and filled out for each analysis segment 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. Urban/Suburban Arterial Segment for 6 to 8 Lanes and One-Way Roadway Data Collection (*Form No. 750-020-05I*)



750-020-05I
TRAFFIC ENGINEERING
September 2020

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

URBAN/SUBURBAN ARTERIALS FOR 6 TO 8 LANES AND ONE-WAY ROADWAYS DATA COLLECTION

General Analysis Information		**Site Information**	
Segment Number	**1**	Roadway Name	**SR 423**
Segment Limits	**Bennet Ave to US 17/92**	Location	**Winter Park**
Analysis Year	**2014**	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 segment independently.
2) Values in this spreadsheet may be copied and pasted directly into NCHRP 17-58 spreadsheets which are available from FDOT Safety Office upon request. Note that only values and not formulas should be copied.

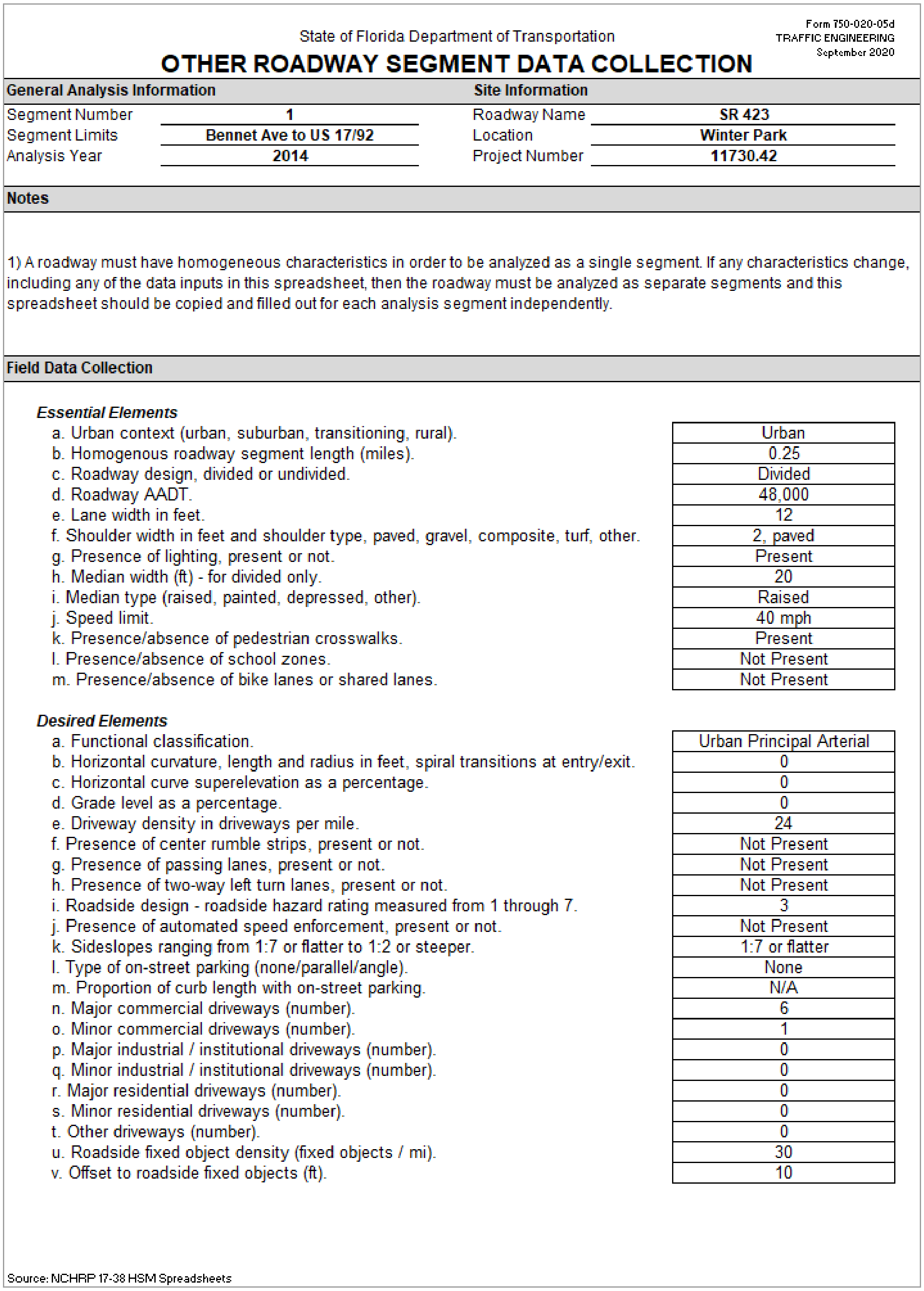
3) 6U = 6 lane undivided, 6D = 6 lane divided, 7T = 7 lane with center left turn lane, 8D = 8 lane divided, 2O = 2 lane one way, 3O = 3 lane one way, 4O = 4 lane one way

Field Data Collection

Roadway type (6U, 6D, 7T, 8D, 2O, 3O, 4O)		6D
Length of segment, L (mi)		0.25
AADT (veh/day)	AADT_{MAX} = 118,000 (veh/day)	75,000
Type of on-street parking (none/parallel/angle)		None
Proportion of curb length with on-street parking		0
Outside shoulder width (ft)		4
Median width (ft) - for divided only		20
Median barrier present?		No
Number of highway-rail grade crossings		0
Major commercial driveways (number)		5
Major industrial driveways (number)		1
Minor Driveways (number)		0
Roadside fixed object density (fixed objects / mi)		30
Offset to roadside fixed objects (ft)		15
Calibration Factor, Cr		1.62

Source: NCHRP 17-58

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



Form 750-020-05d
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

OTHER ROADWAY SEGMENT DATA COLLECTION

General 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 segment independently.

Field Data Collection

Essential Elements

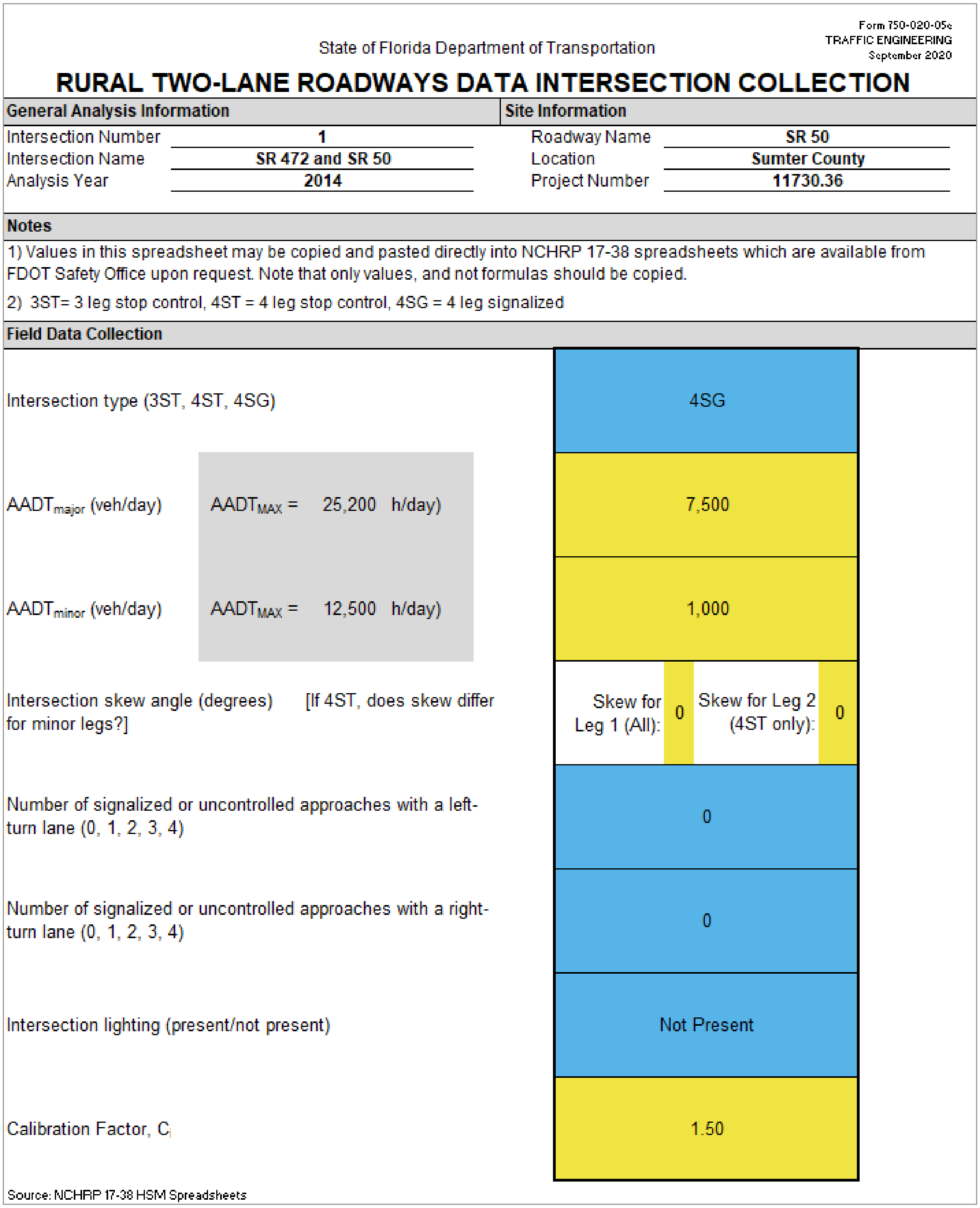
a. Urban context (urban, suburban, transitioning, rural).	Urban
b. Homogenous roadway segment length (miles).	0.25
c. Roadway design, divided or undivided.	Divided
d. Roadway AADT.	48,000
e. Lane width in feet.	12
f. Shoulder width in feet and shoulder type, paved, gravel, composite, turf, other.	2, 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 5-6. Rural Two-Lane Roadway Intersection Data Collection (*Form No. 750-020-05e*)



Form 750-020-05e
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

RURAL TWO-LANE ROADWAYS DATA INTERSECTION COLLECTION

General 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.

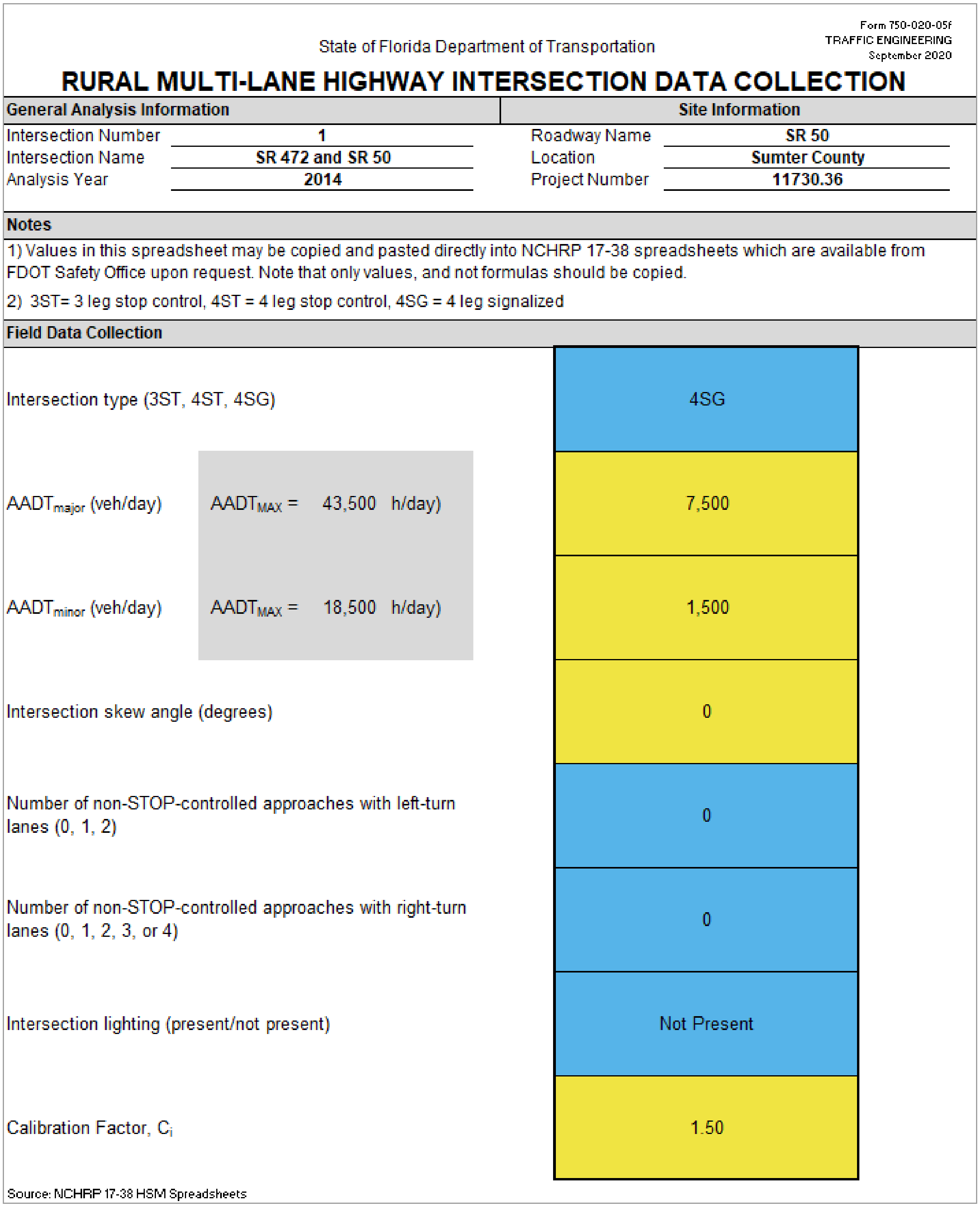
2) 3ST= 3 leg stop control, 4ST = 4 leg stop control, 4SG = 4 leg signalized

Field Data Collection

Intersection type (3ST, 4ST, 4SG)		4SG
$AADT_{major}$ (veh/day)	$AADT_{MAX}$ = 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_i		1.50

Source: NCHRP 17-38 HSM Spreadsheets

Figure 5-7. Rural Multi-Lane Highway Intersection Data Collection (*Form No. 750-020-05f*)



Form 750-020-05f
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

RURAL MULTI-LANE HIGHWAY INTERSECTION DATA COLLECTION

General 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.

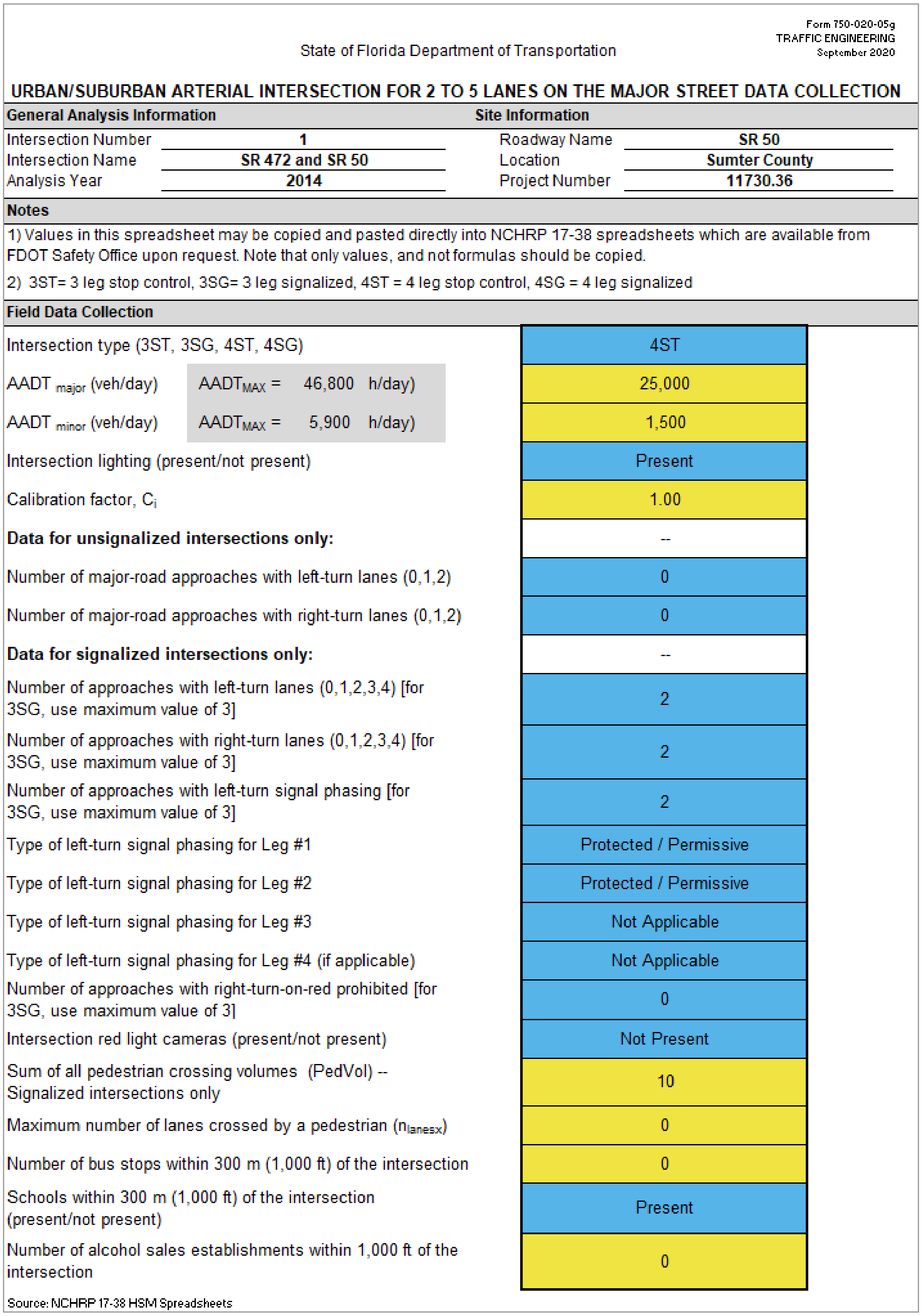
2) 3ST= 3 leg stop control, 4ST = 4 leg stop control, 4SG = 4 leg signalized

Field Data Collection

Intersection type (3ST, 4ST, 4SG)		4SG
$AADT_{major}$ (veh/day)	$AADT_{MAX}$ = 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 5-8. Urban/Suburban Roadway Intersection for 2 to 5 Lanes on the Major Street Data Collection
(*Form No. 750-020-05g*)



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

URBAN/SUBURBAN ARTERIAL INTERSECTION FOR 2 TO 5 LANES ON THE MAJOR STREET DATA COLLECTION

General 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.

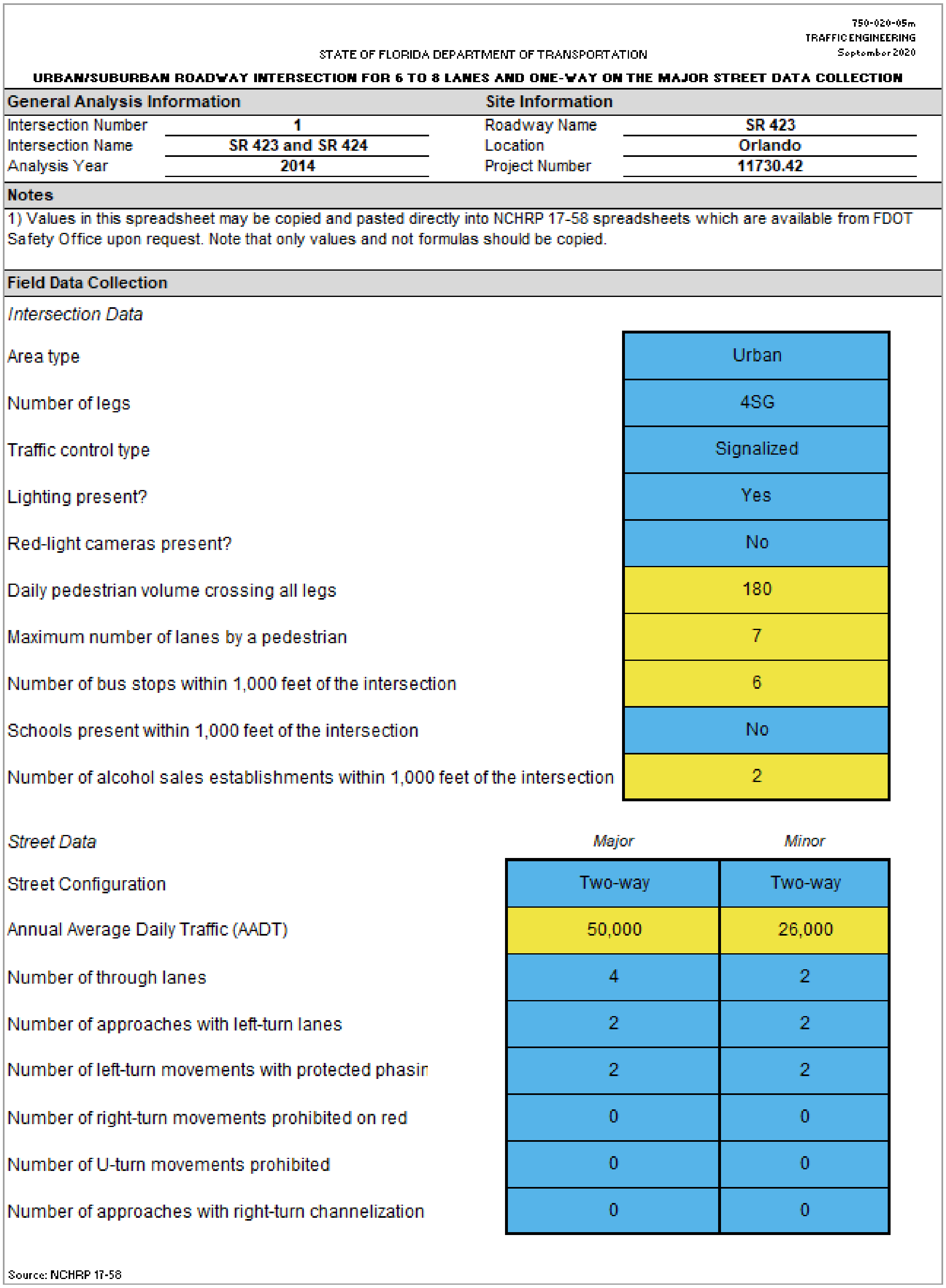
2) 3ST= 3 leg stop control, 3SG= 3 leg signalized, 4ST = 4 leg stop control, 4SG = 4 leg signalized

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 5-9. Urban/Suburban Roadway Intersection for 6 to 8 Lanes and One-Way on the Major Street Data Collection
(*Form No. 750-020-05m*)



750-020-05m
TRAFFIC ENGINEERING
September 2020

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

URBAN/SUBURBAN ROADWAY INTERSECTION FOR 6 TO 8 LANES AND ONE-WAY ON THE MAJOR STREET DATA COLLECTION

General Analysis Information		**Site Information**	
Intersection Number	**1**	Roadway Name	**SR 423**
Intersection Name	**SR 423 and SR 424**	Location	**Orlando**
Analysis Year	**2014**	Project Number	**11730.42**

Notes

1) Values in this spreadsheet may be copied and pasted directly into NCHRP 17-58 spreadsheets which are available from FDOT Safety Office upon request. Note that only values and not formulas should be copied.

Field Data Collection

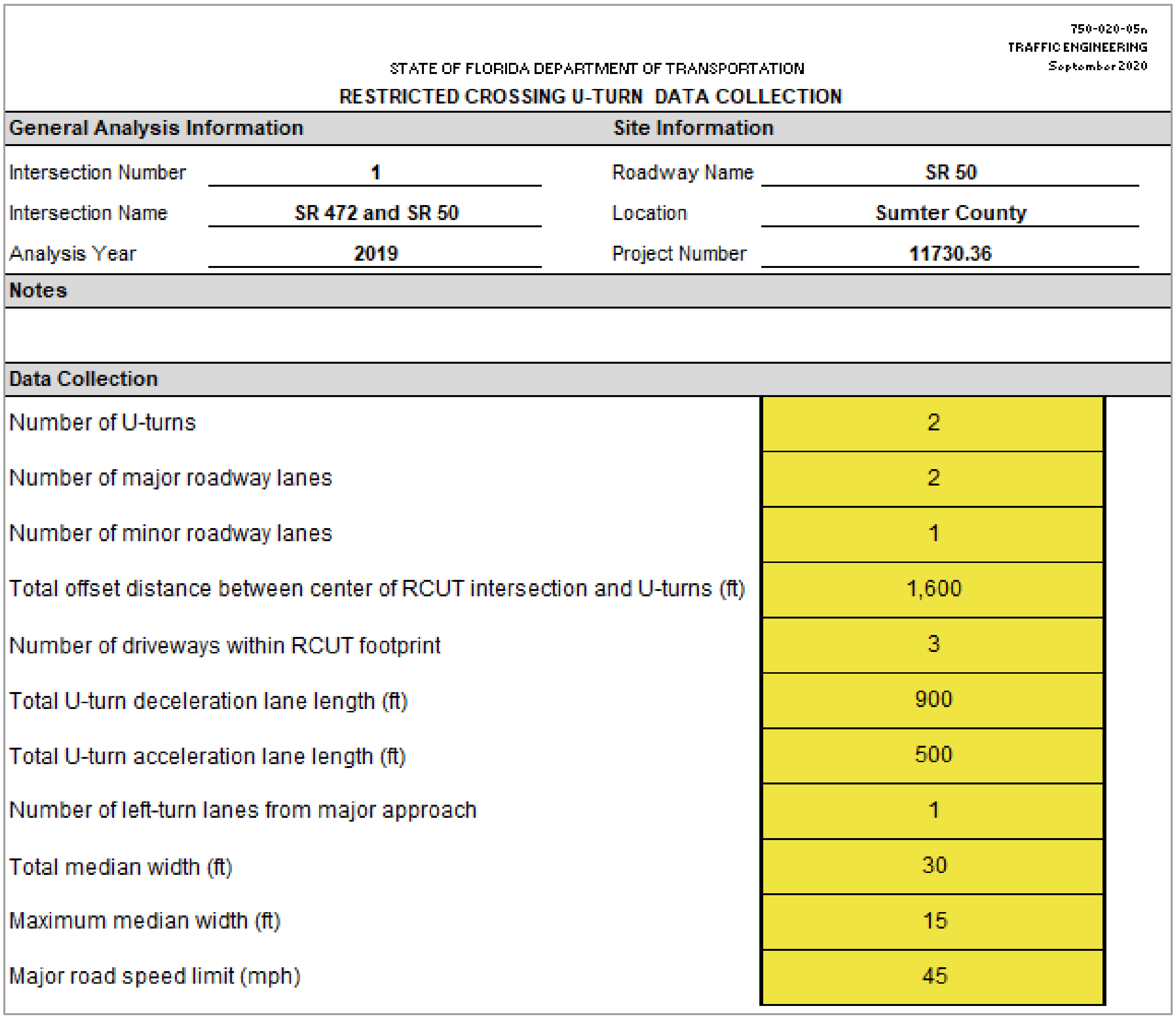
Intersection Data

Area type	Urban
Number of legs	4SG
Traffic control type	Signalized
Lighting present?	Yes
Red-light cameras present?	No
Daily pedestrian volume crossing all legs	180
Maximum number of lanes by a pedestrian	7
Number of bus stops within 1,000 feet of the intersection	6
Schools present within 1,000 feet of the intersection	No
Number of alcohol sales establishments within 1,000 feet of the intersection	2

Street Data	*Major*	*Minor*
Street Configuration	Two-way	Two-way
Annual Average Daily Traffic (AADT)	50,000	26,000
Number of through lanes	4	2
Number of approaches with left-turn lanes	2	2
Number of left-turn movements with protected phasir	2	2
Number of right-turn movements prohibited on red	0	0
Number of U-turn movements prohibited	0	0
Number of approaches with right-turn channelization	0	0

Source: NCHRP 17-58

Figure 5-10. Restricted Crossing U-Turn Data Collection
(*Form No. 750-020-05n*)



750-020-05n
TRAFFIC ENGINEERING
September 2020

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
RESTRICTED CROSSING U-TURN DATA COLLECTION

General Analysis Information

Intersection Number: **1**
Intersection Name: **SR 472 and SR 50**
Analysis Year: **2019**

Site Information

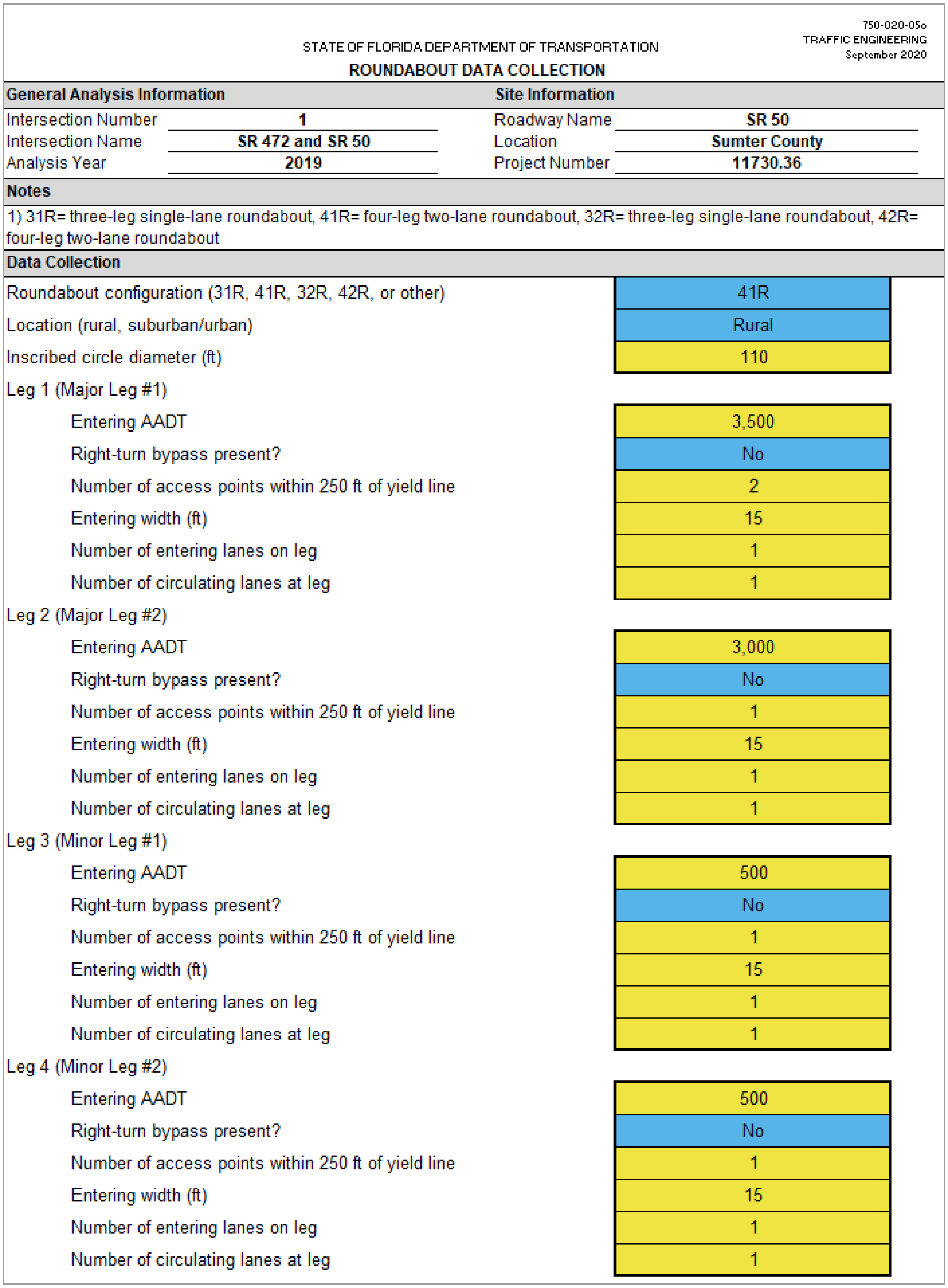
Roadway Name: **SR 50**
Location: **Sumter County**
Project Number: **11730.36**

Notes

Data Collection

Number of U-turns	2
Number of major roadway lanes	2
Number of minor roadway lanes	1
Total offset distance between center of RCUT intersection and U-turns (ft)	1,600
Number of driveways within RCUT footprint	3
Total U-turn deceleration lane length (ft)	900
Total U-turn acceleration lane length (ft)	500
Number of left-turn lanes from major approach	1
Total median width (ft)	30
Maximum median width (ft)	15
Major road speed limit (mph)	45

Figure 5-11. Roundabout Data Collection
(*Form No. 750-020-05o*)



750-020-05o
TRAFFIC ENGINEERING
September 2020

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

ROUNDABOUT DATA COLLECTION

General Analysis Information

Intersection Number **1**
Intersection Name **SR 472 and SR 50**
Analysis Year **2019**

Site Information

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

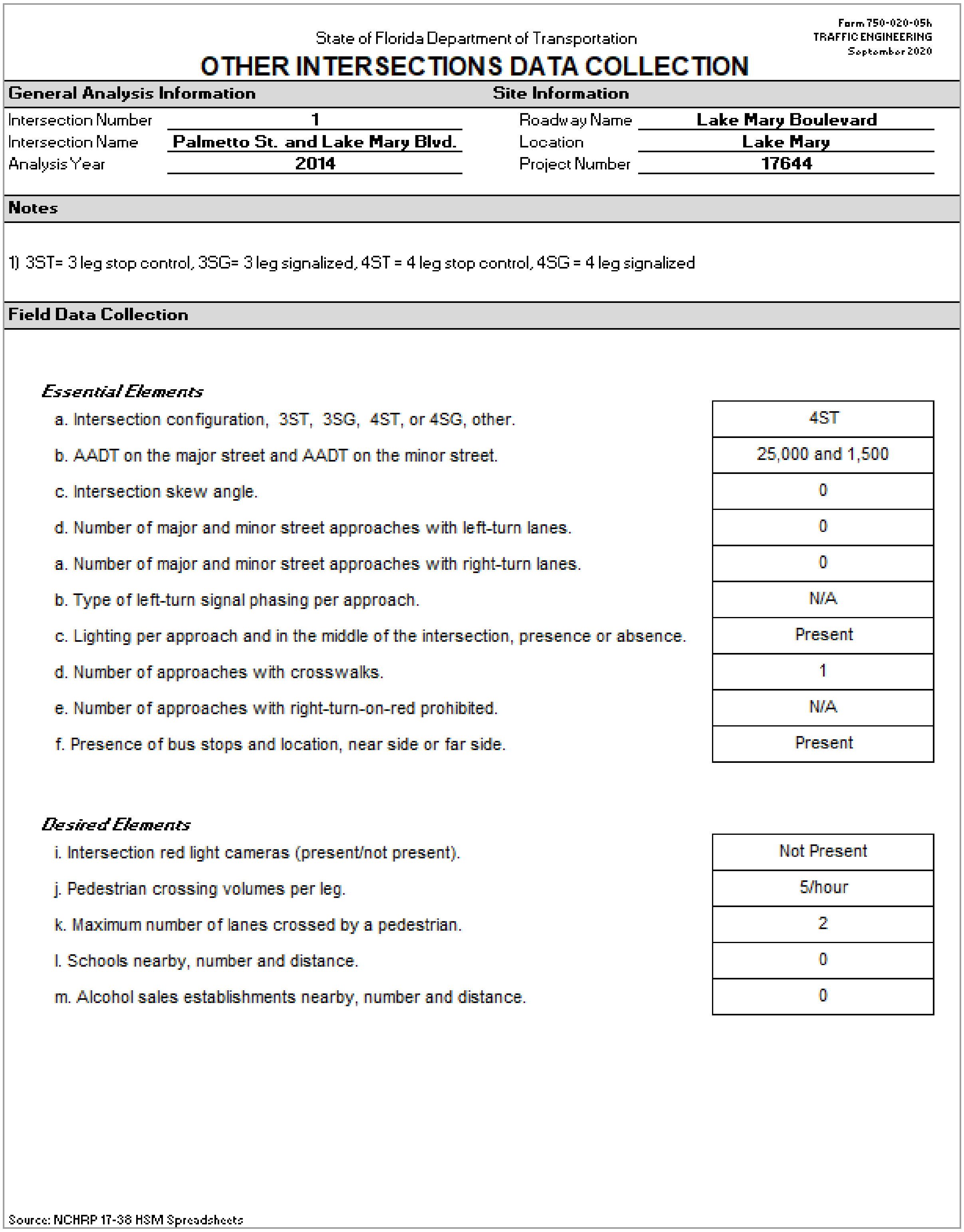
Notes

1) 31R= three-leg single-lane roundabout, 41R= four-leg two-lane roundabout, 32R= three-leg single-lane roundabout, 42R= four-leg two-lane roundabout

Data Collection

Roundabout configuration (31R, 41R, 32R, 42R, or other)	41R
Location (rural, suburban/urban)	Rural
Inscribed circle diameter (ft)	110
Leg 1 (Major Leg #1)	
Entering AADT	3,500
Right-turn bypass present?	No
Number of access points within 250 ft of yield line	2
Entering width (ft)	15
Number of entering lanes on leg	1
Number of circulating lanes at leg	1
Leg 2 (Major Leg #2)	
Entering AADT	3,000
Right-turn bypass present?	No
Number of access points within 250 ft of yield line	1
Entering width (ft)	15
Number of entering lanes on leg	1
Number of circulating lanes at leg	1
Leg 3 (Minor Leg #1)	
Entering AADT	500
Right-turn bypass present?	No
Number of access points within 250 ft of yield line	1
Entering width (ft)	15
Number of entering lanes on leg	1
Number of circulating lanes at leg	1
Leg 4 (Minor Leg #2)	
Entering AADT	500
Right-turn bypass present?	No
Number of access points within 250 ft of yield line	1
Entering width (ft)	15
Number of entering lanes on leg	1
Number of circulating lanes at leg	1

Figure 5-12. Other Intersections Data Collection
(*Form No. 750-020-05h*)



Form 750-020-05h
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

OTHER INTERSECTIONS DATA COLLECTION

General 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 5-13. Condition Diagram Example obtained from the HSM (Section 5.2.2)

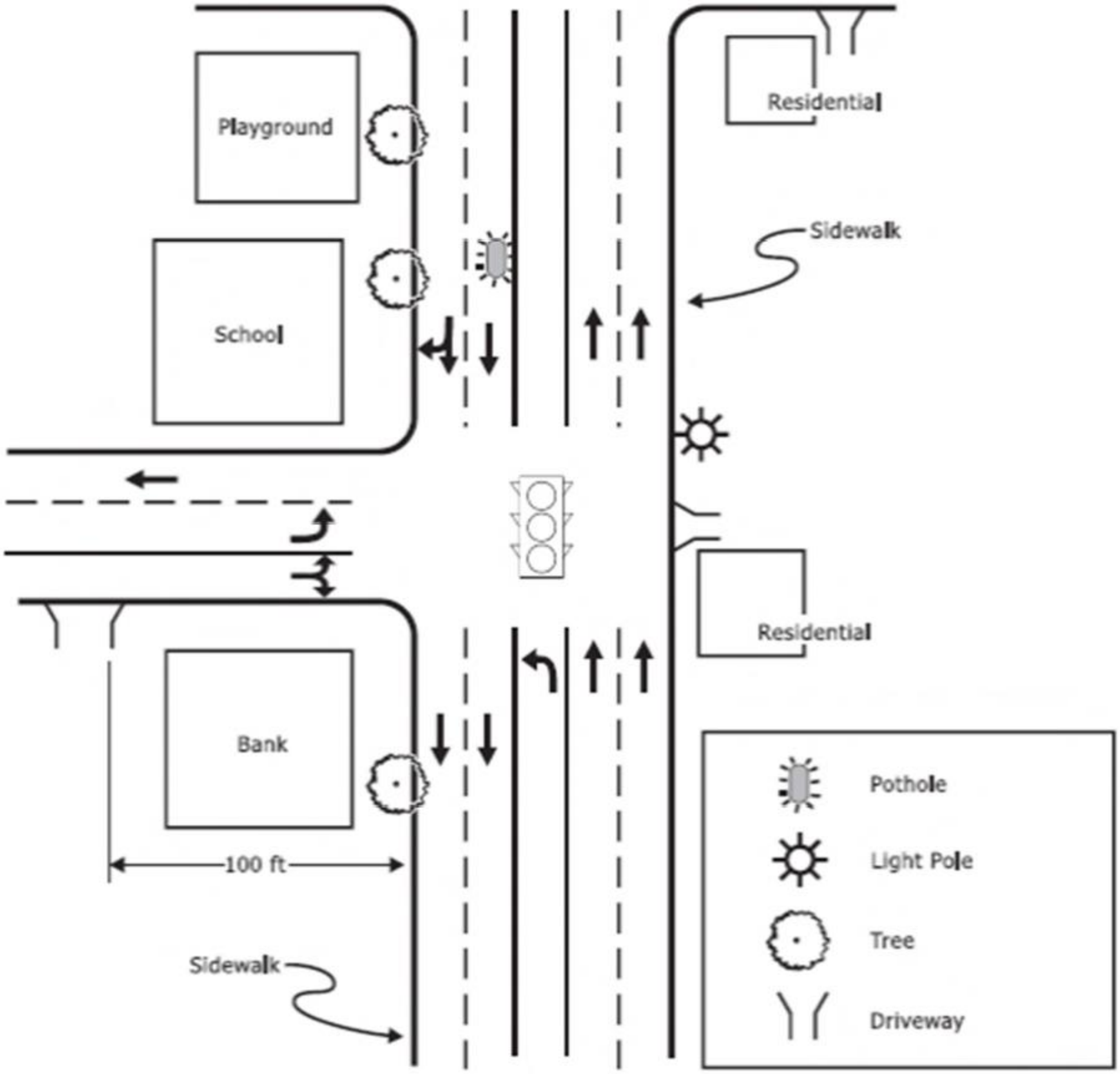
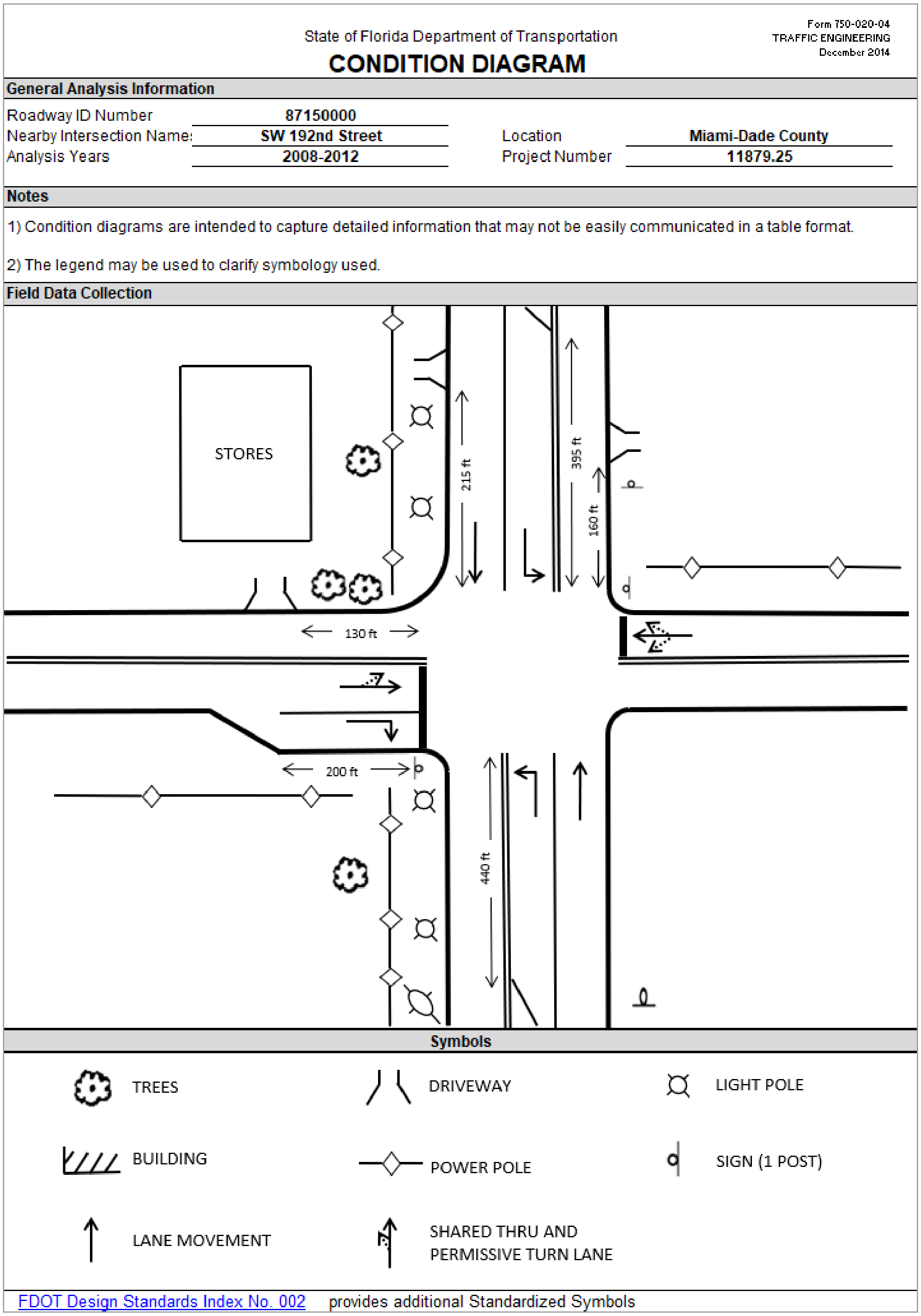


Figure 5-14. Condition Diagram
(*Form No. 750-020-04*)



Form 750-020-04
TRAFFIC ENGINEERING
December 2014

State of Florida Department of Transportation

CONDITION DIAGRAM

General 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

TREES	DRIVEWAY	LIGHT POLE
BUILDING	POWER POLE	SIGN (1 POST)
LANE MOVEMENT	SHARED THRU AND PERMISSIVE TURN LANE	

FDOT Design Standards Index No. 002 provides additional Standardized Symbols

Figure 5-15. Collision Diagram for Segments
(*Form No. 750-020-05i*)

State of Florida Department of Transportation

COLLISION DIAGRAM FOR SEGMENTS

General Analysis Information **Site Information**

Roadway ID Number **75190000**
Nearby Intersection Name **US 17/92 and Bennet Ave**
Analysis Years **2010-2014**
Location **Winter Park**
Project Number **11730.42**

Notes

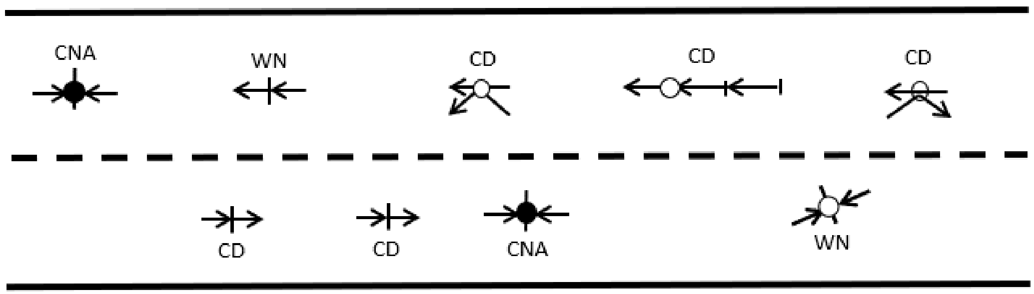
1) Collision diagram symbology illustrated in Figure 5-4 of Chapter 5 of the Highway Safety Manual should be used.

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



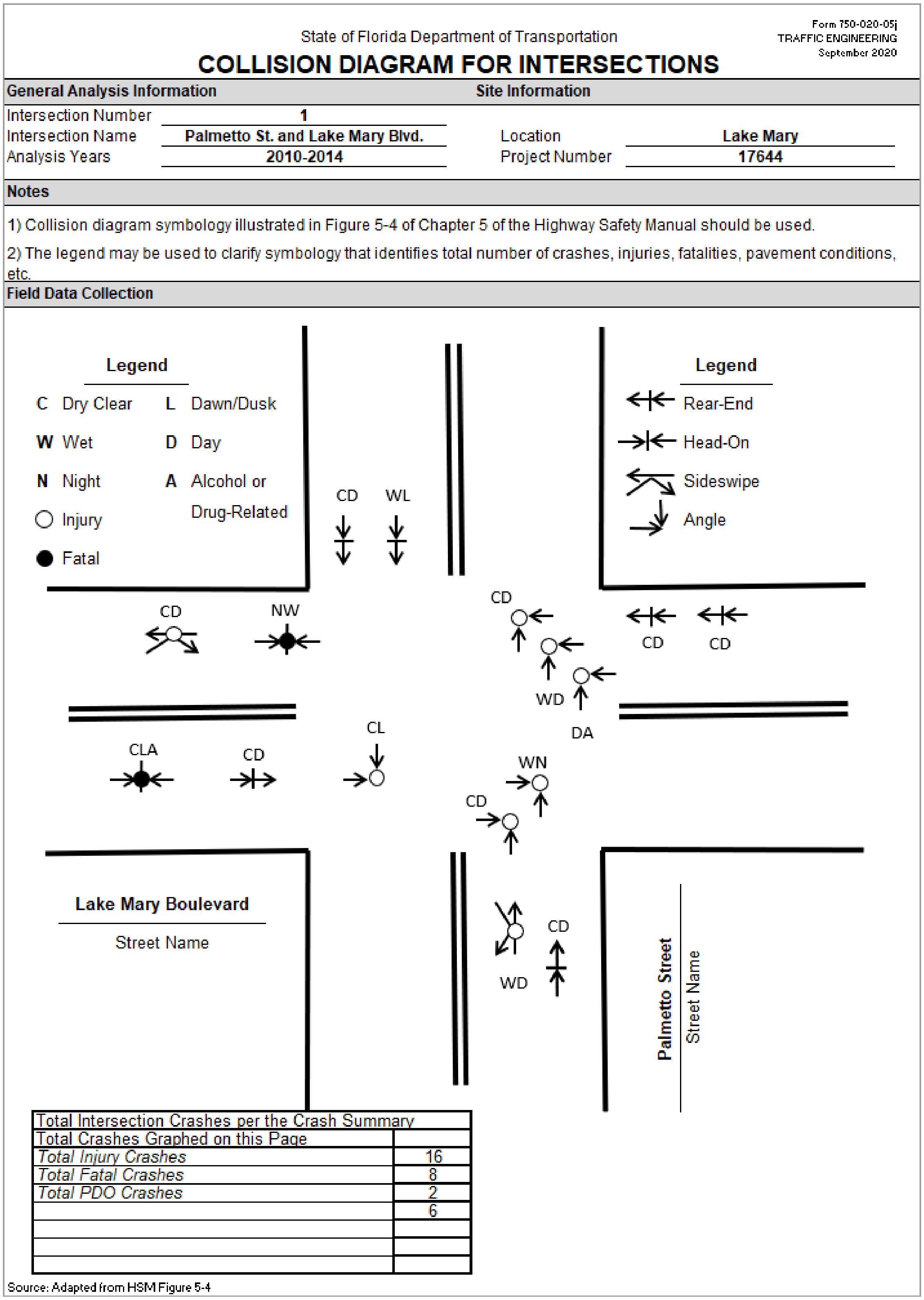
SR 423 (Lee Road)
Street Name

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 5-16. Collision Diagram for Intersections
(*Form No. 750-020-05j*)



Form 750-020-05j
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

COLLISION DIAGRAM FOR INTERSECTIONS

General Analysis Information

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

Site Information

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.

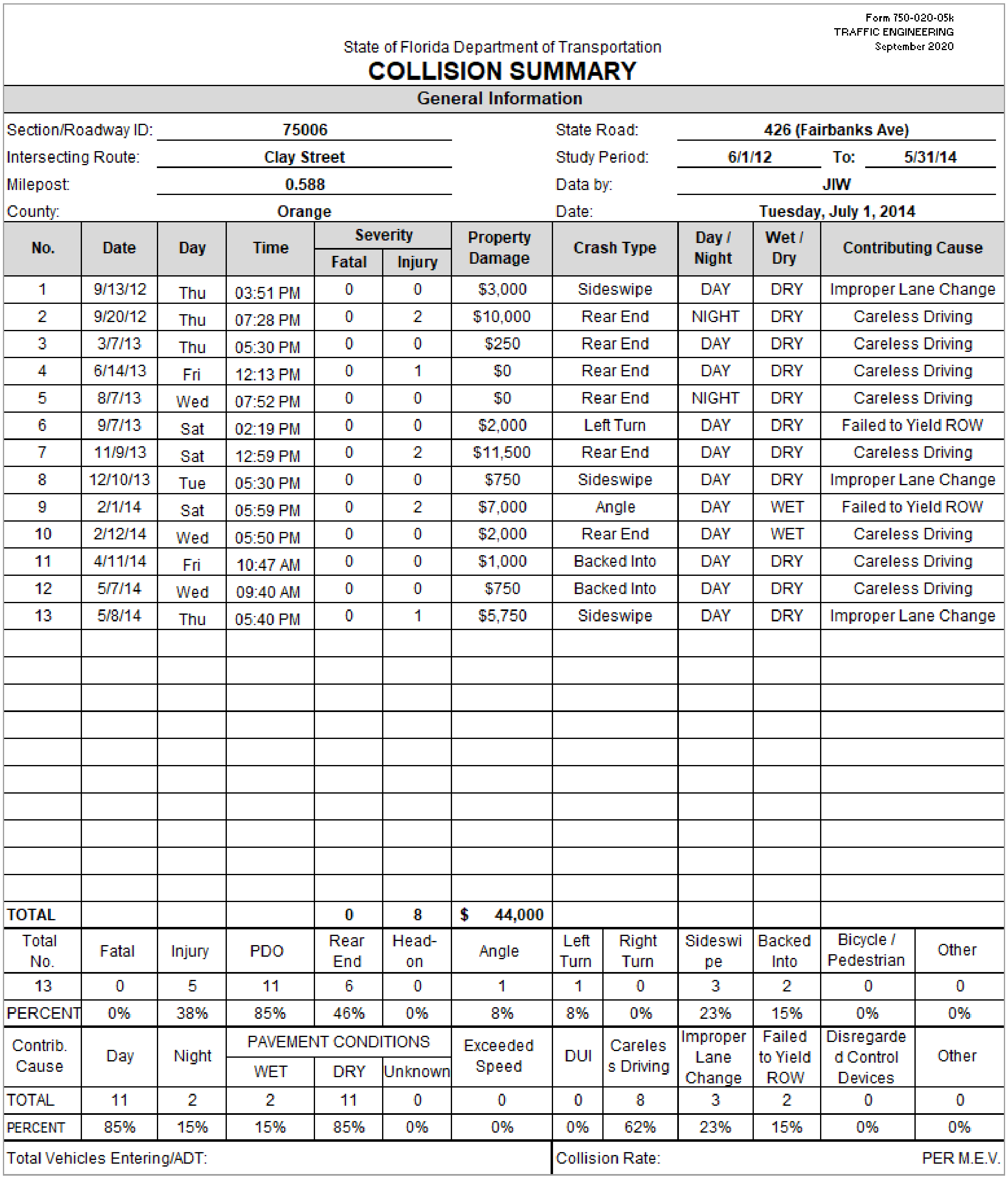
2) The legend may be used to clarify symbology that identifies total number of crashes, injuries, fatalities, pavement conditions, etc.

Field Data Collection

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

Source: Adapted from HSM Figure 5-4

Figure 5-17. Collision Summary
(*Form No. 750-020-05k*)



Form 750-020-05k
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

COLLISION SUMMARY

General 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 1, 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	8/7/13	Wed	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 DATA COLLECTION FOR SAFETY ANALYSIS OF FREEWAY FACILITIES

6.1 PURPOSE

(1) The purpose of the ***Safety Analysis of Freeway Facilities*** chapter is to provide guidance on the data collection requirements for conducting safety analysis of freeway facilities, including application of methodologies developed in ***NCHRP 17-45*** and implemented through the Enhanced Interchange Safety Analysis Tool (ISATe tool)*.* This chapter is divided into sections for freeway segments, ramp segments, and ramp terminals.

6.2 SAFETY STUDY BASICS

(1) Safety study basics are discussed in MUTS Chapter 5; Section 5.2 and are applicable to the freeway facility analysis.

6.3 PREDICTIVE METHOD PROCEDURE BASICS

(1) The Predictive Method is presented in the ***HSM – Part C*** and ***HSM Chapter 18 – Predictive Method for Freeways*** and ***HSM Chapter 19 – Predictive Method for Ramps***. The procedure is discussed in MUTS Chapter 5; Section 5.3, and is also applicable to freeway facility analysis.

Additional detail on the application of the Predictive Method can be found in ***HSM Chapter 3 – Fundamentals***, ***HSM Part C - Introduction and Application Guidance*** and the introductions to ***HSM Chapter 18*** and ***HSM Chapter 19***.

6.4 DATA COLLECTION NEEDS

(1) The data collection needs for safety studies of freeway facilities are outlined in this section.

(2) In situations where the ***HSM Chapter 18*** and ***HSM Chapter 19 Predictive Method for Freeways and Interchanges*** is not applicable, it is still recommended that at a minimum, consistent data be collected as is required for sites where the Predictive Method is applicable. The data collection spreadsheets that are provided are applicable for both situations, and the data collection process is outlined below.

(3) This section includes data collection guidance related to traffic volume and geometric data collection. Additional guidance for historical crash data collection and collision diagram development, as well as existing conditions data collection and condition diagram development is provided in MUTS Chapter 5.

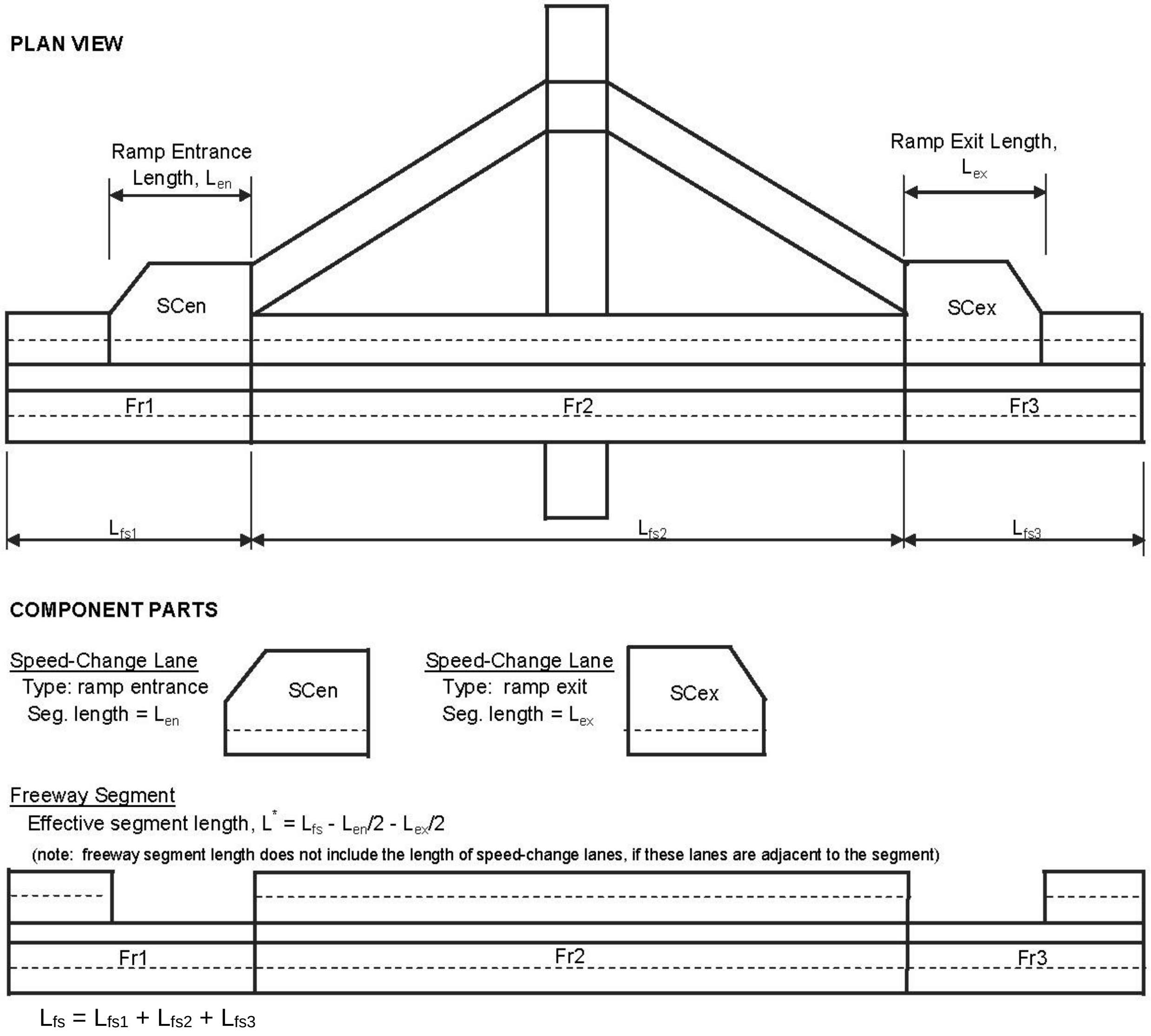
6.4.1 Traffic Volume and Geometry Data Collection

(1) The data collection requirements in this section are divided into freeway segments, ramp segments, and ramp terminals. There are corresponding spreadsheets for each facility type that can be downloaded for use in the field.

(2) Before proceeding, the analyst should determine if the ***HSM Chapter 18*** and ***HSM Chapter 19*** methodologies are applicable by referring those chapters or the Introduction tab of the ISATe spreadsheet tool.

(3) Analysis of freeway facilities is split into freeway segments, ramp segments, and ramp terminals. Freeway segments are further categorized as either a homogeneous freeway segment or a speed-change lane. ***Figure 6-1*** provides guidance on the definition of freeway segments and speed-change lanes and is provided below. A speed-change lane is defined as the section of roadway located between the marked gore and taper points of a ramp merge or diverge area and on the same side of the freeway as the merge or diverge area

Figure 6-1. Example of freeway segments and speed-change lanes (*HSM Chapter 18, Figure 18-10*)



6.4.1.1 Freeway Segments

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on freeway segments. ***Freeway Segment Data Collection*** (Form No. 750-020-06a) may be used to collect this data. An example of this form completed is shown in ***Figure 6-3*** and ***Figure 6-4***.

(2) Data required to compute crash prediction

The parameters noted below are used to compute the base crash prediction of a freeway segment as well as thirteen crash modification factors. These are numbered from CMF_1 to CMF_{13} in the ISATe spreadsheet tool. Details for each of the parameters used to compute CMFs can be found in ***HSM Chapter 18, Section 18.4.2*** and in the ISATe spreadsheet tool.

(a) Basic Roadway Data

- Number of through lanes.

  The number of through lanes does not include HOV or managed lanes. Does not include auxiliary lanes associated with a weaving section, unless the weaving section is longer than 0.85 mi. Does not include a speed-change lane that is associated with a merging or diverging ramp, unless the length exceeds 0.30 mi. A segment with a lane-add or lane-drop taper is considered to have the same number of through lanes as the roadway downstream of the taper. Rural freeway segments are limited to eight lanes. Urban freeway segments are limited to ten lanes.

- Segment length (mi).

  Segment length is measured along the inside edge of the traveled way in the increasing milepost direction. Freeway segment length does not include the length of adjacent speed-change lanes.

(b) Alignment Data

- Horizontal curve presence, curve radius (ft), length of curve (mi), length of curve in segment (mi).

  Horizontal curve data is required for each curve that is fully or partially in the freeway segment. If the curve has spiral transitions, the radius is entered as the central circular portion of the curve. The curve may be present in one direction, both directions (concentric), or both directions (non-concentric), as discussed in ***HSM Chapter 18, Figure 18-4***.

(c) Cross Section Data

- Lane width (ft).

  Average of all through lanes in both travel directions. Record a length-weighted average if the width varies slightly in the segment.

- Outside shoulder width (ft).

  Average width of the paved outside shoulder in both travel directions. Record a length-weighted average if the width varies slightly in the segment.

- Inside shoulder width (ft).

  Average width of the paved inside shoulder in both travel directions. Record a length-weighted average if the width varies slightly in the segment.

- Median width (ft).

  Median width is measured between the edges of traveled roadway, including the width of any inside shoulder. If barrier separated managed lanes are present, these are considered to be part of the median width.

- Presence of rumble strips on outside shoulders, length of rumble strips on outside shoulder in each travel direction (mi).

  If a speed-change lane with rumble strips is present, include the length of the speed-change lane when computing the length of the rumble strips. If a speed change lane without rumble strips is present, do not include the length of the speed-change lane when computing the length of the rumble strips.

- Presence of rumble strips on inside shoulders, length of rumble strips on inside shoulder in each travel direction (mi).

- Presence/type of barrier in median, length of median barrier (mi), distance from edge of traveled way to median barrier face (ft), median barrier width (ft), nearest distance from edge of traveled way to median barrier face (ft).

  Median barrier may be classified as *Center* – barrier is centered in the median and continuous through the segment, *Offset* – barrier is offset from center and continuous through the segment, *Some* – continuous barrier is not present, but shorter sections may be present, or *None* – no barrier is present.

  Median barrier width is the distance from the face of the barrier for one travel direction to the face of the barrier in the opposite travel direction.

(d) Roadside Data

- Clear zone width (ft).

  Clear zone is measure as the distance from the edge of traveled way to the typical limits of vertical obstruction. If this distance varies slightly along the segment, record a length-weighted average. Do not consider roadside barrier when measuring clear zone width. If a continuous roadside barrier is present on both sides for its entire length, enter 30 ft for the clear zone width.

- Presence/type of barrier on roadside, length of roadside barrier (mi), distance from edge of traveled way to roadside barrier face (ft).

  Roadside barrier may be classified as *Full* – barrier is continuous through the segment on both sides of the roadway, *Some* – continuous barrier is not present, but shorter barrier sections are present, or *None* – no roadside barrier is present.

(e) Ramp Access Data

- Presence/type of ramp entrance in segment, distance from begin milepost to upstream entrance ramp gore (mi), length of ramp entrance (mi), length of ramp entrance in segment (mi), side of ramp entrance.

  For travel in each direction, ramp type in a segment can either be a lane-add or a speed-change lane. Distance is measured from the segment boundary to the ramp gore point. Record a value of 999 (in ISATe) for the distance if a ramp does not exist or is located more than 0.5 mi from the segment. Distance to nearest ramp measurement is illustrated in ***Figure 6-2***.

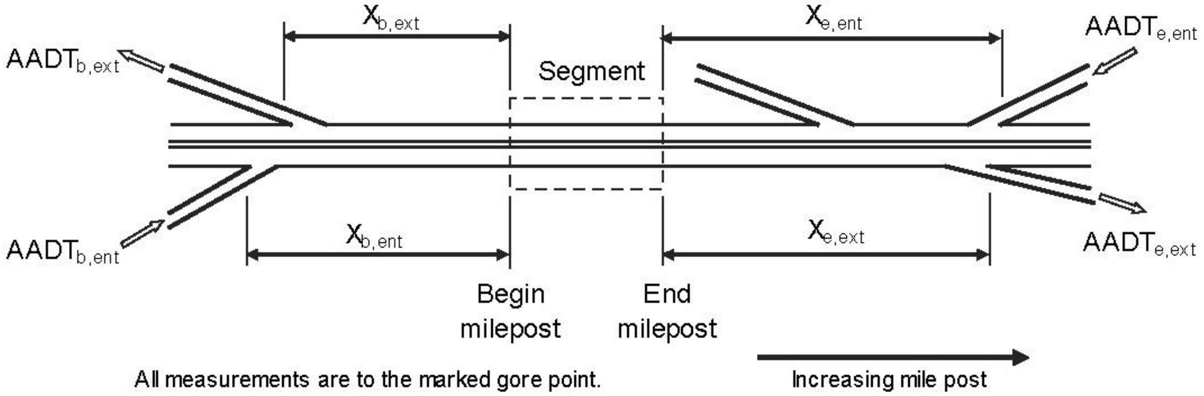
- Presence/type of ramp exit in segment, distance from end milepost to downstream exit ramp gore (mi), length of ramp exit (mi), length of ramp exit in segment (mi), side of ramp exit.

  For travel in each direction, ramp type in a segment can either be a lane-drop or a speed-change lane. Distance is measured from the segment boundary to the ramp gore point. Record a value of 999 (in ISATe) for the distance if a ramp does not exist or is located more than 0.5 mi from the segment.

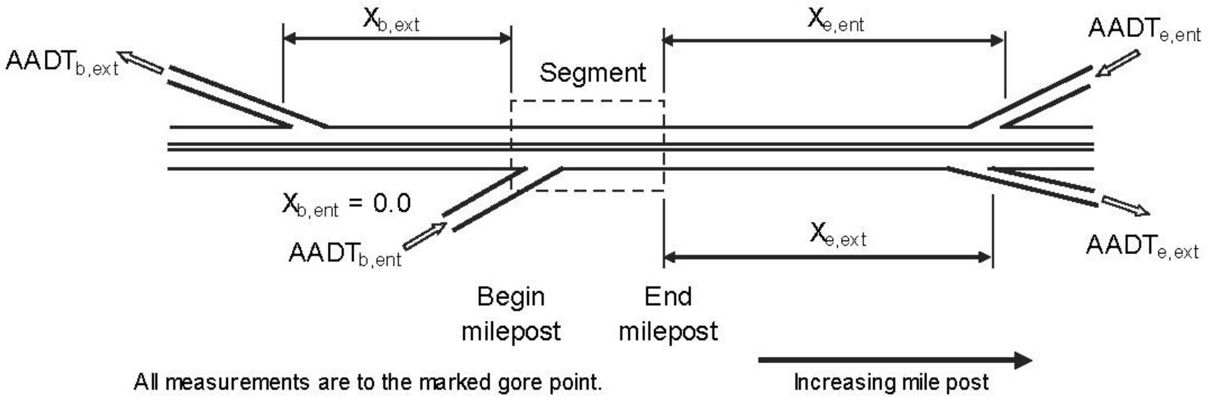
- Presence of Type B weave in segment, length of weaving section (mi), length of weaving section in segment (mi).

A Type B weaving section has the following characteristics: 1) one of the two weaving movements can be made without making any lane change, 2) the other weaving movement requires at most one lane change, and 3) both the ramp entrance and ramp exit associated with the weaving section are located on the right side of the freeway. These weaves are illustrated in ***HSM Chapter 18, Figure 18-7***.

Figure 6-2. Distance to nearest ramp measurement
(*HSM Chapter 18, Figure 18-8*)



a. All Ramps External to the Segment



b. Three Ramps External to the Segment and One Ramp in the Segment

(f) Traffic Data

- Proportion of AADT during high-volume hours.

  The proportion of AADT in the average 24-hr day where to hourly volume exceeds 1,000 veh/hr/ln.

- AADT by year on freeway segment.
- AADT by year on entrance ramp.
- AADT by year on exit ramp.

(4) Crash data to compute crash prediction

(5) In the Main tab of the ISATe spreadsheet tool, the user has the opportunity to input crash data for “each individual segment” or for “all segments combined”. This selection should be set to crash data “for each individual segment” best results and is the recommended practice in Florida.

(a) Count of crashes by year for each of the following:

- Multiple-vehicle fatal-and-injury crashes (not ramp related)
- Single-vehicle fatal-and-injury crashes (not ramp related)
- Ramp-entrance-related fatal-and-injury crashes
- Ramp-exit-related fatal-and-injury crashes
- Multiple-vehicle property-damage-only crashes (not ramp related)
- Single-vehicle property-damage-only crashes (not ramp related)
- Ramp-entrance-related property-damage-only crashes
- Ramp-exit-related property-damage-only crashes

6.4.1.2 Ramp Segments

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on ramp segments. ***HSM Chapter 19, Figure 19-10*** provides guidance on the definition of ramp segments. ***Ramp Segment Data Collection*** (Form No. 750-020-06b) may be used to collect this data. An example of this form completed is shown in ***Figure 6-5*** and ***Figure 6-6***.

(2) Data required to compute crash prediction

The parameters noted below are used to compute the base crash prediction of a freeway segment as well as nine crash modification factors. These are numbered from CMF_1 to CMF_9 in the ISATe spreadsheet tool. Details for each of the parameters used to compute CMFs can be found in ***HSM Chapter 19, Section 19.4.2*** and in the ISATe spreadsheet tool.

(a) Basic Roadway Data

- Number of through lanes.

  The total number of through lanes in the segment. Rural ramp segments are limited to one lane. Urban ramp segments are limited to two lanes. Do not include HOV bypass lanes. Do not include any auxiliary lanes associated with a collector-distributor road weaving section, unless the weaving section length exceeds 0.3 mi. Do not include any auxiliary lanes that are developed as a turn bay at the crossroad ramp terminal. Do not include the speed-change lane that is associated with a second ramp merging or diverging from the subject ramp, unless its length exceeds 0.19 mi.

- Segment length (mi).

  Segment length is measured along the right edge of the traveled way in the direction of travel. For guidance on ramp segmentation see ***HSM Chapter 19, Figure 19-3***.

- Average traffic speed on the freeway (mph).

  Average traffic speed during off-peak periods of the typical day. If better information is not available, then this speed can be estimated as the freeway's maximum speed limit.

- Segment type.

  Ramp segment type may be classified as Entrance, Exit, Collector-Distributor Road, or Connector.

- Type of control at crossroad ramp terminal – none, yield, stop, signal.

(b) Alignment Data

- Horizontal curve presence, curve radius (ft), length of curve (mi), length of curve in segment (mi), milepost of beginning of curve in direction of travel (mi).

  Length of curve is measured along the reference line from the point where the tangent ends and the curve beings to the point where the curve ends and the tangent begins (i.e., PC to PT). The length of curve in segment is the length of the curve only within the boundaries of the segment (this cannot exceed the segment length or the curve length).

  Curve radius is measured to the right edge of traveled way in the direction of travel. If the curve has spiral transitions, then enter the radius of the central circular portion of the curve.

  The milepost of beginning of curve in direction of travel is measured to the point where the tangent ends and the curve begins. The starting location for ramp mileposts is measured from the gore point as shown in ***HSM Chapter 19, Figure 19-4***.

(c) Cross Section Data

- Lane width (ft).

  Average through lane width of all lanes on the ramp. If the lane width varies slightly through the segment, use a length-weighted average for the lane width.

- Right shoulder width (ft).

  Width of paved right shoulder in the direction of travel. If the width varies slightly through the segment, use a length-weighted average for the width.

- Left shoulder width (ft).

  Width of paved left shoulder in the direction of travel. If the width varies slightly through the segment, use a length-weighted average for the width.

- Presence of lane add or lane drop, length of taper for lane add or lane drop (mi).

(d) Roadside Data

- Presence of barrier on right/left side of roadway, length of barrier (mi), distance from edge of traveled way to barrier face (ft).

(e) Ramp Access Data

- Presence/type of ramp entrance in segment, length of entrance speed-change lane in segment (mi).

  The speed-change lane length is measured along the edge of the ramp traveled way from the gore point to the taper point.

- Presence/type of ramp exit in segment, length of entrance speed-change lane in segment (mi).

  The speed-change lane length is measured along the edge of the ramp traveled way from the gore point to the taper point, as shown in ***HSM Chapter 19, Figure 19-6***.

- Presence of weaving section in collector-distributor segment, length of weaving section (mi), length of weaving section in segment (mi).

  Weaving section length is measured along the edge of collector-distributor road traveled way from the gore point of the ramp entrance to the gore point of the next ramp exit, as shown in ***HSM Chapter 19, Figure 19-7***.

(f) Traffic Data

- AADT by year on ramp segment.

(g) Crash Data

- Crash data by year to compute crash prediction (at least five years)

  Count of crashes by year for each of the following:

- Multiple-vehicle fatal-and-injury crashes
- Single-vehicle fatal-and-injury crashes
- Multiple-vehicle property-damage-only crashes
- Single-vehicle property-damage-only crashes

6.4.1.3 Ramp Terminals

(1) The following is a list of data collection input parameters required to conduct a predictive analysis on ramp terminals. ***HSM Chapter 19, Figure 19-8*** provides guidance on the definition of ramp terminals. ***Ramp Terminal Data Collection*** (Form No. 750-020-06c) may be used to collect this data. An example of this form completed is shown in ***Figure 6-7***.

(2) Data required to compute crash prediction

The parameters noted below are used to compute the base crash prediction of a ramp terminal as well as eleven crash modification factors. These are numbered from CMF_{10} to CMF_{20} in the ISATe spreadsheet tool. Details for each of the parameters used to compute CMFs can be found in ***HSM Chapter 19*** and in the ISATe spreadsheet tool.

At a ramp terminal, the inside crossroad approach is on the side of the ramp terminal nearest to the freeway. The outside crossroad approach is on the other side of the ramp terminal.

(a) Basic Intersection Data

- Ramp terminal configuration.

  Supported ramp terminal configurations include the following, which can be found in ***HSM Chapter 19, Figure 19-1***:

- D3ex – three-leg terminal with diagonal freeway exit ramp
- D3en – three-leg terminal with diagonal freeway entrance ramp
- D4 – four-leg terminal with diagonal ramps
- A4 – four-leg terminal at four-quadrant parclo A
- B4 – four-leg terminal at four-quadrant parclo B
- A2 – three-leg terminal at two-quadrant parclo A
- B2 – three-leg terminal at two-quadrant parclo B
- Crossroads must provide two-way travel.
- Ramp terminal traffic control type.
- Presence of a non-ramp public street leg at the terminal.

(b) Alignment Data

- Exit ramp skew angle (degrees), as shown in ***HSM Chapter 19, Figure 19-9***.

- Distance to the next public street intersection on the outside crossroad leg (mi).

- Distance to adjacent ramp terminal (mi).

  If there is no adjacent ramp terminal, measure the distance to the nearest public street intersection on the inside crossroad leg.

(a) Traffic Control

- Left-turn operational mode of inside and outside approach on crossroad. An affirmative response is indicated if the left-turn operates as protected only. If it operates as permissive or protected-permissive, then the response is negative.

- Right-turn control type on exit ramp approach.

(b) Cross Section Data

- Crossroad median width (ft).

- Number of lanes on crossroad (each approach and total). This is for either shared or exclusive lanes which continue through the intersection.

- Number of lanes on exit ramp approach. Lanes can serve any movement (left, right or through)

- Presence of right-turn channelization on crossroad approaches and exit ramp approach.

  A right-turn channelization exists if there is a turning roadway serving right-turn vehicles with a channelized island present. The right-turn movement can be free-flow, stop, or yield controlled. The channelizing island can be delineated by pavement markings or raised curb.

- Presence of left-turn lane or bay on each crossroad approach, total width of lane(s) or bay(s) (ft).

- Presence of right-turn lane or bay on each crossroad approach.

(c) Access Data

- Number of driveways on the outside crossroad leg.

  Count of unsignalized driveways on the outside crossroad leg and within 250 ft of the ramp terminal. The count is taken on both sides of the leg. The count should only include active driveways with an average daily volume of 10 veh/d or greater.

- Number of public street approaches on the outside crossroad leg.

  Count of unsignalized public street approaches on the outside crossroad leg and within 250 ft of the ramp terminal. The count is taken on both sides of the leg. If the public street approach is located at the ramp terminal, it is not included in this count.

(d) Traffic Data

- AADT by year on the inside crossroad leg.
- AADT by year on the outside crossroad leg.
- AADT by year on the exit ramp.
- AADT by year on the entrance ramp.

(e) Crash Data

- Crash data by year to compute crash prediction (at least five years)

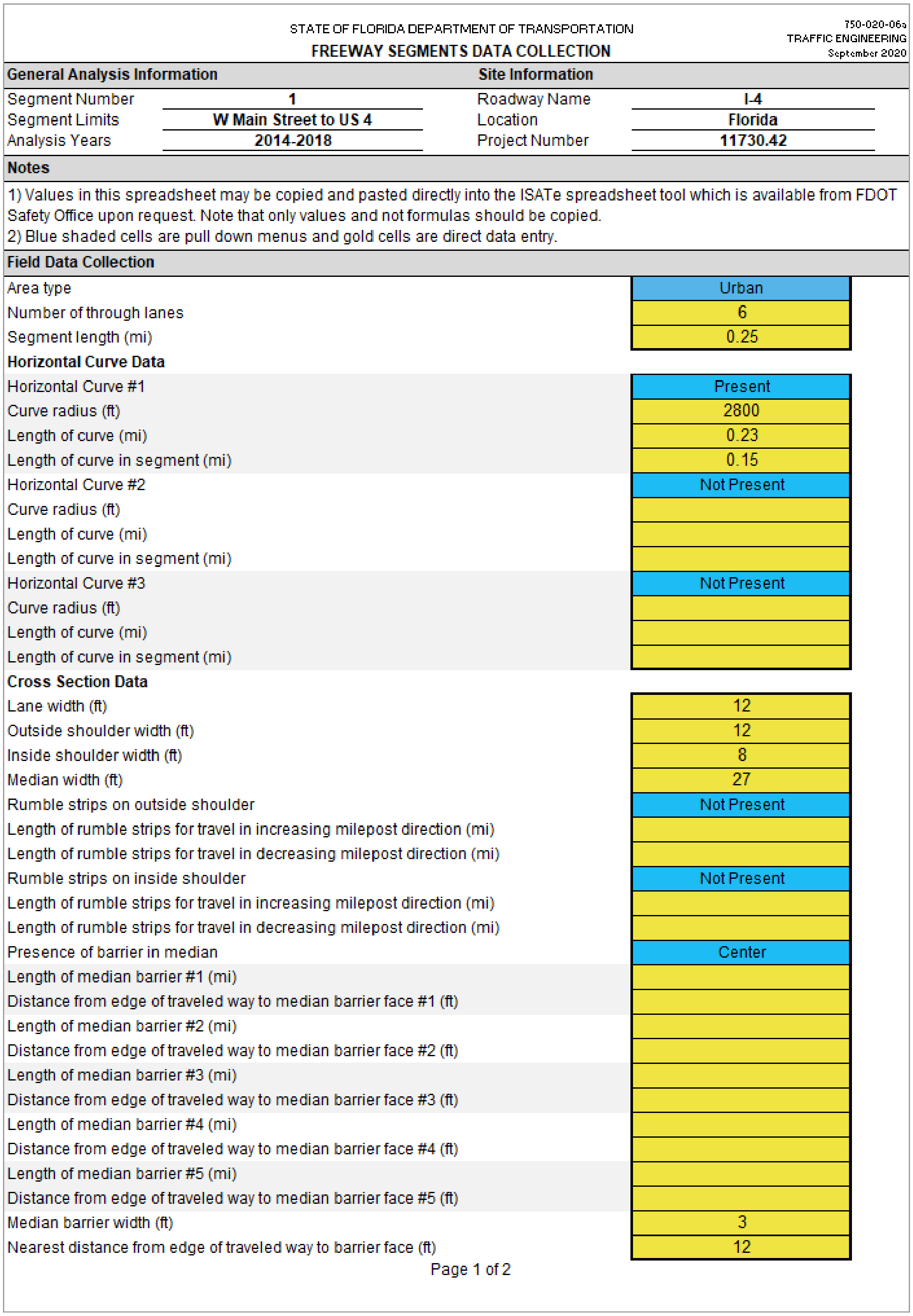
  Count of crashes by year for each of the following:

- Fatal-and-injury crashes
- Property-damage-only crashes

6.5 FORMS ACCESS

(1) Reproducible copies of the ***Freeway Segments Data Collection*** (Form No. 750-020-06a), ***Ramp Segments Data Collection*** (Form No. 750-020-06b) and the ***Ramp Terminal Data Collection*** (Form No. 750-020-06c) forms are available in the Department's Forms Library.

Figure 6-3. Freeway Segments Data Collection – Sheet 1 (Form No. 750-020-06a)



750-020-06a
TRAFFIC ENGINEERING
September 2020

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION

FREEWAY SEGMENTS DATA COLLECTION

General Analysis Information		**Site Information**	
Segment Number	**1**	Roadway Name	**I-4**
Segment Limits	**W Main Street to US 4**	Location	**Florida**
Analysis Years	**2014-2018**	Project Number	**11730.42**

Notes

1) Values in this spreadsheet may be copied and pasted directly into the ISATe spreadsheet tool which is available from FDOT Safety Office upon request. Note that only values and not formulas should be copied.
2) Blue shaded cells are pull down menus and gold cells are direct data entry.

Field Data Collection

Area type	Urban
Number of through lanes	6
Segment length (mi)	0.25
Horizontal Curve Data	
Horizontal Curve #1	Present
Curve radius (ft)	2800
Length of curve (mi)	0.23
Length of curve in segment (mi)	0.15
Horizontal Curve #2	Not Present
Curve radius (ft)	
Length of curve (mi)	
Length of curve in segment (mi)	
Horizontal Curve #3	Not Present
Curve radius (ft)	
Length of curve (mi)	
Length of curve in segment (mi)	
Cross Section Data	
Lane width (ft)	12
Outside shoulder width (ft)	12
Inside shoulder width (ft)	8
Median width (ft)	27
Rumble strips on outside shoulder	Not Present
Length of rumble strips for travel in increasing milepost direction (mi)	
Length of rumble strips for travel in decreasing milepost direction (mi)	
Rumble strips on inside shoulder	Not Present
Length of rumble strips for travel in increasing milepost direction (mi)	
Length of rumble strips for travel in decreasing milepost direction (mi)	
Presence of barrier in median	Center
Length of median barrier #1 (mi)	
Distance from edge of traveled way to median barrier face #1 (ft)	
Length of median barrier #2 (mi)	
Distance from edge of traveled way to median barrier face #2 (ft)	
Length of median barrier #3 (mi)	
Distance from edge of traveled way to median barrier face #3 (ft)	
Length of median barrier #4 (mi)	
Distance from edge of traveled way to median barrier face #4 (ft)	
Length of median barrier #5 (mi)	
Distance from edge of traveled way to median barrier face #5 (ft)	
Median barrier width (ft)	3
Nearest distance from edge of traveled way to barrier face (ft)	12

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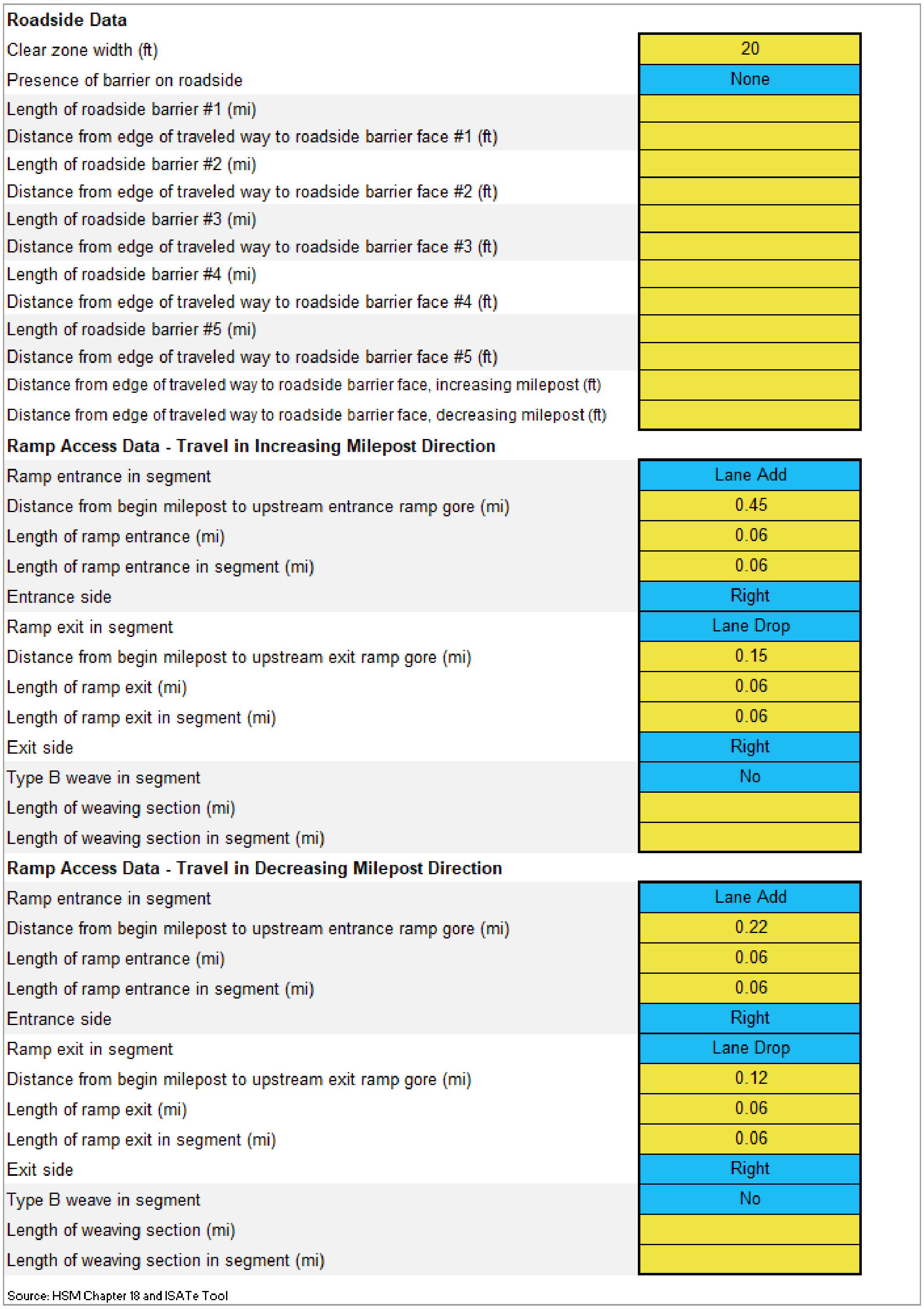
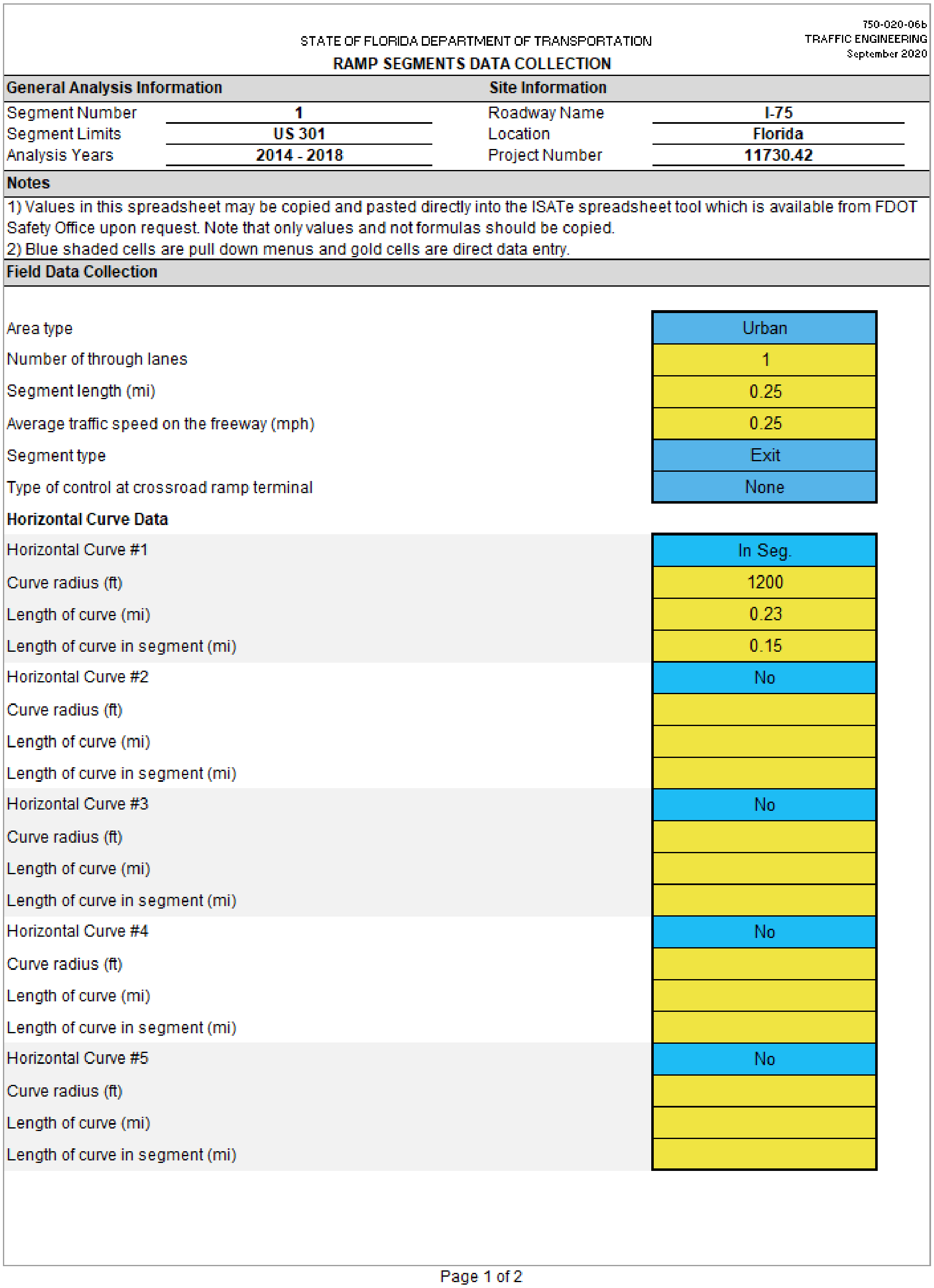
Figure 6-4. Freeway Segments Data Collection – Sheet 2
(*Form No. 750-020-06a*)



Roadside Data	
Clear zone width (ft)	20
Presence of barrier on roadside	None
Length of roadside barrier #1 (mi)	
Distance from edge of traveled way to roadside barrier face #1 (ft)	
Length of roadside barrier #2 (mi)	
Distance from edge of traveled way to roadside barrier face #2 (ft)	
Length of roadside barrier #3 (mi)	
Distance from edge of traveled way to roadside barrier face #3 (ft)	
Length of roadside barrier #4 (mi)	
Distance from edge of traveled way to roadside barrier face #4 (ft)	
Length of roadside barrier #5 (mi)	
Distance from edge of traveled way to roadside barrier face #5 (ft)	
Distance from edge of traveled way to roadside barrier face, increasing milepost (ft)	
Distance from edge of traveled way to roadside barrier face, decreasing milepost (ft)	
Ramp Access Data - Travel in Increasing Milepost Direction	
Ramp entrance in segment	Lane Add
Distance from begin milepost to upstream entrance ramp gore (mi)	0.45
Length of ramp entrance (mi)	0.06
Length of ramp entrance in segment (mi)	0.06
Entrance side	Right
Ramp exit in segment	Lane Drop
Distance from begin milepost to upstream exit ramp gore (mi)	0.15
Length of ramp exit (mi)	0.06
Length of ramp exit in segment (mi)	0.06
Exit side	Right
Type B weave in segment	No
Length of weaving section (mi)	
Length of weaving section in segment (mi)	
Ramp Access Data - Travel in Decreasing Milepost Direction	
Ramp entrance in segment	Lane Add
Distance from begin milepost to upstream entrance ramp gore (mi)	0.22
Length of ramp entrance (mi)	0.06
Length of ramp entrance in segment (mi)	0.06
Entrance side	Right
Ramp exit in segment	Lane Drop
Distance from begin milepost to upstream exit ramp gore (mi)	0.12
Length of ramp exit (mi)	0.06
Length of ramp exit in segment (mi)	0.06
Exit side	Right
Type B weave in segment	No
Length of weaving section (mi)	
Length of weaving section in segment (mi)	

Source: HSM Chapter 18 and ISATe Tool

Figure 6-5. Ramp Segments Data Collection – Sheet 1
(*Form No. 750-020-06b*)



750-020-06b
TRAFFIC ENGINEERING
September 2020

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
RAMP SEGMENTS DATA COLLECTION

General Analysis Information		**Site Information**	
Segment Number	**1**	Roadway Name	**I-75**
Segment Limits	**US 301**	Location	**Florida**
Analysis Years	**2014 - 2018**	Project Number	**11730.42**

Notes

1) Values in this spreadsheet may be copied and pasted directly into the ISATe spreadsheet tool which is available from FDOT Safety Office upon request. Note that only values and not formulas should be copied.
2) Blue shaded cells are pull down menus and gold cells are direct data entry.

Field Data Collection

Area type	Urban
Number of through lanes	1
Segment length (mi)	0.25
Average traffic speed on the freeway (mph)	0.25
Segment type	Exit
Type of control at crossroad ramp terminal	None
Horizontal Curve Data	
Horizontal Curve #1	In Seg.
Curve radius (ft)	1200
Length of curve (mi)	0.23
Length of curve in segment (mi)	0.15
Horizontal Curve #2	No
Curve radius (ft)	
Length of curve (mi)	
Length of curve in segment (mi)	
Horizontal Curve #3	No
Curve radius (ft)	
Length of curve (mi)	
Length of curve in segment (mi)	
Horizontal Curve #4	No
Curve radius (ft)	
Length of curve (mi)	
Length of curve in segment (mi)	
Horizontal Curve #5	No
Curve radius (ft)	
Length of curve (mi)	
Length of curve in segment (mi)	

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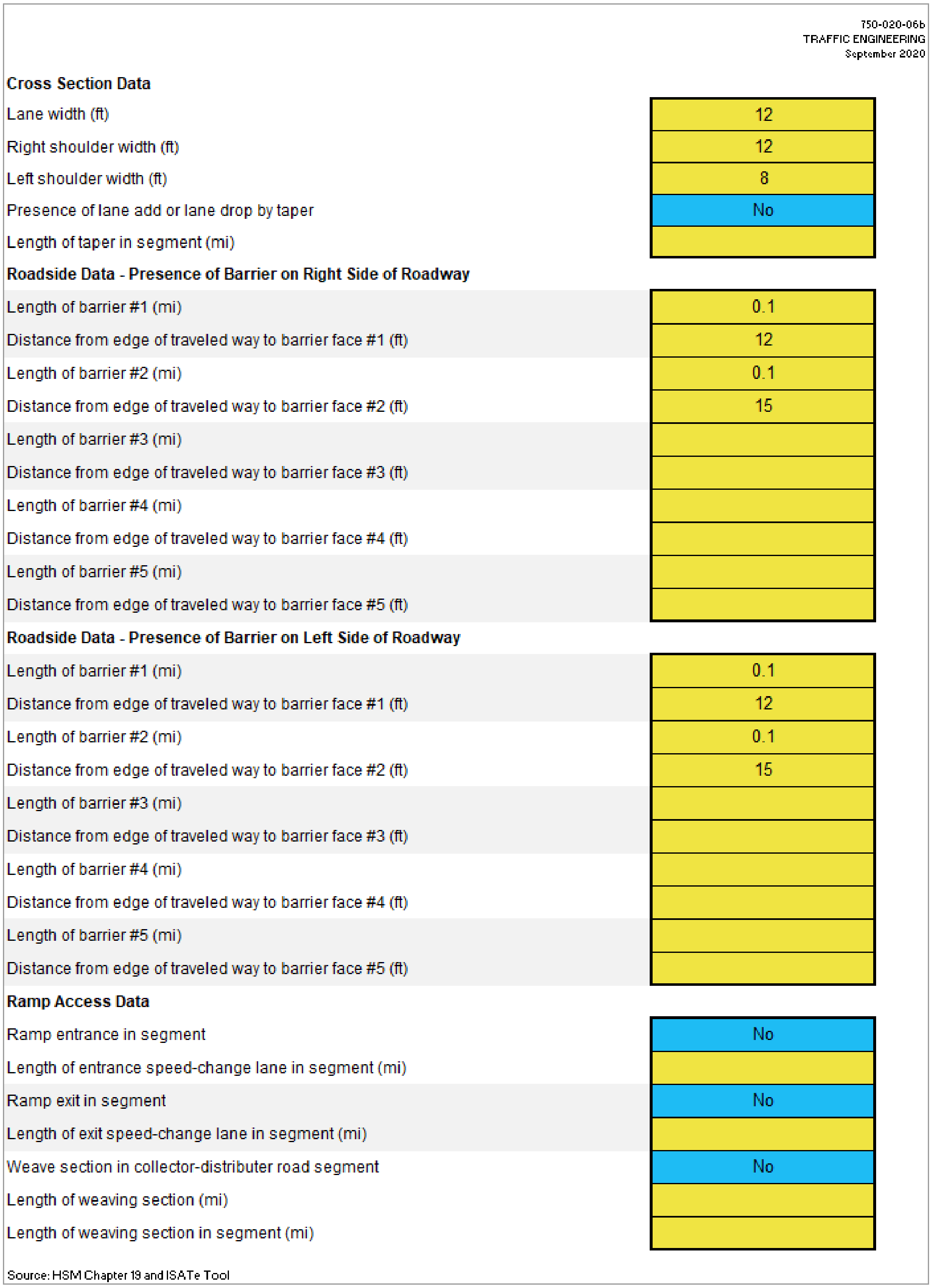
Figure 6-6. Ramp Segments Data Collection – Sheet 2
(*Form No. 750-020-06b*)



750-020-06b
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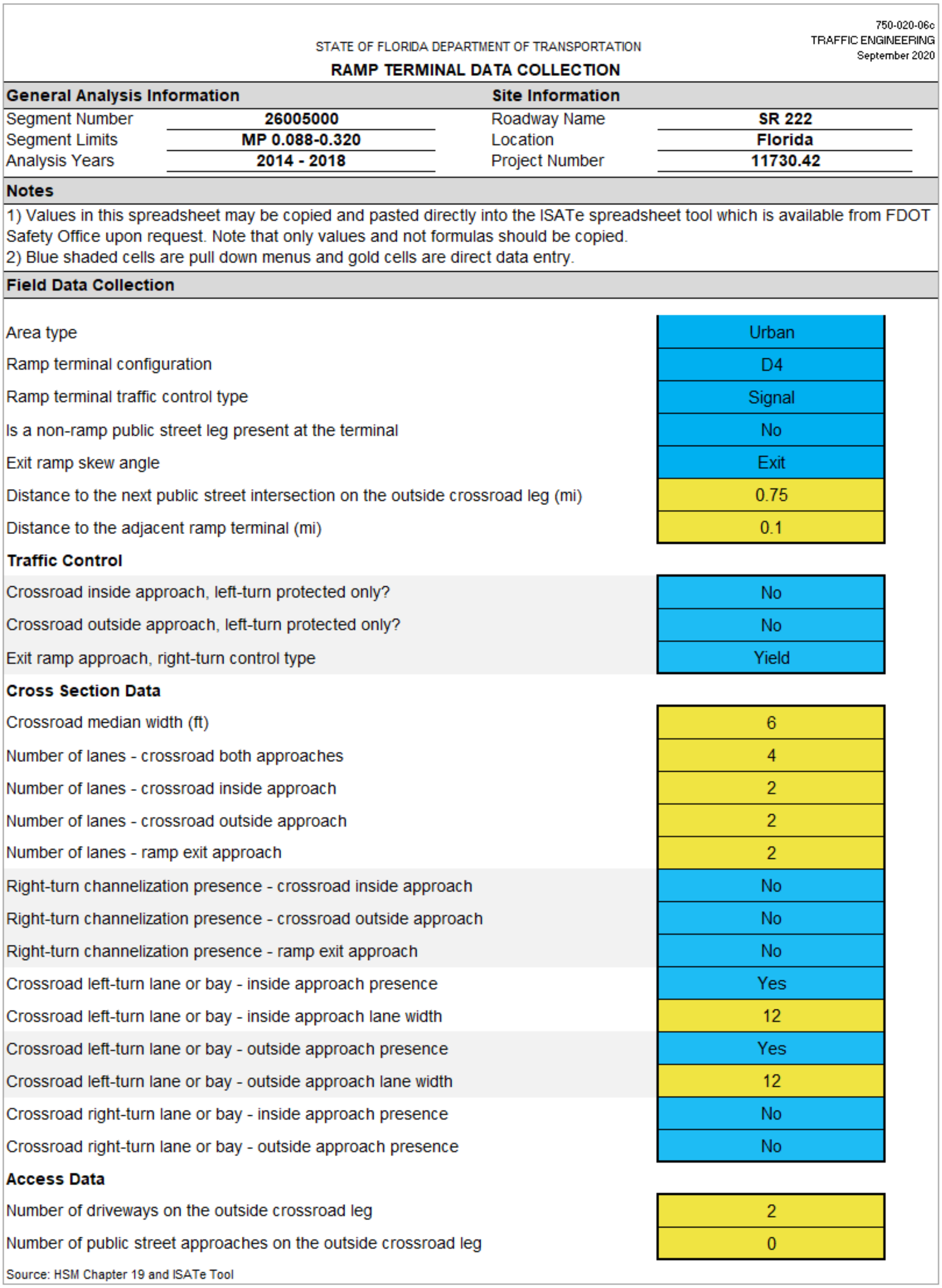
Cross Section Data	
Lane width (ft)	12
Right shoulder width (ft)	12
Left shoulder width (ft)	8
Presence of lane add or lane drop by taper	No
Length of taper in segment (mi)	
Roadside Data - Presence of Barrier on Right Side of Roadway	
Length of barrier #1 (mi)	0.1
Distance from edge of traveled way to barrier face #1 (ft)	12
Length of barrier #2 (mi)	0.1
Distance from edge of traveled way to barrier face #2 (ft)	15
Length of barrier #3 (mi)	
Distance from edge of traveled way to barrier face #3 (ft)	
Length of barrier #4 (mi)	
Distance from edge of traveled way to barrier face #4 (ft)	
Length of barrier #5 (mi)	
Distance from edge of traveled way to barrier face #5 (ft)	
Roadside Data - Presence of Barrier on Left Side of Roadway	
Length of barrier #1 (mi)	0.1
Distance from edge of traveled way to barrier face #1 (ft)	12
Length of barrier #2 (mi)	0.1
Distance from edge of traveled way to barrier face #2 (ft)	15
Length of barrier #3 (mi)	
Distance from edge of traveled way to barrier face #3 (ft)	
Length of barrier #4 (mi)	
Distance from edge of traveled way to barrier face #4 (ft)	
Length of barrier #5 (mi)	
Distance from edge of traveled way to barrier face #5 (ft)	
Ramp Access Data	
Ramp entrance in segment	No
Length of entrance speed-change lane in segment (mi)	
Ramp exit in segment	No
Length of exit speed-change lane in segment (mi)	
Weave section in collector-distributer road segment	No
Length of weaving section (mi)	
Length of weaving section in segment (mi)	

Source: HSM Chapter 19 and ISATe Tool

Figure 6-7. Ramp Terminal Data Collection
(*Form No. 750-020-06c*)



750-020-06c
TRAFFIC ENGINEERING
September 2020

STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION
RAMP TERMINAL DATA COLLECTION

General Analysis Information		**Site Information**	
Segment Number	**26005000**	Roadway Name	**SR 222**
Segment Limits	**MP 0.088-0.320**	Location	**Florida**
Analysis Years	**2014 - 2018**	Project Number	**11730.42**

Notes

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Field Data Collection

Area type	Urban
Ramp terminal configuration	D4
Ramp terminal traffic control type	Signal
Is a non-ramp public street leg present at the terminal	No
Exit ramp skew angle	Exit
Distance to the next public street intersection on the outside crossroad leg (mi)	0.75
Distance to the adjacent ramp terminal (mi)	0.1
Traffic Control	
Crossroad inside approach, left-turn protected only?	No
Crossroad outside approach, left-turn protected only?	No
Exit ramp approach, right-turn control type	Yield
Cross Section Data	
Crossroad median width (ft)	6
Number of lanes - crossroad both approaches	4
Number of lanes - crossroad inside approach	2
Number of lanes - crossroad outside approach	2
Number of lanes - ramp exit approach	2
Right-turn channelization presence - crossroad inside approach	No
Right-turn channelization presence - crossroad outside approach	No
Right-turn channelization presence - ramp exit approach	No
Crossroad left-turn lane or bay - inside approach presence	Yes
Crossroad left-turn lane or bay - inside approach lane width	12
Crossroad left-turn lane or bay - outside approach presence	Yes
Crossroad left-turn lane or bay - outside approach lane width	12
Crossroad right-turn lane or bay - inside approach presence	No
Crossroad right-turn lane or bay - outside approach presence	No
Access Data	
Number of driveways on the outside crossroad leg	2
Number of public street approaches on the outside crossroad leg	0

Source: HSM Chapter 19 and ISATe Tool

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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 (Traffic Signal Timing Manual 2nd Edition) and (Highway Capacity Manual (HCM) 6th Edition).

(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 Delay and Geometric Delay.

(e) *Extra Travel Time Delay* was introduced in the HCM 6th Edition to better capture the experience of travelers through alternative intersection designs and signalized interchanges. Extra Travel Time Delay is the sum of Control Delay and the distance travel time imposed on drivers by the intersection design.

(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 impractical to measure directly in the field. Extra Travel Time Delay can be computed using the delay components described above.

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 MUTS Chapter 4 for a detailed description of intersection data collection electronic equipment, new tools and available technology.

(2) The measurement of the approach speed of vehicles is frequently required before performing the Intersection Delay Study. Refer to MUTS Chapter 12 for a detailed description of tools and techniques. Some of the methods suggested are to estimate the approach speed with a radar or laser gun.

Table 7-1. Commonly Used Equipment for Delay Studies

Method	Tool	Advantage	Disadvantage	Type of Study
Manually	Tally sheets	Minimizes equipment cost and set-up time. Easy to use in the field	Tends 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	
	Mobile devices	Internet-connectivity and sophisticated data input capabilities. Spreadsheets can be used for calculations	Spreadsheet setup, post-processing, and analysis may be required	
	Time-synced video cameras	Permanent record, reduce number of field personnel	Physical restrictions in the field may include poor lighting conditions and vantage points, may require much more labor in the office	
Floating Car	Manual collection	High degree of control over route	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	Field labor-saving tool	Software costs, field information is still required and calibration	
Probe Data	Bluetooth/ Wi-Fi readers or commercial data vendors	Year-round data at high temporal resolution (e.g., five-minute intervals)	Data quality varies with roadway volumes and sample rate: small sample sizes on low-volume intersections can impact accuracy. Post-processing and data analysis are 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 recordings can be used as an alternative).

(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 per approach based on the number 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 3 mph or two-three vehicle lengths from the vehicle that is queued in front of it.

(5) Drone technology may be used as an alternative to record intersection footage. This technology requires special personnel, including having Federal Aviation Administration-licensed drone pilot(s) in addition to the personnel required to post process the drone footage in the office. For short-duration counts using a single drone, a single drone pilot may be sufficient. Additional drones, crew members and pilots may be necessary to count multiple locations and to ensure continuity in the video footage as drones are recharged or have batteries swapped. Refer to MUTS Chapter 4; Section 4.3.1.2 for additional guidance on personnel to collect drone footage.

7.4 FIELD PROCEDURES AND ANALYSIS

7.4.1 Time-In-Queue Delay (TIQD) and Control Delay

(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 a stop-controlled intersection, the number of vehicles stopping (*Stopped* sub-column) should only be those vehicles that stopped completely. A vehicle that stops at the back of the queue, but when it reaches the head of the queue proceeds without a full stop, would be counted as a stopped vehicle. 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 at the intersection approach in 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 25 vehicles per lane. If the queues are expected to be longer than 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.

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

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

$$\mathrm{TIQD}\left(\mathrm{d_{vq}}\right) = \left(\mathrm{I_S}\frac{\sum \mathrm{V_{iq}}}{\mathrm{V_{tot}}}\right) \times 0.9 \qquad \text{Equation 7.3}$$

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 6th Edition, Exhibit 31-44)

Approach 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. Include queuing vehicles during the green phase.
- At the selected sampling interval (e.g., 13 sec), the observer should record the number of queued vehicles. A stopwatch 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 three possible methods: floating car driver data, floating car GPS data, and probe data.

(3) In using the floating car technique, 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. 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 travel time during the actual study period (TT_2) by conducting the floating car measurement between the same two points.

(4) Floating car personnel may also use GPS devices to aid in determining the TTD. GPS units can be used to measure the floating car's position and speed along the corridor.

(5) Thanks to recent advances, probe data can also be used to calculate TTD at the intersection or segment levels. Probe data may be obtained using Bluetooth/Wi-Fi readers or be purchased from commercial vendors that aggregate GPS and cell phone location data (e.g., INRIX, HERE, StreetLight Data, etc.). Due to the low sample sizes in most probe datasets, a long data collection period is required to calculate TTD. The minimum data collection period should be determined based on the volume of the roadway and the data source being used.

(6) ***Table 7-4*** provides guidance on the length of the minimum data collection period. The table provides the minimum number of weeks for a segment study and it provides the minimum number of weeks for an intersection study in parenthesis.

This table has been adapted from minimum sample sizes in ***ITE Manual of Transportation Engineering Studies 2nd Edition, Exhibit 9-1*** for the 95% confidence level and 1 mph permitted error. Capture rate refers to the sampling rate of the probe dataset. A few simplifying assumptions were necessary to develop ***Table 7-4***:

(a) AADTs assume Monday - Thursday peak hour studies based on K = 0.09 and D = 0.55.

(b) For intersection studies, it is assumed that turning movements dictate sample size. A turning movement representing 15% of the directional peak hour volume is used. The lowest AADT of the intersecting roads must be used.

(c) A minimum of one week of data is always recommended to provide redundancy in case of unusual events, to capture off-peak conditions, and to simplify data collection procedures.

The difference between lower bound and upper bound travel speeds in the study period ($\bar{R}$), referred to as speed range, may be estimated using readily available datasets—for example, spot speed studies—and updated as the probe data is collected and analyzed. The analyst may use the minimum speed from an initial spot speed study or probe data analysis in the study period as the lower bound speed, and the maximum speed as the upper bound speed. If these minimum or maximum values are outliers, the 10th percentile speed may be used as the lower bound speed as the alternative to define the speed range. Similarly, the 90th percentile speed may be used as the upper bound speed.

(7) ***Figure 7-1*** provides a graphical representation of a spot speed study data distribution. More information on spot speed studies is available in MUTS Chapter 12. From this scenario, the Speed Range ($\bar{R}$) may be calculated as the following:

$$\bar{R} = speed_{max} - speed_{min} = 55\ mph - 25\ mph = 30$$

Or (if the maximum and minimum speeds were to be considered outliers):

$$\bar{R} = 90^{th}\ percentile - 10^{th}\ percentile = 47\ mph - 29mph = 18$$

Figure 7-1. Example of a Spot Speed Study Distribution

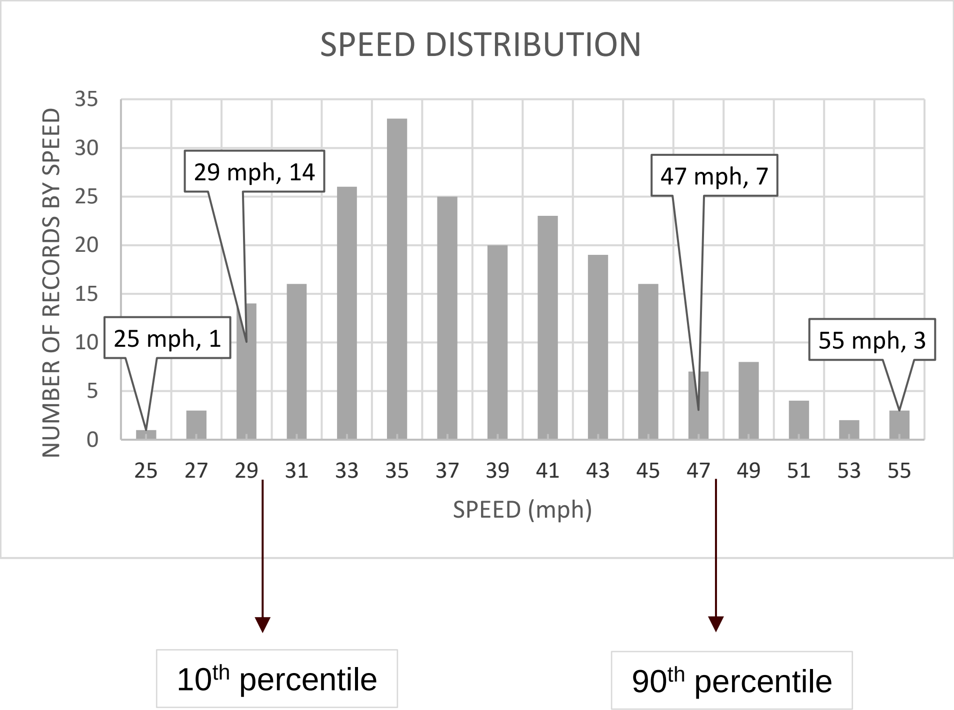


Table 7-4. Minimum Number of Weeks for Probe Data Collection*

$Speed\ Range\ (\bar{R}) = Maximum\ Speed - Minimum\ Speed = 10\ mph$						
AADT \ Capture Rate	2%	5%	10%	15%	30%	50%
5,000	2 (10)	1 (4)	1 (2)	1 (2)	1 (1)	1 (1)
10,000	1 (5)	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)
20,000	1 (3)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
30,000	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
40,000	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
50,000	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
75,000	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
100,000	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
$Speed\ Range\ (\overline{R}) = Maximum\ Speed - Minimum\ Speed = 15\ mph$						
AADT \ Capture Rate	2%	5%	10%	15%	30%	50%
5,000	3 (16)	1 (7)	1 (4)	1 (3)	1 (2)	1 (1)
10,000	2 (8)	1 (4)	1 (2)	1 (2)	1 (1)	1 (1)
20,000	1 (4)	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)
30,000	1 (3)	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)
40,000	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
50,000	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
75,000	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
100,000	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
$Speed\ Range\ (\overline{R}) = Maximum\ Speed - Minimum\ Speed = 25\ mph$						
AADT \ Capture Rate	2%	5%	10%	15%	30%	50%
5,000	5 (34)	2 (14)	1 (7)	1 (5)	1 (3)	1 (2)
10,000	3 (17)	1 (7)	1 (4)	1 (3)	1 (2)	1 (1)
20,000	2 (9)	1 (4)	1 (2)	1 (2)	1 (1)	1 (1)
30,000	1 (6)	1 (3)	1 (2)	1 (1)	1 (1)	1 (1)
40,000	1 (5)	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)
50,000	1 (4)	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)
75,000	1 (3)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
100,000	1 (2)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)

Legend: Minimum number of weeks for a segment study (Minimum number of weeks for an intersection study).

(8) Using probe data, unimpeded travel time (TT_1) can be estimated based on average travel times during low-traffic hours, such as early morning or late night. The actual travel time (TT_2) can be calculated as the average travel time over the time period of interest.

(9) If the segment of interest extends over multiple probe data segments (sometimes referred to as Traffic Message Channels), the analyst must first sum the Traffic Message Channel travel times for each timestamp in the dataset to obtain segment travel times. Only then can travel times be averaged to obtain TT_1 and TT2. The analyst may consider the use of mean or median for averaging depending on the spread of the segment travel times.

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

where,

TTD = travel time delay through the intersection

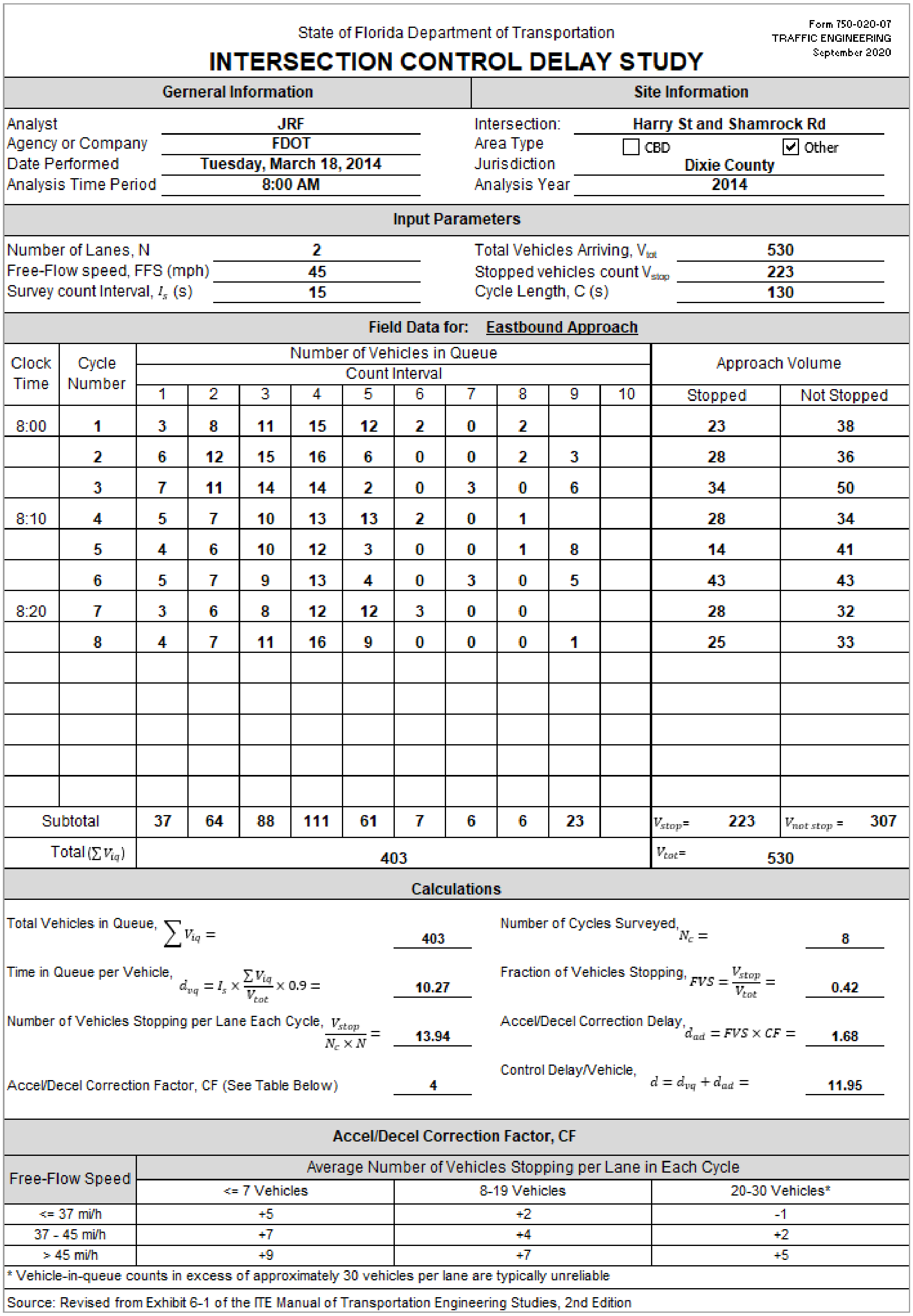
TT_1 = unimpeded travel time through the intersection

TT_2 = actual peak period 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

Form 750-020-07
TRAFFIC ENGINEERING
September 2020

INTERSECTION CONTROL DELAY STUDY

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 Count Interval 1	2	3	4	5	6	7	8	9	10	Approach Volume 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

Number of Cycles Surveyed, $N_c =$ 8

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

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

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

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 (See Table Below) 4

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, distribution, and number of gaps available in the major street traffic stream at two-way stop-controlled (TWSC) intersections or driveways. While gap studies can also be used at YIELD-controlled intersections, the methodologies presented in this chapter do not include a detailed method for estimating delay at YIELD-controlled intersections (except for roundabouts).

(2) This chapter discusses how to conduct gap studies and estimate the critical gap for vehicular traffic and pedestrians.

(3) Some of the most common uses of the vehicular gap studies include simulation model calibrations, capacity analysis and vehicular delay considerations. An intersection delay study can be used as an alternative procedure to a vehicular gap study to help determine if a change in the intersection control is needed. See MUTS Chapter 7 for additional guidance on how to conduct an Intersection Delay Study.

(4) The pedestrian gap study is commonly used as part of the ***FHWA MUTCD Signal Warrant Analysis*** – Warrant 4: Pedestrian Volume where the major street volume is so heavy that pedestrians experience excessive delays in crossing the major street. The critical gap calculations are not part of the input for the numerical analysis of Warrant 4, they are a condition to be considered for the application of the warrant itself. The pedestrian gap study can also be used as part of Warrant 5: School Crossing to determine adequacy of gaps in the vehicular traffic stream. Warrant 5 does require the gap calculation results as part of the warrant analysis. Refer to MUTS Chapter 3 for additional guidance on these traffic signal warrants.

8.2 DEFINITIONS

Critical gap or **critical headway** - the minimum time duration measured in the major traffic stream that will allow the entry of one vehicle on a minor movement or pedestrian.

Gap - the time duration between the rear bumper and the front bumper of two consecutive vehicles. A driver or non-motorist can accept or reject gaps.

Gap acceptance - in the context of this study, it describes the completion of a vehicle's movement into a gap. It is defined as the decision-making process a driver or pedestrian follows to determine 1) when a gap on the major street is large enough to permit entry, and 2) when to enter the intersection on the basis of the relative priority of the competing movements (i.e., left turns from the major street).

Headway - the time between successive vehicles as they pass a point on a lane or roadway, measured from the same point on each vehicle.

Lag - the time between the arrival of a minor street vehicle at the stop bar and the arrival of the front bumper of the next vehicle in the major street traffic stream.

8.3 EQUIPMENT AND PERSONNEL NEEDS

(1) Electronic count boards, laptop computers, automatic vehicle detectors, audio and video tapes, and stopwatches can be used to collect gap study data. The audiotape method requires an observer at the intersection to speak into a tape recorder when the vehicle crosses the stop bar or pedestrian walks into the roadway to be crossed. If audio or video tape are primarily used for the data collection, the engineer must listen to the tape at the same speed at which it was recorded.

The videotape method requires a clear vantage point and good lighting condition. If automated detectors are used, the engineer must verify that only the lanes of interest are being captured in the data collection. The selected method for data collection needs to provide the data with timestamps for the post processing efforts.

(2) It is suggested to collect the data in the field and supplement it with simultaneous video recordings to allow the review of any potential errors. In addition to providing an error-check method, the video recordings enable engineers to process additional information once in the office (i.e., truck drivers behavior).

(3) Observers need to find a location in the field where there is good visibility of the reference point and should avoid influencing driver behavior.

(4) A single observer should be sufficient to record the gap data for a multilane major street if no additional data needs to be collected simultaneously.

8.4 FIELD PROCEDURE

(1) The header of Form No. 750-020-08a should be filled out completely. Under *Site* Information, the *Roadway I.D.* should be noted as well as the *Roadway Name*. Consider including the *U.S. route number* and *state road number* if applicable.

Additionally, the corresponding checkbox shall be marked, indicating whether the subject location is at an intersection or a segment, and a reference point along the street such as a *cross street name* and/or *milepost* should be provided. The *City* and *County* should be entered.

(2) The General *Information* section including the *Analyst*, *Agency* or *Company*, and *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. Note that volumes may significantly fluctuate over any given day, an analyst must sample gaps during each period of interest.

(4) Data collection should be conducted under normal weather conditions where normal traffic volumes are not impacted.

(5) When video data collection as explained in MUTS Chapter 8, Section 8.3*,* is not used, stopwatches or other timing devices are used. The observer measures the headway between vehicles in seconds (measured headways are rounded to the nearest second).

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

The total number of gaps (accepted and rejected) should be recorded 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 5) described in MUTS Chapter 3.

8.5 VEHICULAR GAP

(1) The number, distribution, and size of acceptable gaps in the major street vehicular traffic for entrance from the minor street traffic can be used as an indicator of an intersection’s performance. Intersection improvements can be supported by the results of a gap study.

(2) The estimating process presented in this section is a method to approximate vehicular mean critical gap. The method utilizes the same field data to estimate the critical gap distribution, does not require assumptions regarding the critical gap distribution, and it can be applied to gap or lag data.

(3) For additional discussion on other applicable methodologies available to estimate gap acceptance characteristics, reference the procedures found in the ***Institute of Transportation Engineers (ITE), Manual of Transportation Engineering Studies, 2nd Edition, 2010, Chapter 6 (Page109-112)***.

8.5.1 Estimating Critical Gap

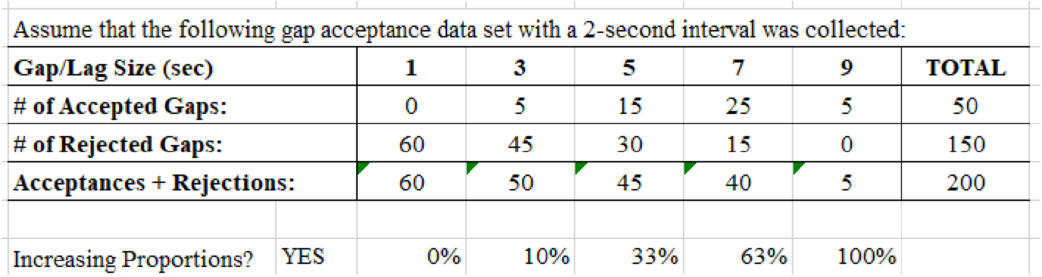
(1) The gap data can be recorded by grouping gaps into “bins” with a pre-determined interval. The commonly used interval or adequate interval for most gap acceptance studies is 2 seconds resulting in the number of gaps grouped between 1 and 3 seconds, 3 and 5 seconds, etc.

(2) The engineer should determine in advance of the field data collection the bin size in seconds to be used. Per the ***ITE Manual of Transportation Engineering Studies, 2nd Edition, 2010, Chapter 6 (Page109-112)***, a suggested sample size of 200 acceptances for a 2-second interval is provided**.** If a 1-second bin interval is used for the data collection, a 500-sample size of acceptances is suggested.

(3) Once the field procedure and data collection have been completed, ***Vehicular Gap Study*** (Form 750-020-08b) can be used to perform the corresponding gap study calculations. The engineer can also complete the form and corresponding calculation in a manual format.

(4) The calculations to be completed in the form include the following:

(a) Summarize the collected accepted and rejected gaps into their corresponding bins. Calculate the proportion of records by bin size over the total sample size for each gap or lag size (measured in seconds) and confirm there is an increasing proportion.



Assume that the following gap acceptance data set with a 2-second interval was collected:

Gap/Lag Size (sec)	**1**	**3**	**5**	**7**	**9**	**TOTAL**
# of Accepted Gaps:	0	5	15	25	5	50
# of Rejected Gaps:	60	45	30	15	0	150
Acceptances + Rejections:	60	50	45	40	5	200
Increasing Proportions? YES	0%	10%	33%	63%	100%	

(b) Convert these proportions to a distribution of accepted gaps that would be observed if all drivers had a determined critical gap. When the critical gap is assumed to be 0 seconds, the distribution is calculated to be the number of accepted/rejected gaps over the total sample size.

$$Gap\ Proportion = \frac{No.of\ accepted\ gaps + No.of\ rejected\ gaps}{Total\ Sample\ Size} * 100\%$$

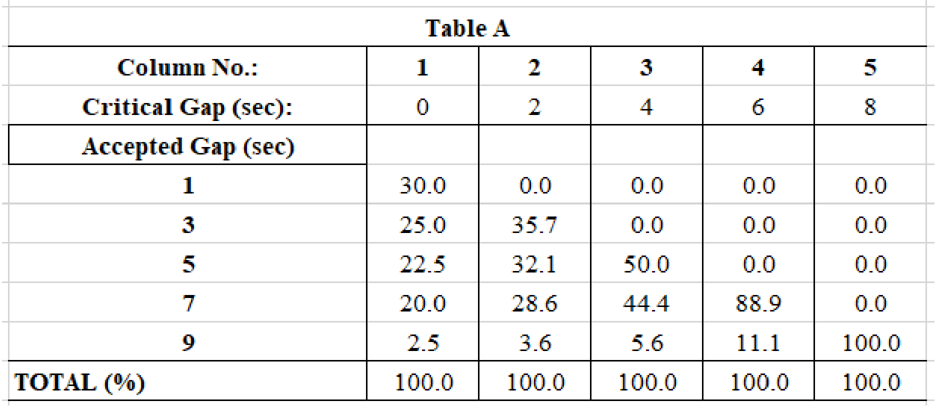


Table A

Column No.:	**1**	**2**	**3**	**4**	**5**
Critical Gap (sec):	0	2	4	6	8
Accepted Gap (sec)					
1	30.0	0.0	0.0	0.0	0.0
3	25.0	35.7	0.0	0.0	0.0
5	22.5	32.1	50.0	0.0	0.0
7	20.0	28.6	44.4	88.9	0.0
9	2.5	3.6	5.6	11.1	100.0
TOTAL (%)	100.0	100.0	100.0	100.0	100.0

(c) The second critical gap proportion (Column No. 2), any accepted gaps below the critical gap would be coded as zero as it is assumed none of the drivers would accept a gap lower than the critical gap. The next proportion for the critical gap in question is the percentage of dividing the previous critical gap bin proportion by 100 minus the lowest accepted gap size proportion.

(d) For the following critical gap proportions, again, any accepted gaps below the critical gap would be coded as zero. The next proportion for the critical gap in question is calculated as the first proportions divided by 100 minus the sum of the proportions of the lower accepted gap bins $(25/(100-30)=35.7\%)$.

(e) Continue with these calculations until the critical gap proportions are generated for all the critical gaps $(22.5/(100-30)=32.1)$.

(f) Next, the analyst should calculate the number of drivers with each critical gap size that accept a gap of a given size. Note this calculation considers accepted gaps only hence the table can be limited to begin the accepted/critical gaps where there are accepted gaps only.

The first input can be directly filled out with the number of accepted gaps from the raw data. It is assumed that all of the drivers under the first accepted gaps had critical gaps that were lower than the accepted gap. For example, gap acceptance data in the example above, shows 5 vehicles accepted a 3 second gap. This value is entered into Column No. 1 of Table B for the 3 second accepted gap.

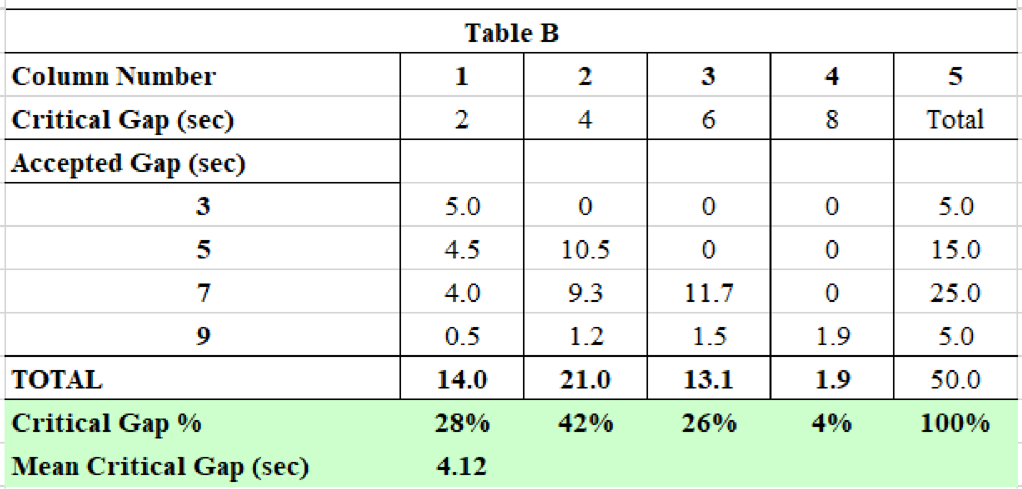


Table B

Column Number	**1**	**2**	**3**	**4**	**5**
Critical Gap (sec)	2	4	6	8	Total
Accepted Gap (sec)					
3	5.0	0	0	0	5.0
5	4.5	10.5	0	0	15.0
7	4.0	9.3	11.7	0	25.0
9	0.5	1.2	1.5	1.9	5.0
TOTAL	**14.0**	**21.0**	**13.1**	**1.9**	50.0
Critical Gap %	**28%**	**42%**	**26%**	**4%**	**100%**
Mean Critical Gap (sec)	**4.12**				

- The Total for each critical gap column is calculated by multiplying the number of accepted gaps times 100 divided by the gap distribution proportions. For example, Column 1's total is $5\ x\ 100/35.7\ =\ 14.0$.

- The following number of drivers per accepted gap size is calculated by multiplying the corresponding critical gap proportion times the total of the corresponding critical gap number of drivers divided by 100. $(32.1/100\ x\ 14.0\ =\ 4.5)$

First entry on the next critical gap column would be 0 since drivers with a higher critical gap do not accept smaller gaps. The next entry is calculated as the total accepted gaps minus the number of drivers that accepted a lower critical gap $(15 - 4.5\ =\ 10.5)$. Steps (f), (i) and Steps (f), (ii) should be repeated until the column entries are completed.

Repeat this last step until all the number of drivers with for each critical gap columns are generated.

(g) The mean critical gap is calculated as the sum of total number of accepting drivers multiplied by the corresponding critical gap size divided by the total number of accepted gaps.

8.6 PEDESTRIAN CRITICAL HEADWAY

(1) The critical headway for a single pedestrian (t_c) is estimated using the following equation (***HCM 6th Edition, Equation 20-77, Page 20-39***):

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

where,

t_c single pedestrian critical headway (sec)

S_p = 15th percentile pedestrian walking speed (default 3.5 ft/sec)

L = crosswalk length (ft)

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

(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.). See MUTS Chapter 9 for guidance on how to conduct a walking speed study.

(3) If a median refuge is provided, a two-stage crossing movement can be expected. When pedestrians cross in two stages, the calculations should be conducted separately for each stage of the crossing. To determine the entire crossings headway, the average among the crossings should be considered.

(4) The critical headway for a group of pedestrians ($t_{c,G}$) is calculated by using the following equations (***HCM 6th Edition, Equation 20-80, Page 20-40***):

$$t_{c,G} = tc + 2(N_p - 1)$$

where

$t_{c,G}$ = pedestrian group critical headway (sec)

t_c = single pedestrian critical headway (sec)

N_p = spatial distribution of pedestrians (ped). Assume one (1) if no platooning of pedestrian is observed in the field or if the crosswalk is wide enough to accommodate a group of pedestrians traveling side-by-side; otherwise, use the following equation ***(HCM 6th Edition, Equation 20-78)***:

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

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 = total number of pedestrians in the crossing platoon (ped) calculated using the following equation ***(HCM 6th Edition, Equation 20-79)***:

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

where

v_p = pedestrian flow rate (ped/sec). This value is suggested to be measured during field observations.

v = vehicular flow rate (veh/sec). Combined or bidirectional flow rates for one-stage crossings; separate or directional flows for two-stage crossings should be considered.

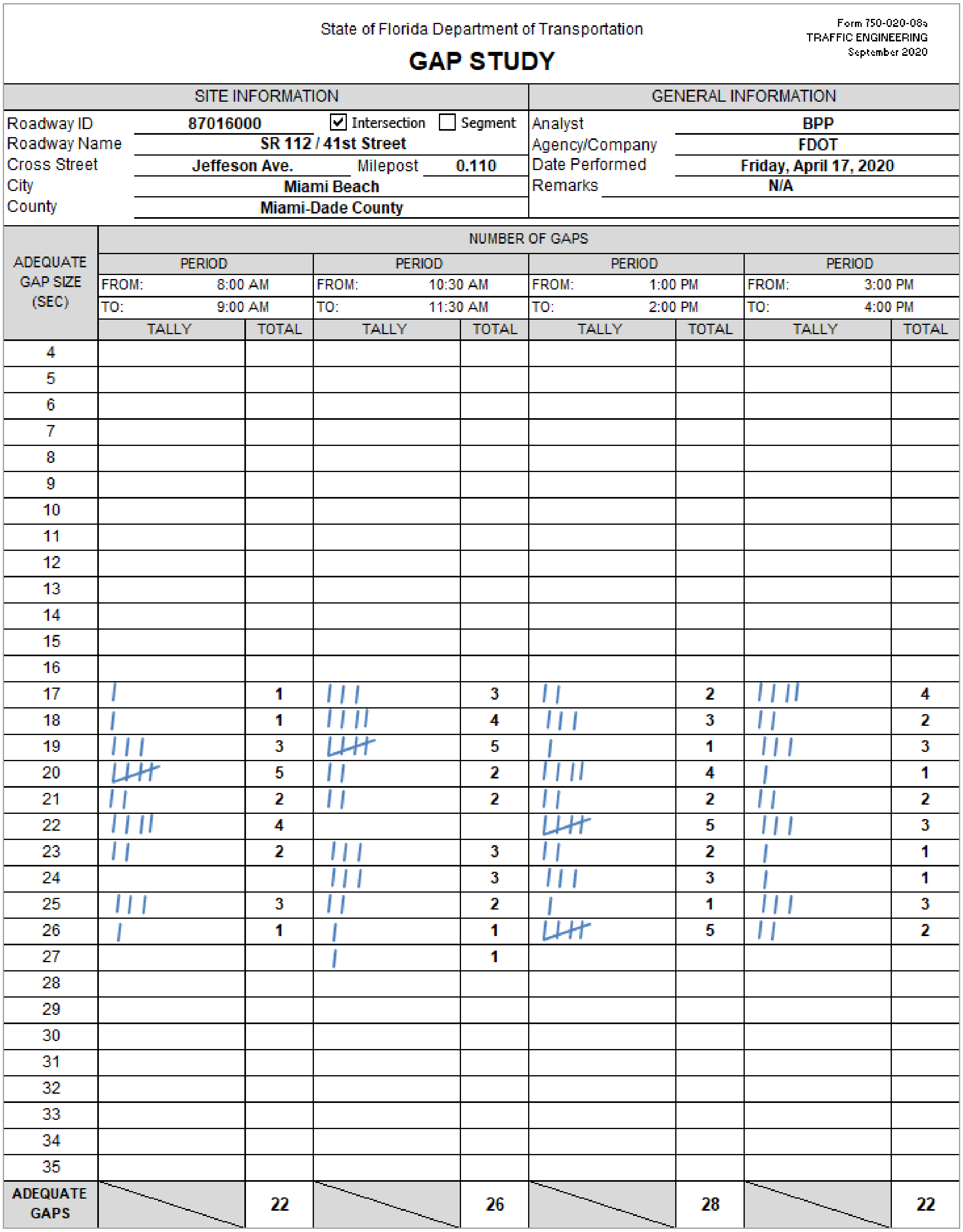
t_c = single pedestrian critical headway (sec)

(5) For an alternative 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 (Page109-112)***.

8.7 FORMS ACCESS

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

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



State of Florida Department of Transportation

Form 750-020-08a
TRAFFIC ENGINEERING
September 2020

GAP STUDY

SITE INFORMATION

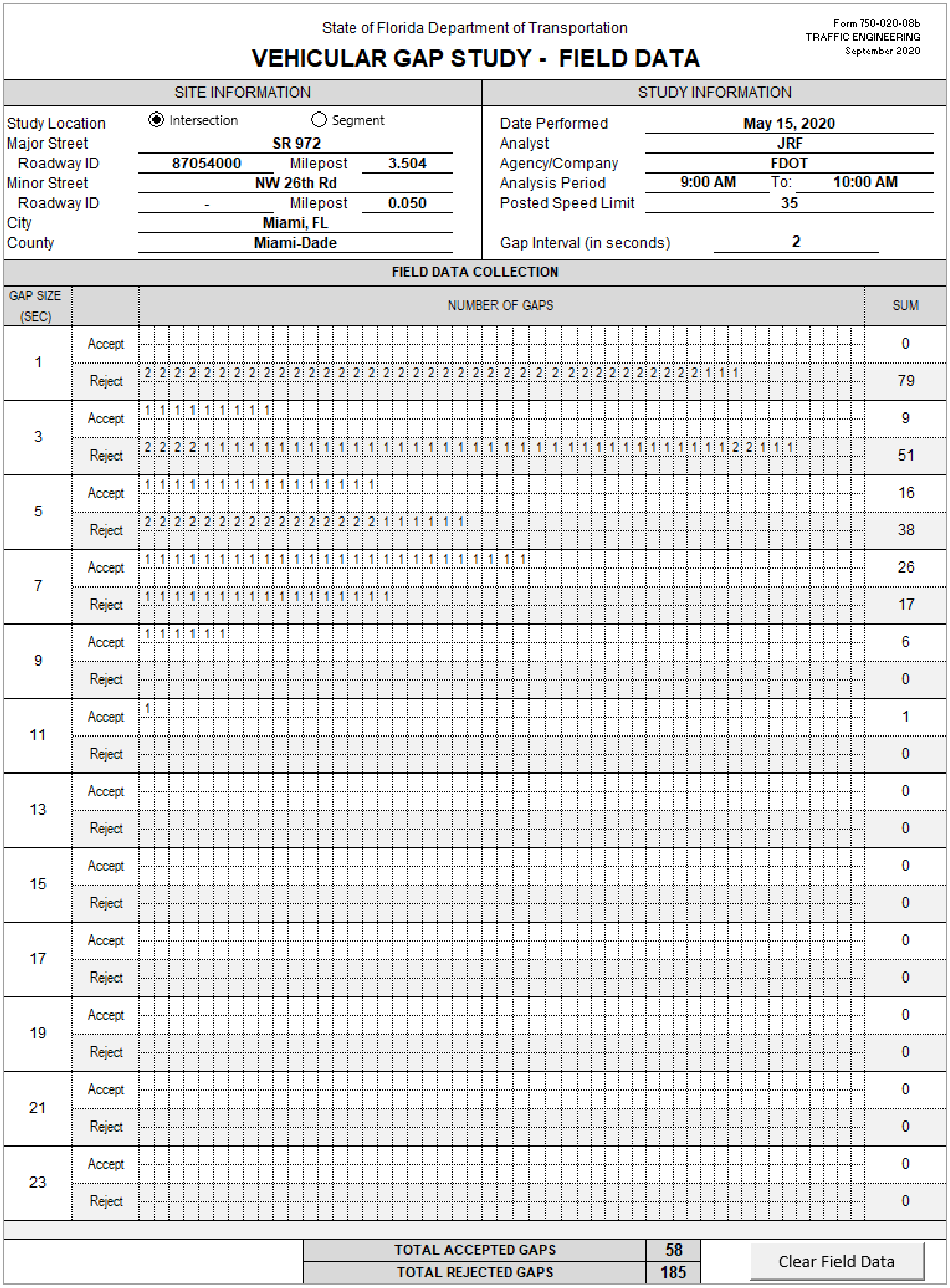
Roadway ID **87016000** ☑ Intersection ☐ Segment
Roadway Name **SR 112 / 41st Street**
Cross Street **Jeffeson Ave.** Milepost **0.110**
City **Miami Beach**
County **Miami-Dade County**

GENERAL INFORMATION

Analyst **BPP**
Agency/Company **FDOT**
Date Performed **Friday, April 17, 2020**
Remarks **N/A**

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**

Figure 8-2. Vehicular Gap Study – Field Data
(*Form No. 750-020-08b*)



State of Florida Department of Transportation

Form 750-020-08b
TRAFFIC ENGINEERING
September 2020

VEHICULAR GAP STUDY - FIELD DATA

SITE INFORMATION

Study Location ● Intersection ○ Segment
Major Street **SR 972**
Roadway ID **87054000** Milepost **3.504**
Minor Street **NW 26th Rd**
Roadway ID **-** Milepost **0.050**
City **Miami, FL**
County **Miami-Dade**

STUDY INFORMATION

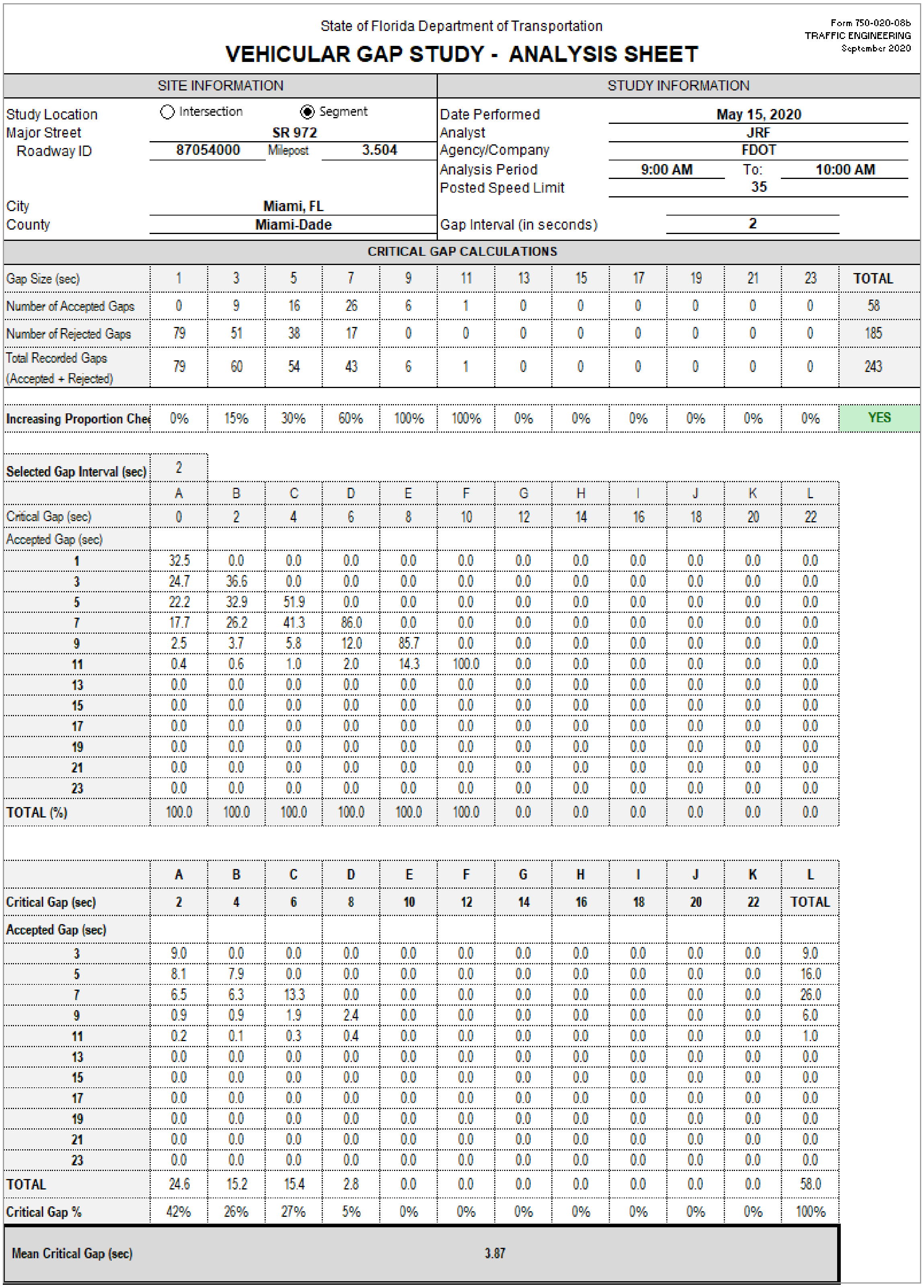
Date Performed **May 15, 2020**
Analyst **JRF**
Agency/Company **FDOT**
Analysis Period **9:00 AM** To: **10:00 AM**
Posted Speed Limit **35**
Gap Interval (in seconds) **2**

FIELD DATA COLLECTION

GAP SIZE (SEC)		NUMBER OF GAPS	SUM
1	Accept		0
	Reject	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 1	79
3	Accept	1 1 1 1 1 1 1 1 1	9
	Reject	2 2 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 2 1 1 1	51
5	Accept	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	16
	Reject	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1 1	38
7	Accept	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	26
	Reject	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	17
9	Accept	1 1 1 1 1 1	6
	Reject		0
11	Accept	1	1
	Reject		0
13	Accept		0
	Reject		0
15	Accept		0
	Reject		0
17	Accept		0
	Reject		0
19	Accept		0
	Reject		0
21	Accept		0
	Reject		0
23	Accept		0
	Reject		0

TOTAL ACCEPTED GAPS	58
TOTAL REJECTED GAPS	185

Figure 8-3. Vehicular Gap Study – Analysis Sheet (*Form No. 750-020-08b*)



State of Florida Department of Transportation

Form 750-020-08b
TRAFFIC ENGINEERING
September 2020

VEHICULAR GAP STUDY - ANALYSIS SHEET

SITE INFORMATION				STUDY INFORMATION			
Study Location	○ Intersection	● Segment		Date Performed	May 15, 2020		
Major Street	SR 972			Analyst	JRF		
Roadway ID	87054000	Milepost	3.504	Agency/Company	FDOT		
				Analysis Period	9:00 AM	To:	10:00 AM
				Posted Speed Limit	35		
City	Miami, FL						
County	Miami-Dade			Gap Interval (in seconds)	2		

CRITICAL GAP CALCULATIONS

Gap Size (sec)	1	3	5	7	9	11	13	15	17	19	21	23	TOTAL
Number of Accepted Gaps	0	9	16	26	6	1	0	0	0	0	0	0	58
Number of Rejected Gaps	79	51	38	17	0	0	0	0	0	0	0	0	185
Total Recorded Gaps (Accepted + Rejected)	79	60	54	43	6	1	0	0	0	0	0	0	243
Increasing Proportion Che	0%	15%	30%	60%	100%	100%	0%	0%	0%	0%	0%	0%	YES

Selected Gap Interval (sec) 2

	A	B	C	D	E	F	G	H	I	J	K	L
Critical Gap (sec)	0	2	4	6	8	10	12	14	16	18	20	22
Accepted Gap (sec)												
1	32.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	24.7	36.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	22.2	32.9	51.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	17.7	26.2	41.3	86.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	2.5	3.7	5.8	12.0	85.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.4	0.6	1.0	2.0	14.3	100.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL (%)	100.0	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
Critical Gap (sec)	**2**	**4**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**TOTAL**
Accepted Gap (sec)												
3	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0
5	8.1	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0
7	6.5	6.3	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.0
9	0.9	0.9	1.9	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0
11	0.2	0.1	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	24.6	15.2	15.4	2.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.0
Critical Gap %	42%	26%	27%	5%	0%	0%	0%	0%	0%	0%	0%	100%

Mean Critical Gap (sec) 3.87

CHAPTER 9 NON-MOTORIZED VOLUME STUDIES

9.1 PURPOSES

(1) Non-motorized traffic monitoring studies are used to capture some aspects of non-motorist presence and behavior. Non-motorized traffic includes bicyclists, pedestrians, scooters, rollerbladers, and other users of non-motorized transportation. Non-motorized traffic monitoring may include one or more of the following components:

(a) Volume[1]

(b) Walking or travel speed[2]

(c) Gaps in traffic[2]

(d) Accessibility for non-motorists with physical or vision impairments

(e) Exhibited behaviors[2]

- Conflicts with vehicles
- Compliance with traffic control devices
- User perception

(2) This chapter focuses on conducting volume studies. Non-motorized traffic volumes are obtained by recording the number of non-motorists crossing a midblock point, entering an intersection, or using a particular facility such as a crosswalk, sidewalk, or bikeway. For intersection or midblock crossing studies, an influence area should be determined based on the intent of the study.

(3) Volume studies can be used in a variety of ways including:

(a) Support volume warrants for the installation of a pedestrian crossing

(b) Conduct Warrant 4, Pedestrian Volume as described in the MUTS Chapter 3.

- Establish the need for a wider sidewalk (Florida Design

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[1] *ITE Manual of Transportation Engineering Studies, 2nd Edition Chapter 12 Pedestrian and Bicycle Studies; FHWA Traffic Monitoring Guidebook, Chapter 4; FDOT Traffic Monitoring Guidebook, Chapter 5; NCHRP 797: Guidebook on Pedestrian and Bicycle Volume Data Collection, Chapter 2*

[2] *ITE Manual of Transportation Engineering Studies, 2nd Edition Chapter 12 Pedestrian and Bicycle Studies*

Manual (FDM) 222.2.1.1)

- Develop exposure statistics for evaluating non-motorist safety[3]

- Prioritize corridors for enhanced non-motorist facilities

- Conduct before and after studies considering new or improved non-motorist facilities[3]

- Understand non-motorized travel patterns[3]

- Develop and validate non-motorized travel demand models[3]

(4) Pedestrian Critical Gap procedures can be found in the MUTS Chapter 8.

(5) Walking speed studies can be manually collected during field observations. MUTS Chapter 9, Section 9.6, provides guidance on how to conduct this procedure and provides guidance on the use of a form for the data collection.

(6) A detailed description of walking speed studies and gap studies can be found in the ***ITE Manual of Transportation Engineering Studies, 2nd Edition, Chapter 12 Pedestrian and Bicycle Studie***s page 246.

9.2 TYPES OF COUNTS

(1) Non-motorist counts typically occur at either intersections or segments. Depending on the count type being performed, different methods of data collection may be available. MUTS Chapter 9; Section 9.3 further describes some of the common methods available.

(2) The difference between intersection and segment counts is further described in ***The FHWA Traffic Monitoring Guide*** and ***FDOT Traffic Monitoring Handbook***.

9.2.1 Intersection Counts

(1) Intersection counts occur at the intersection of two roadways. When intersection counts are collected, the number and direction of non-motorists at each approach and in each crosswalk should be counted.

(2) Intersection counts provide an understanding of operations at the intersection

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[3] *NCHRP 797: Guidebook on Pedestrian and Bicycle Volume Data Collection, Chapter 2*

along with an understanding of an approximate volume of non-motorists along the segments connecting to the intersection. Intersection counts tend to include more entry and exit points than segment counts, requiring a greater number of devices or more complex data collection methods.

9.2.2 Segment Counts

(1) Segment counts are generally considered to be collected between intersections and their purpose is to record the number of non-motorists at a specific length on the roadway over a study period.

(2) Segment counts tend to be less complex than intersection counts; however, data collection should consider all facilities along the segment. For example, if counts are taken at a particular point along a segment, non-motorists on all facilities at that point should be counted. This may require counting across sidewalks, bicycle facilities, or shared-use paths.

(3) When choosing a location to conduct segment counts, consider selecting a location that serves as a bottleneck, redirecting users from different facilities onto one facility (such as a bridge) or combining facilities on a single roadway (such as transitioning from a bike lane and sidewalk to a shared-use path).

9.3 METHODS OF DATA COLLECTION

(1) Manual observation and automated counts are the two basic methods of obtaining non-motorist 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 technology to perform the counts.

(2) NCHRP 797[3] presents several considerations for choosing the appropriate method of data collection.

9.4 MANUAL OBSERVATION

(1) Using this procedure, the observer manually records each non-motorist as they proceed through the point of interest. Field-based manual counts minimize equipment cost and set-up time; however, they can become inefficient the longer the observer stays in the field.

(2) The minimum recommended duration for manual observation is four to six hours and should be completed during the heaviest non-motorized use. The preferred duration for short-term counts is 12 hours[4].

(3) Some types of non-motorist 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).

(4) Complex intersection geometries may require manual counts.

(5) For some projects, time and resources may be good justifications for choosing manual observation over an automatic count.

(6) Manual counts are described in the FDOT Traffic Monitoring Handbook[5]

9.4.1 Personnel Required

(1) Manual counts require trained observers who must be relieved periodically to avoid fatigue and degraded performance. 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 number of trained observers required is dependent upon the length of the counting period, type of count being performed, number of crosswalks or bike lanes, and the anticipated volume of non-motorists. A single observer can perform a non-motorist volume count at a 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 help 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.

9.4.2 Equipment

(1) **Tally sheets**: The traditional way to perform a manual count is to record each non-motorist with a tick mark on a prepared field form. 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.

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[4] *FHWA Traffic Monitoring Guide, Chapter 4*

[5] *FDOT Traffic Monitoring Handbook, Chapter 5*

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

(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 format.

Generally, the added benefits of reduced time of manual data reduction and summary justify the expense of electronic count boards. These are considered a cost-effective, labor-saving tool. No field forms are required with this alternative and the boards contain an internal clock that separates data by a specified interval. A common disadvantage is the difficulty to retrieve disaggregated data from electronic count boards.

(3) **Mobile Devices**: Laptop computers, tablets, and mobile phones can be used in place of electronic count boards. On computers, macro-enabled spreadsheets can be used to record time stamps of different events. The benefit of using these to collect data is the ability to customize spreadsheets to a user's specific needs. A disadvantage is the software coding needs and post-processing analysis required.

Commercial tablet and mobile applications are available which mimic the functionality of a count board but with improved data input and export capabilities. On the data input side, the touchscreen on commercial tablets enables new functionalities such as finger-tracing the bicycle or pedestrian movements on the screen or double-tapping to denote bicycle or pedestrian movements. On the data export side, the Internet connectivity of mobile devices can be used to email counts as they are completed.

(4) **Video Cameras**: Manual counts can be conducted as a post-processing operation from video recordings. Drone technology can be used as an alternative to traditional cameras. See MUTS Chapter 4 for additional guidance on drone personnel requirements. It is critical to have well-chosen camera angles and adequate lighting conditions to capture all bicyclist and pedestrian movements at a typical intersection with one or multiple cameras. If counts are intended to be taken during hours of darkness, ensure sufficient light is available to illuminate pedestrians and bicyclists. A digital clock can help note the end of the intervals.

The observer can record the counts from video recordings 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. In addition, the video recordings can usually be slowed down to facilitate the manual count recording – this is particularly helpful at intersection with high volume levels.

It can be beneficial to record twice as much data as the project intends to use. Collecting additional data reduces the probability of rain, temporary lack of visibility, or other chance event requiring the data collector to return to the field to collect more data. Typically recording device set-up and data analysis consume more resources than the length of time the recording device is in the field.

9.4.3 Field Procedure

9.4.3.1 Preparation:

(1) 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 (time intervals usually range from 15 minutes to several hours, depending on the purpose of the count), and
- **(c)** information about the site (e.g., geometric layout, volume levels by time of day, signal timing, pedestrian/bicyclist facilities, pedestrian/bicyclist attractors and generators etc.)

9.4.3.2 Observer Location:

(1) Observers should be positioned in a location with a clear view of the non-motorists to be counted and must avoid vantage points regularly blocked. They should be located away from the edge of the travel way for safety purposes and to avoid distracting drivers, obstructing non-motorist movements, or obstructing non-motorists from the line of sight for drivers.

(2) If more than one observer is performing the study, they should maintain visual contact with one another, and be able to communicate to coordinate their activities. Safety vests should be worn at all times. 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.

9.4.3.3 Data Recording:

(1) 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.

(2) Factors regarding non-motorist characteristic or behavior should be recorded, according to the purpose of the data collection. Factors may include, but not limited to: mode, direction of travel (for example with vehicle travel or against vehicle travel), age, gender, helmet use, facility of use (for example bike lane, sidewalk, or vehicle travel lane), and number in group. Example 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- 1 and Exhibit 12- 2***.

(3) The observer should maintain organized and correctly labeled data to ensure a successful non-motorized volume study. Some specific considerations are:

- **(a)** Properly orient the equipment to the geographic and geometric layout of the intersection.
- **(b)** Maintain and coordinate accurate time intervals between observers.
- **(c)** Concentrate on accurately recording each count in the proper place on the form or with the proper button regardless of the method being used.

9.4.4 Manual Field Observation Forms

9.4.4.1 Non-Motorized Volume Sheet (*Form No. 750-020-09*)

(1) Enter the Major and Minor Street names, Roadway ID (if applicable), mileposts, City, County, Intersection Control Type, Agency or Company, Observer(s), Date Performed, Analysis Period, and Weather. The observer should note under Remarks any information that may need to be considered in addition to the data being collected such as intersection geometry.

(2) 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 MUTS Chapter 3. It is also important to write the names of the two intersecting streets and indicate which way is north.

(3) At the top of each block, enter the time interval during which the counts were made. Non-motorist 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.

(4) If additional data on non-motorist behavior or characteristics are being recorded observer(s) can subdivide the spaces for tally marks and Totals to record the volume of non-motorists pertaining to the considered behavior or characteristic. If the spaces for tally marks and totals are subdivided, the observer(s) should include a clear note on the study form to indicate the behavior or characteristic observed.

9.4.4.2 *Summary of Non-Motorized Movements (Form No. 750-020-10)*

(1) The data gathered in the field using the ***Non-Motorized Volume Sheet*** is summarized using the ***Summary of Non-Motorized Movements***. 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, pedestrian signal heads, and countdown signals where appropriate.

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

9.5 AUTOMATIC COUNTS

(1) Using this procedure, equipment is installed to record non-motorist activity. Depending on the equipment, data may be downloaded at the device location or remotely via a wireless or landline modem. Equipment capabilities vary in the level of detail provided in the data.

(2) Automatic counting allows data to be collected over long periods of time, with limited manual efforts. Automatic counters may require maintenance or calibration over time, depending on the equipment used.

(3) Depending on the data needs, automatic counts may also be used to collect counts over a short period of time. A minimum of 7 days and a preferred duration of 14 days is recommended [6].

(4) Automatic counting provides a means of gathering non-motorized volume data where complex classifications are not required.

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[6] *FHWA Traffic Monitoring Guide, Chapter 4; FDOT Traffic Monitoring Handbook, Chapter 5; NCHRP 797: Guidebook on Pedestrian and Bicycle Volume Data Collection, Chapter 3 & 5*

(5) Engineers should be aware of the existing limitations in accuracy and where these technologies can be used. Refer to the FDOT Traffic Monitoring Handbook for guidance on the limitations and applicability of the technology.

9.5.1 Personnel Required

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

(2) For some equipment, the installation crew may need to temporarily close vehicle lanes or a portion of the pedestrian and bicyclist facility. In these instances, equipment should be installed during periods of low traffic.

9.5.2 Equipment

(1) The two basic components of equipment required generally include sensors to detect the presence of pedestrians or bicycles and a data recorder. Guidance for selecting bicyclists and pedestrians counting technologies is included in NCHRP 797, the FHWA Traffic Monitoring Guide and in the FDOT Traffic Monitoring Handbook[6].

(2) 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 devices, and laser counters.

(3) Studies have found when using automated counting devices to estimate average annual daily bicyclists (AADB), AADB average estimation errors were found to range from 15% with four weeks of continuous count data to 54% when only one hour is counted per year. The study found that the most cost-effective duration for a short-term bicycle count is seven consecutive days when using automated counting devices. For counts less than seven days of consecutive hourly count data, the study found it was difficult to understand the weekly travel pattern and the average absolute error is higher. (Institute for Transportation Research and Education (ITRE); Bicycle and Pedestrian Data Collection – Phase 1 Final Report; October 2016).

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

9.5.3 Field Procedure

(1) **Preparation**: A checklist should be prepared in preparation of the 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 during field installations.

(2) **Location Selection**: 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.

Some studies may use both automated and manual methodologies. In these cases, supplemental cameras may be needed for special studies, such as compliance at signalized intersections. Additional information on count location selection can be found in the MUTS Chapter 4 Information regarding pedestrian volume warrants for traffic signals is provided in the MUTS Chapter 3.

(3) ***The FDOT Statewide Non-Motorized Traffic Monitoring Program*** has developed a program for assessing locations for consideration of automated bicyclist and pedestrian counter. This program includes both virtual and on-site reviews of the location. The Implementation Plan cites virtual and on-site evaluations as a required pre-requisite for installing continuous or short-term bicycle and pedestrian counters.

(4) **Installation and Retrieval**: Installation and retrieval operations should be accomplished during low-traffic-volume periods for safety reasons. Traffic control measures should be implemented to maintain a safe work zone whenever work is conducted on the roadway itself or when the field personnel’s vehicle is interacting with a travel lane or shoulder. Field personnel should adhere to a strict Personal Protective Equipment protocol (PPE) including:

- **(a)** ANSI Class II reflective clothing
- **(b)** ID badges
- **(c)** Safety glasses
- **(d)** Gloves
- **(e)** Hard hats (as required)
- **(f)** Headlamps for night work
- **(g)** Closed-toe shoes

Additional safety indications for the installation and retrieval of data equipment can be found in the ***MUTCD*** and ***OSHA*** materials.

Calibration should be completed during installation, and periodically in the case of long term count locations[3].

(5) **Data Summary**: 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 on the type of study being conducted, the data may require a simple extraction or a sophisticated statistical treatment.

9.6 WALKING SPEED STUDIES

(1) The ***ITE Manual of Transportation Engineering Studies, 2nd Edition*** suggests the following walking speed ranges as typical:

  (a) Fully abled pedestrian: 2.8 to 5.7 feet per second (fps)

  (b) Disabled pedestrian: 2.0 to 3.7 fps

(2) Walking speeds can be affected by pedestrian characteristics (age, fitness level, etc.), roadway characteristics (grade, crossing path, etc.) or environmental conditions (pedestrian volume, weather conditions, oncoming vehicle speeds, etc.).

(3) If a walking speed is required, below is the personnel, equipment, and field procedure to follow. The study should be conducted under the location and conditions of interest.

(4) The procedure described below can be modified and applied to other non-motorist road users (e.g., bicycles, scooters).

9.6.1 Personnel Required

(1) The number of observers required to conduct a walking speed study can increase if the conditions vary over the period of interest and the desired classes of data required.

(2) Observer placement should be selected to avoid distracting or conflicting with pedestrians and where the observers will have a clear view of the location of interest.

9.6.2 Equipment

(1) The number of observers required to conduct a walking speed study can increase if the conditions vary over the period of interest and the desired classes of data required.

(2) Tally sheets, handheld count boards, mobile devices or video cameras can be used to record the data. Refer to Chapter 9, Section 9.4.2 for additional guidance on this equipment.

(3) The ***Walking Speed Study – Intersection*** (Form 720-020-11a) and ***Walking Speed Study – Mid-block*** (Form 720-020-11b) forms can be used to collect the data and conduct the necessary calculations described below.

(4) ***Figure 9-3*** and ***Figure 9-4*** provide an example of Form No. 750-020-11a and Form No. 750-020-11b completed, respectively.

9.6.3 Field Procedure

(1) The observers should measure and mark the crossing distance traveled by the pedestrians of interest prior the beginning of the pedestrian data recording.

(2) Once the influence area has been determined and marked, the observer will time individual pedestrians as they walk through the crossing distance.

(3) A sample size of 100 observations is suggested. If 100 observations cannot be recorded, it is suggested to collect 90% of the speeds of pedestrians during the 4 daily peak hours. The peak hours can be established by pedestrian counts at the crossing location of interest.

(4) For two stage crossings, individual measurements should be conducted.

9.6.4 Calculations

(1) Once the data is collected in the field, the calculations can be conducted in the office. If the electronic copy of the form is used, the calculations are automated.

(2) Step 1: calculate each individual average walking speed

$$average\ walking\ speed_i = \frac{speed\ trap\ distance}{seconds_i}$$

(3) Step 2: classify the observed speeds

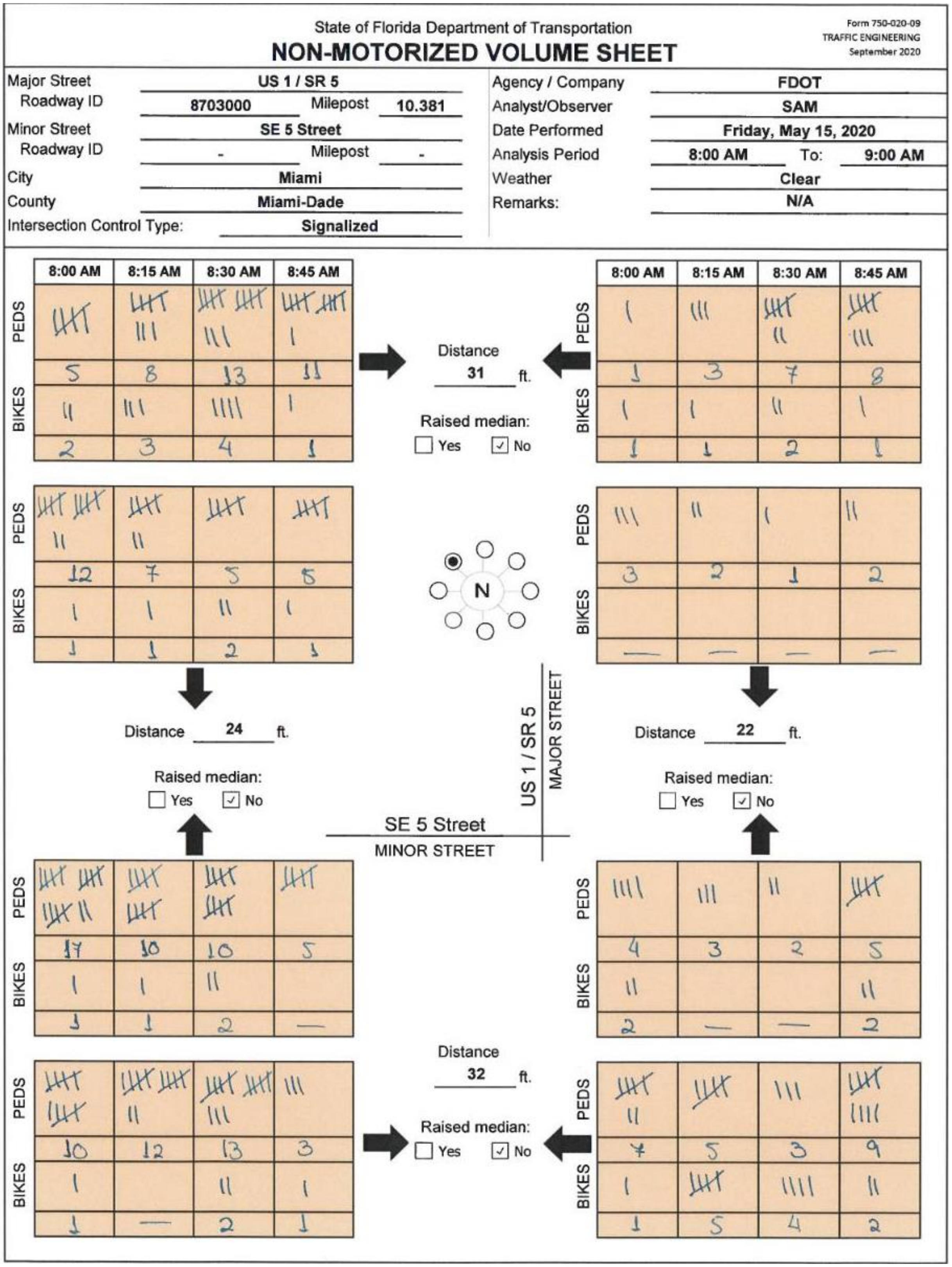
(4) Step 3: plot the cumulative percentage of observations by class to produce a cumulative speed curve. This graph provides various speed percentiles.

(5) The 15th percentiles speed is generally used for design purposes (e.g., signal timing clearance calculations). Other percentiles may be used as needed.

9.7 FORMS ACCESS

(1) Forms Access: Reproducible copies of the ***Non-Motorized Volume Sheet*** (Form 750-020-09), the ***Summary of Non-Motorized Movements*** (Form 750-020-10), ***Walking Speed Study - Intersection*** (Form 720-020-11a), and the ***Walking Speed Study - Mid-block*** (Form 720-020-11b), are available in the Department's Forms Library. Also, an electronic format is available for field and office use.

Figure 9-1. Non-Motorized Volume Sheet
(*Form No. 750-020-09*)



State of Florida Department of Transportation

NON-MOTORIZED VOLUME SHEET

Form 750-020-09
TRAFFIC ENGINEERING
September 2020

Major Street: **US 1 / SR 5**
Roadway ID: **8703000** Milepost: **10.381**
Minor Street: **SE 5 Street**
Roadway ID: **-** Milepost: **-**
City: **Miami**
County: **Miami-Dade**
Intersection Control Type: **Signalized**

Agency / Company: **FDOT**
Analyst/Observer: **SAM**
Date Performed: **Friday, May 15, 2020**
Analysis Period: **8:00 AM** To: **9:00 AM**
Weather: **Clear**
Remarks: **N/A**

	8:00 AM	8:15 AM	8:30 AM	8:45 AM
PEDS	卌	卌 |||	卌 卌 |||	卌 卌 |
	5	8	13	11
BIKES	||	|||	||||	|
	2	3	4	1

Distance **31** ft.

Raised median:
☐ Yes ☑ No

	8:00 AM	8:15 AM	8:30 AM	8:45 AM
PEDS	|	|||	卌 ||	卌 |||
	1	3	7	8
BIKES	|	|	||	|
	1	1	2	1

PEDS	卌 卌 ||	卌 ||	卌	卌
	12	7	5	5
BIKES	|	|	||	|
	1	1	2	1

● ○ ○ ○ N ○ ○ ○ ○

PEDS	|||	||	|	||
	3	2	1	2
BIKES				
	—	—	—	—

Distance **24** ft.

Raised median:
☐ Yes ☑ No

Distance **22** ft.

Raised median:
☐ Yes ☑ No

US 1 / SR 5
MAJOR STREET

SE 5 Street
MINOR STREET

PEDS	卌 卌 卌 ||	卌 卌	卌 卌	卌
	17	10	10	5
BIKES	|	|	||	
	1	1	2	—

PEDS	||||	|||	||	卌
	4	3	2	5
BIKES	||			||
	2	—	—	2

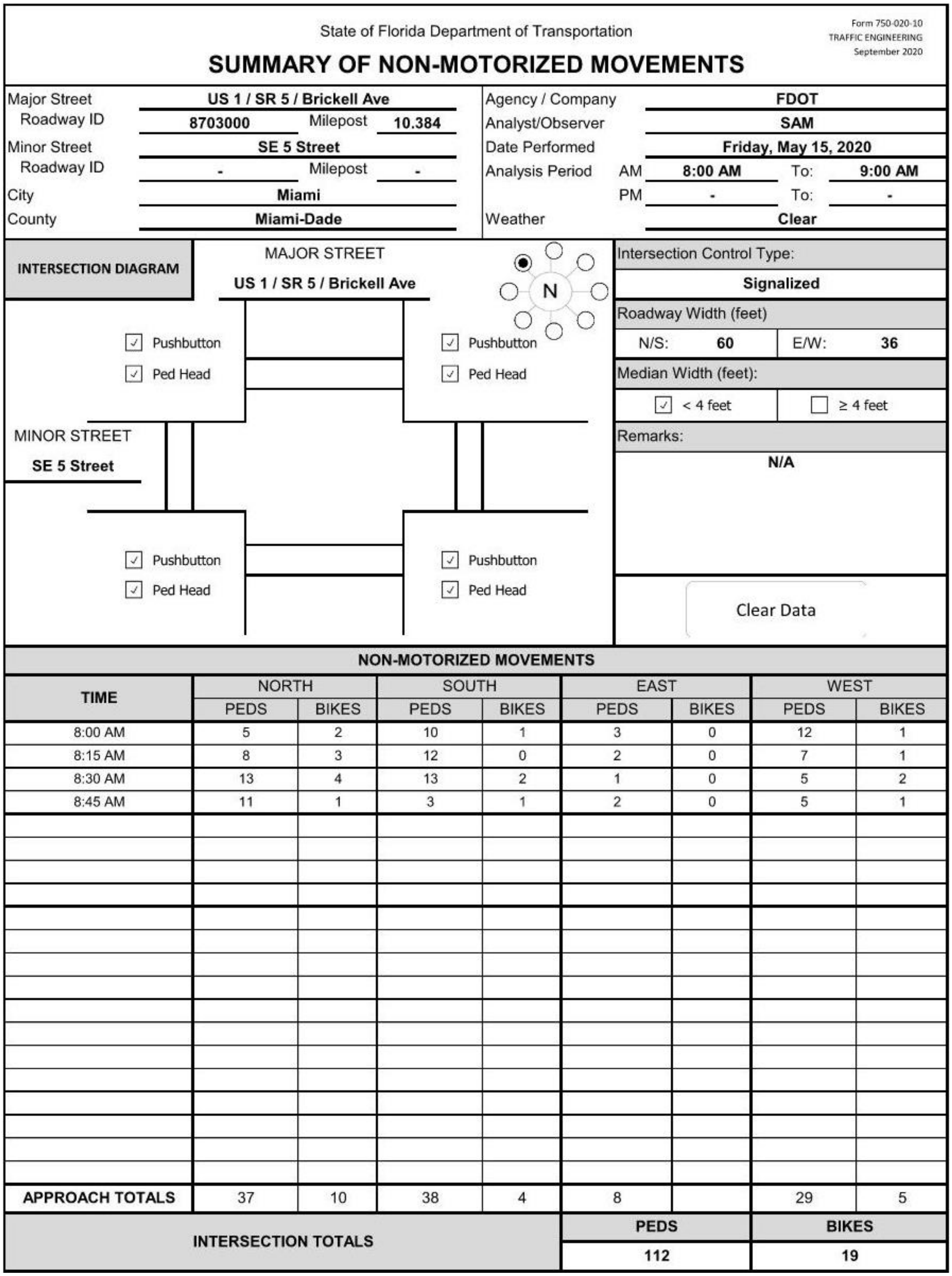
Distance **32** ft.

Raised median:
☐ Yes ☑ No

PEDS	卌 卌	卌 卌 ||	卌 卌 |||	|||
	10	12	13	3
BIKES	|		||	|
	1	—	2	1

PEDS	卌 ||	卌	|||	卌 ||||
	7	5	3	9
BIKES	|	卌	||||	||
	1	5	4	2

Figure 9-2 Summary of Non-Motorized Movements (*Form No. 750-020-10*)



State of Florida Department of Transportation

Form 750-020-10
TRAFFIC ENGINEERING
September 2020

SUMMARY OF NON-MOTORIZED MOVEMENTS

Major Street: **US 1 / SR 5 / Brickell Ave**
Roadway ID: **8703000** Milepost: **10.384**
Minor Street: **SE 5 Street**
Roadway ID: **-** Milepost: **-**
City: **Miami**
County: **Miami-Dade**

Agency / Company: **FDOT**
Analyst/Observer: **SAM**
Date Performed: **Friday, May 15, 2020**
Analysis Period AM: **8:00 AM** To: **9:00 AM**
PM: **-** To: **-**
Weather: **Clear**

INTERSECTION DIAGRAM

MAJOR STREET
US 1 / SR 5 / Brickell Ave

MINOR STREET
SE 5 Street

● ○ ○ ○ N ○ ○ ○ ○

☑ Pushbutton
☑ Ped Head

☑ Pushbutton
☑ Ped Head

☑ Pushbutton
☑ Ped Head

☑ Pushbutton
☑ Ped Head

Intersection Control Type: **Signalized**

Roadway Width (feet)
N/S: **60** E/W: **36**

Median Width (feet):
☑ < 4 feet ☐ ≥ 4 feet

Remarks:
N/A

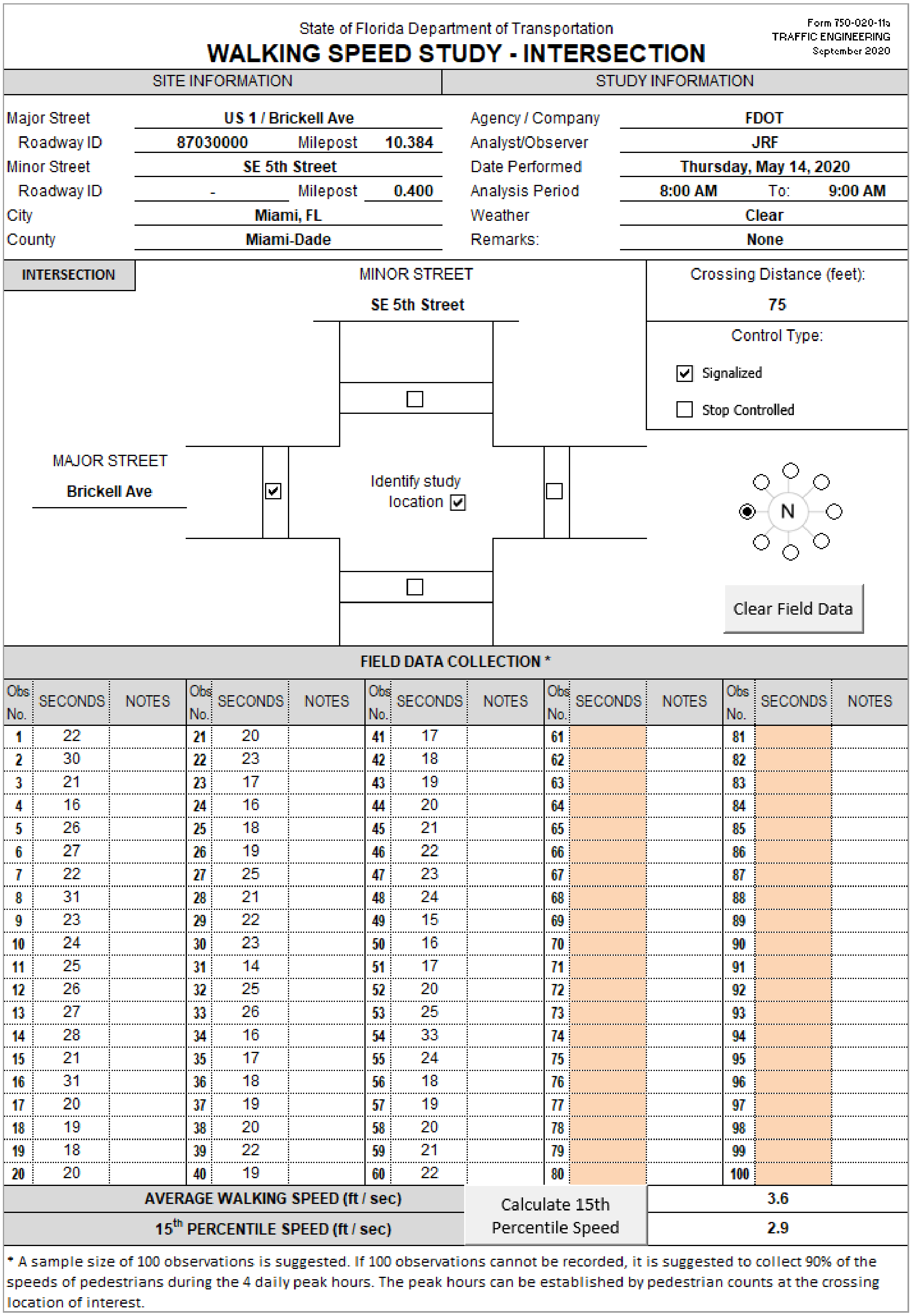
Clear Data

NON-MOTORIZED MOVEMENTS

TIME	NORTH		SOUTH		EAST		WEST	
	PEDS	BIKES	PEDS	BIKES	PEDS	BIKES	PEDS	BIKES
8:00 AM	5	2	10	1	3	0	12	1
8:15 AM	8	3	12	0	2	0	7	1
8:30 AM	13	4	13	2	1	0	5	2
8:45 AM	11	1	3	1	2	0	5	1
APPROACH TOTALS	37	10	38	4	8		29	5

INTERSECTION TOTALS	**PEDS**	**BIKES**
	112	**19**

Figure 9-3. Walking Speed Study – Intersection
(*Form No. 720-020-11a*)



Form 750-020-11a
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

WALKING SPEED STUDY - INTERSECTION

SITE INFORMATION		STUDY INFORMATION	
Major Street	**US 1 / Brickell Ave**	Agency / Company	**FDOT**
Roadway ID	**87030000** Milepost **10.384**	Analyst/Observer	**JRF**
Minor Street	**SE 5th Street**	Date Performed	**Thursday, May 14, 2020**
Roadway ID	**-** Milepost **0.400**	Analysis Period	**8:00 AM** To: **9:00 AM**
City	**Miami, FL**	Weather	**Clear**
County	**Miami-Dade**	Remarks:	**None**

INTERSECTION

MINOR STREET
SE 5th Street

MAJOR STREET
Brickell Ave

☐ ☑ ☐ ☐

Identify study location ☑

Crossing Distance (feet):
75

Control Type:
☑ Signalized
☐ Stop Controlled

Clear Field Data

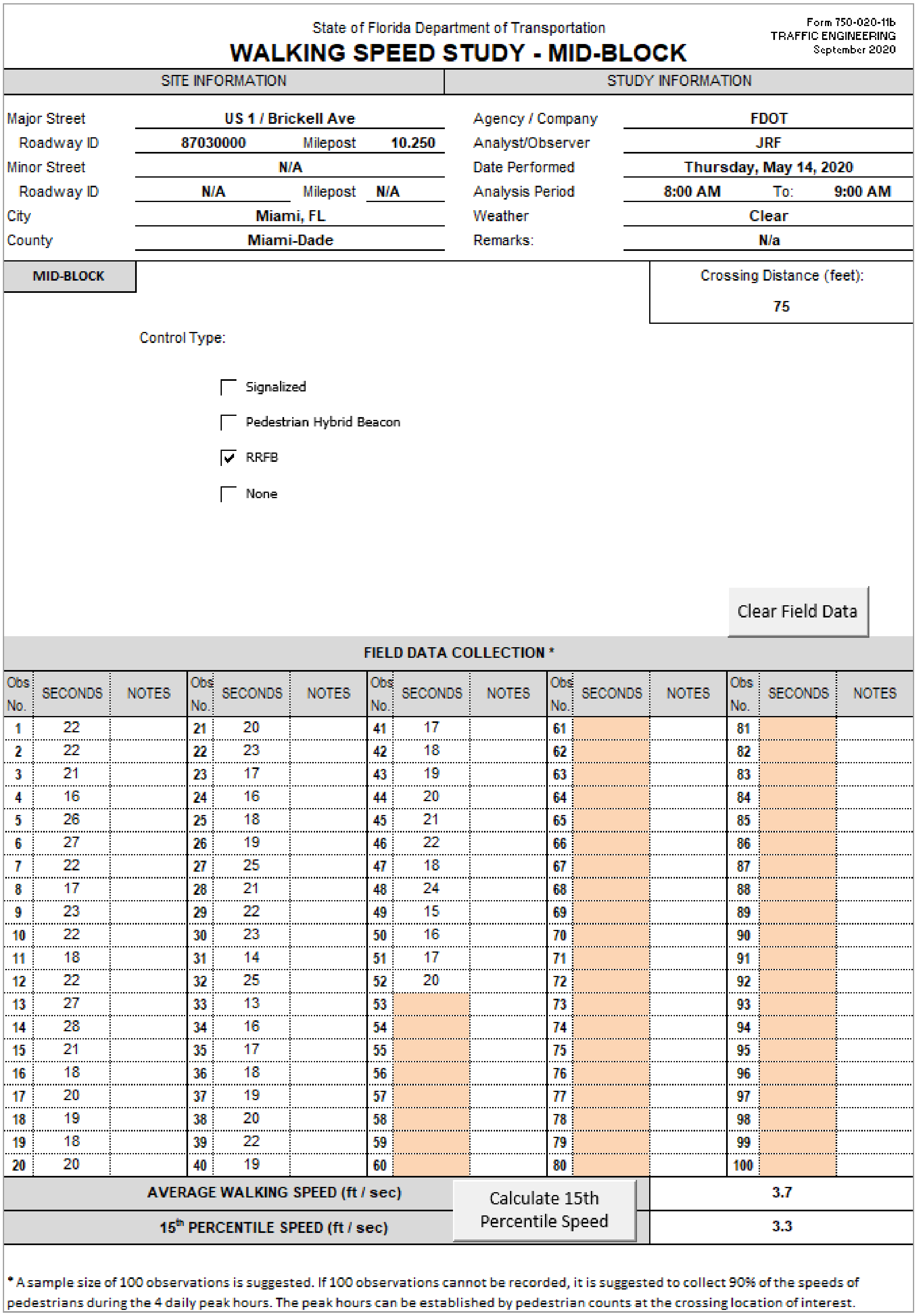
FIELD DATA COLLECTION *

Obs No.	SECONDS	NOTES	Obs No.	SECONDS	NOTES	Obs No.	SECONDS	NOTES	Obs No.	SECONDS	NOTES	Obs No.	SECONDS	NOTES
1	22		**21**	20		**41**	17		**61**			**81**		
2	30		**22**	23		**42**	18		**62**			**82**		
3	21		**23**	17		**43**	19		**63**			**83**		
4	16		**24**	16		**44**	20		**64**			**84**		
5	26		**25**	18		**45**	21		**65**			**85**		
6	27		**26**	19		**46**	22		**66**			**86**		
7	22		**27**	25		**47**	23		**67**			**87**		
8	31		**28**	21		**48**	24		**68**			**88**		
9	23		**29**	22		**49**	15		**69**			**89**		
10	24		**30**	23		**50**	16		**70**			**90**		
11	25		**31**	14		**51**	17		**71**			**91**		
12	26		**32**	25		**52**	20		**72**			**92**		
13	27		**33**	26		**53**	25		**73**			**93**		
14	28		**34**	16		**54**	33		**74**			**94**		
15	21		**35**	17		**55**	24		**75**			**95**		
16	31		**36**	18		**56**	18		**76**			**96**		
17	20		**37**	19		**57**	19		**77**			**97**		
18	19		**38**	20		**58**	20		**78**			**98**		
19	18		**39**	22		**59**	21		**79**			**99**		
20	20		**40**	19		**60**	22		**80**			**100**		

AVERAGE WALKING SPEED (ft / sec)	Calculate 15th Percentile Speed	**3.6**
15th PERCENTILE SPEED (ft / sec)		**2.9**

* A sample size of 100 observations is suggested. If 100 observations cannot be recorded, it is suggested to collect 90% of the speeds of pedestrians during the 4 daily peak hours. The peak hours can be established by pedestrian counts at the crossing location of interest.

Figure 9-4. Walking Speed Study – Mid-Block
(*Form No. 720-020-11b*)



State of Florida Department of Transportation

WALKING SPEED STUDY - MID-BLOCK

Form 750-020-11b
TRAFFIC ENGINEERING
September 2020

SITE INFORMATION

Major Street: **US 1 / Brickell Ave**
Roadway ID: **87030000** Milepost: **10.250**
Minor Street: **N/A**
Roadway ID: **N/A** Milepost: **N/A**
City: **Miami, FL**
County: **Miami-Dade**

STUDY INFORMATION

Agency / Company: **FDOT**
Analyst/Observer: **JRF**
Date Performed: **Thursday, May 14, 2020**
Analysis Period: **8:00 AM** To: **9:00 AM**
Weather: **Clear**
Remarks: **N/a**

MID-BLOCK

Crossing Distance (feet): **75**

Control Type:

☐ Signalized
☐ Pedestrian Hybrid Beacon
☑ RRFB
☐ None

Clear Field Data

FIELD DATA COLLECTION *

Obs No.	SECONDS	NOTES	Obs No.	SECONDS	NOTES	Obs No.	SECONDS	NOTES	Obs No.	SECONDS	NOTES	Obs No.	SECONDS	NOTES
1	22		**21**	20		**41**	17		**61**			**81**		
2	22		**22**	23		**42**	18		**62**			**82**		
3	21		**23**	17		**43**	19		**63**			**83**		
4	16		**24**	16		**44**	20		**64**			**84**		
5	26		**25**	18		**45**	21		**65**			**85**		
6	27		**26**	19		**46**	22		**66**			**86**		
7	22		**27**	25		**47**	18		**67**			**87**		
8	17		**28**	21		**48**	24		**68**			**88**		
9	23		**29**	22		**49**	15		**69**			**89**		
10	22		**30**	23		**50**	16		**70**			**90**		
11	18		**31**	14		**51**	17		**71**			**91**		
12	22		**32**	25		**52**	20		**72**			**92**		
13	27		**33**	13		**53**			**73**			**93**		
14	28		**34**	16		**54**			**74**			**94**		
15	21		**35**	17		**55**			**75**			**95**		
16	18		**36**	18		**56**			**76**			**96**		
17	20		**37**	19		**57**			**77**			**97**		
18	19		**38**	20		**58**			**78**			**98**		
19	18		**39**	22		**59**			**79**			**99**		
20	20		**40**	19		**60**			**80**			**100**		

AVERAGE WALKING SPEED (ft / sec)	**3.7**
15th PERCENTILE SPEED (ft / sec)	**3.3**

Calculate 15th Percentile Speed

* A sample size of 100 observations is suggested. If 100 observations cannot be recorded, it is suggested to collect 90% of the speeds of pedestrians during the 4 daily peak hours. The peak hours can be established by pedestrian counts at the crossing location of interest.

CHAPTER 10 ADVISORY SPEED STUDY

10.1 PURPOSE

(1) The purpose of the ***Advisory Speed Study*** is to determine the maximum comfortable and 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 several manual and automated methods available to determine advisory speeds along horizontal curves.

(3) Among the most commonly used manual methods to collect the field information to determine the safe curve speed for a horizontal curve are design speed equation, traditional ball-bank indicator, and accelerometer method.

Form No. 750-020-12 provides a data collection template for the ball-bank indicator and accelerometer methods. One of identified disadvantages of these methods is the need to drive through curves multiple times under free-flow conditions to determine maximum recommended speeds. Due to the availability of safe turn-around points these methods can be time-consuming to perform and error-prone.

(4) Most of the automated data collection methods consist of Global Positioning System (GPS) based data collection paired with a curve advisory software platform. The road survey system automatically records vehicle activity (through geospatial data) and determines recommended safe curve speed. One of the reported advantages of these methods is the reduced need of minimum samples, it typically requires a minimum of one pass in each direction (it is suggested to conduct additional runs to analyze the consistency of the results – 2 runs suggested), with traffic, at any speed (except for loss of GPS signal where multiple runs may be required).

10.2 EQUIPMENT AND PERSONNEL

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

(2) In addition to the equipment listed in ***Table 10-1***, a camera or camcorder mounted to the windshield has been proven helpful to record the field conditions at the time of data collection. The video recordings have also helped with corroborating or conducting sign inventory along the curves.

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 each directions of travel
Accelerometer	1 person (driver)	Accelerometer, Test vehicle	
GPS based data collection	2 people (driver and observer)	GPS receiver, Digital Ball-Bank Indicator, tablet, or laptop computer	minimum 1 run in each direction of travel, suggested 2 runs

* 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 (feet)

l = chord length (feet)

h = middle ordinate (feet)

(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 boundary. 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.

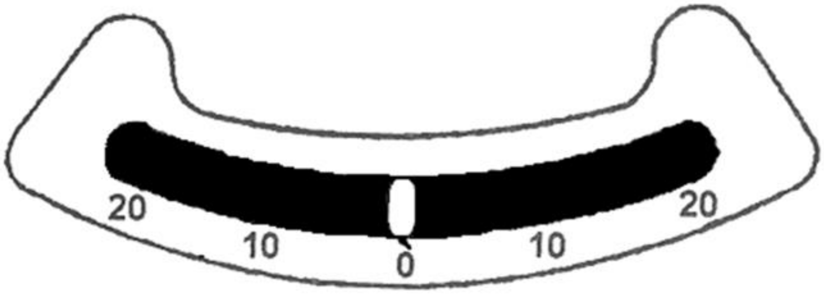
10.3.2 Ball-Bank Indicator Method

(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***.

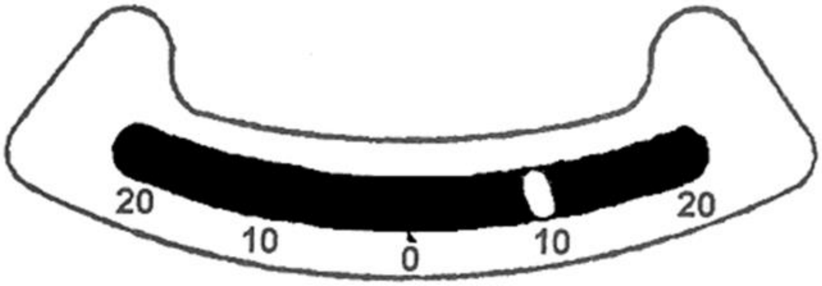
(2) The ball bank can be easily mounted to the dashboard by means of rubber suction cups or other stable methods. It should be mounted in a position that allows the ball to rest freely at the zero-degree position when the vehicle is standing level. The movement of a car around a curve to the left, for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

(3) 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



(4) 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.

(5) 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***.

(6) 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.

(7) 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.

(8) 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.

(9) 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 FHWA Manual on Uniform Traffic Control Devices (MUTCD) Section 2C 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 methods discussed in this chapter.

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) Warning signs alert road users of unexpected conditions that may not be readily apparent, it is very important that care be given to the placement of such signs. Section 2C.07 – Table 2C-5 of the MUTCD provides a detailed breakdown of the required, recommended and optional warning signs per the differential between the posted speed limit and the advisory speed identified through one of the methods listed in this chapter. Note that the MUTCD Horizontal Alignment Signing guidelines are being reviewed for proposed modifications through a technical committee of the NCUTCD which will need FHWA approval for inclusion into the MUTCD revision.

(2) 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.

(3) 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).

(4) In addition, the Advisory Speed Warning signs consideration and placement should be in accordance with the *FDOT Manual on Speed Zoning for Highways, Roads, and Streets 2018*, **Chapter 16 Section 16.1**.

10.5 USE OF ADVISORY SPEED STUDY FORM

(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.

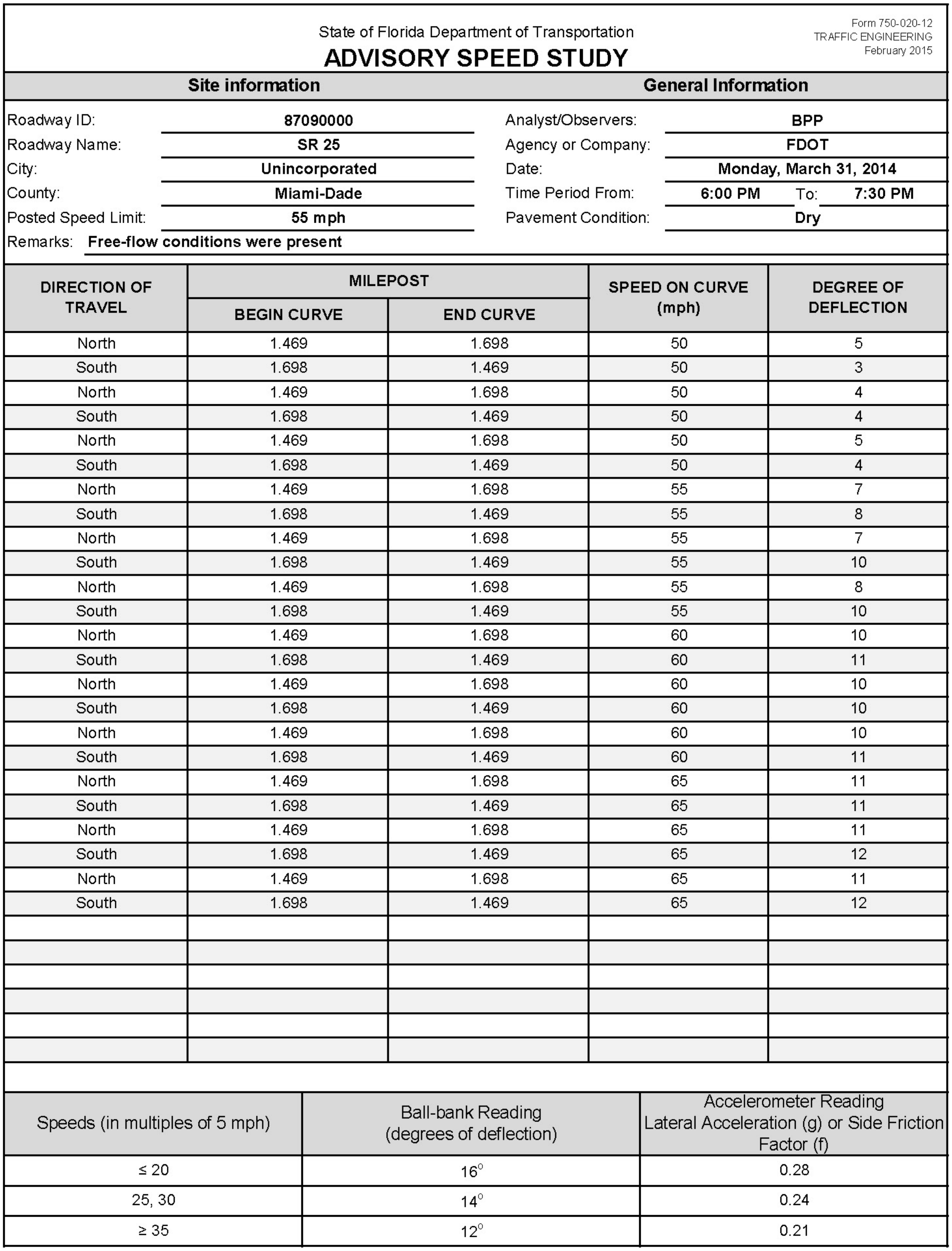
(4) In the *Speed on Curve* column, enter the constant speed of the study vehicle as the vehicle travels through the curve. In the *Degree of Deflection* column, enter the degree of deflection as shown on the ball bank indicator for constant speed of the study vehicle as the vehicle passed through the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

(5) ***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

Form 750-020-12
TRAFFIC ENGINEERING
February 2015

ADVISORY SPEED STUDY

Site information | **General Information**

Roadway ID: **87090000**
Roadway Name: **SR 25**
City: **Unincorporated**
County: **Miami-Dade**
Posted Speed Limit: **55 mph**
Remarks: **Free-flow conditions were present**

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**

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. Minimum passing sight distance is determined using either 85th percentile or posted speed limit. FDM Section 210.11.1 defines stopping sight distance as the distance needed for drivers to see an object on the roadway ahead and bring their vehicles to a safe stop before colliding with the object. The FDM further defines this to be derived based upon design speed. The values shown in ***Table 11-1*** are for operational use in marking no-passing zones and are less than values contained in FDM Table 210.11.2 for the construction of new alignments. These values are acceptable for resurfacing, restoration, and rehabilitation (RRR) construction projects.

(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

(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 prior to the beginning of the zone.

(5) Where the distance between successive no-passing zones is less than the minimum passing sight distance specified in ***Table 11-1***, 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 FDOT Design Manual shall be used to check and determine no-passing zones.

Table 11-2. Minimum Stopping Sight Distance

Design Speed (mph)	Minimum Stopping Sight Distance (feet)
25	155
30	200
35	250
40	305
45	360
50	425
55	495
60	570
65	645
70	730

Source: FDOT Design Manual Table 210.11.1. Note: Adjustments for grades greater than 2% should be applied and are included in Table 210.11.1.

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. MUTCD Section 3B.02 says the minimum passing sight distance shall be based upon the 85th percentile speed or posted speed limit. 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 509-070 of the Standard Plans for Road Construction. 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 509-070) 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 the FDOT Design Manual, Section 210.11.

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 on-street parking, that roadway shall be marked with a continuous no-passing zone. If the roadway does not have on-street 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 the FDOT Design Manual, Section 210.11.

(3) When roadways form an intersection outside the city limits and the intersecting roadway (stop controlled) is marked along the major roadway 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 should 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 700-106 ***of the Standard Plans for Road Construction.***

(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 1,570 feet in advance of the narrow bridge per FDOT Standard Plans Index Number 700-106.

11.3.5 Warrant 5: Roadway Transitions

(1) Roadway transitions shall be marked in accordance with Index Number 711-001 of the Standard Plans for Road Construction.

(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 as dimension “B” in Index Number 711-001.

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. Section 3B.10 of the MUTCD notes fixed obstructions within a paved roadway can include bridge supports, refuge islands, median islands, toll plaza islands and raised channelization islands.

(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. An example of a special condition is a school zone.

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 Warrant 1 no-passing zones within the State of Florida:

- **(a)** Method One (two vehicle),
- **(b)** Method Two (one vehicle),
- **(c)** Method Three (two person),
- **(d)** Method Four (ITS techniques),
- **(e)** Method Five (plan review).

(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 or cellphones using hands free technology, 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, verbal communications 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.

(4) **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.

(5) 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.

(6) 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.

(7) 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.

(8) 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.

(9) 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.

(10) 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.

(11) 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.

(12) 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.

(13) 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 or cell phones 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.

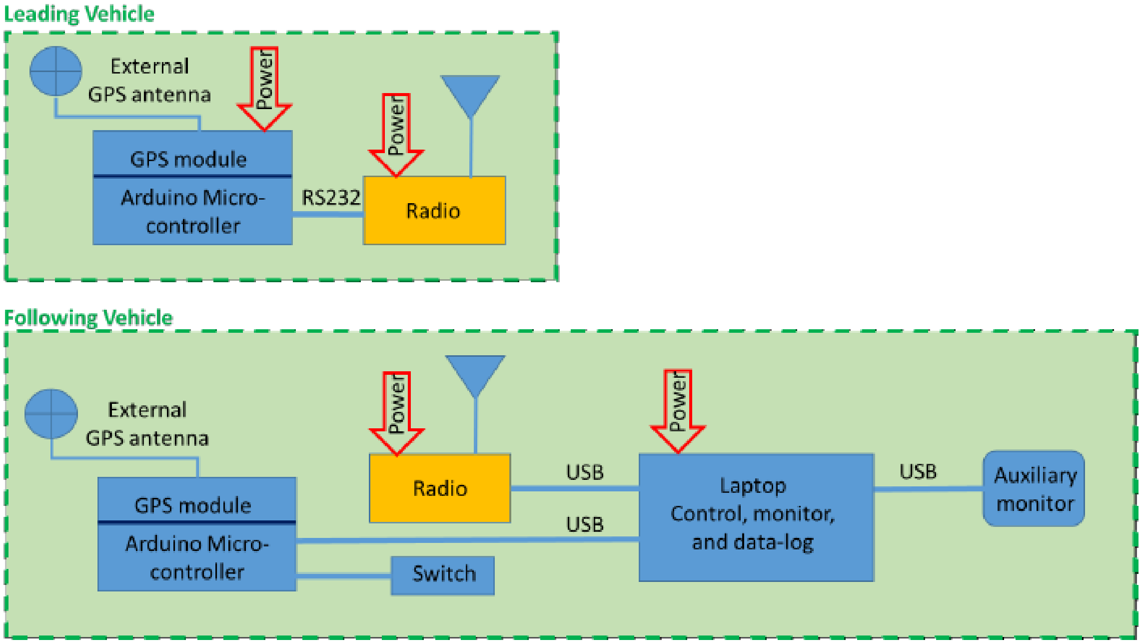
11.5.4 Method Four - ITS Techniques

(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 using GPS coordinates to report the boundaries of passing and no-passing zones. This maintains the basic characteristics of the two-vehicle system, in which the driver of the following vehicle manually confirms the visibility (or lack thereof) of the target on the lead vehicle continuously along the roadway. The GPS system can be taken at or near highway speeds and keeps staff out of the roadway and roadside. This system is described in ***Developing a System to Identify Passing and No Passing Zone Boundaries for Rural Two-Lane Highways*** prepared for the Missouri Department of Transportation (MoDOT) by MRIGlobal, July 2016. It is further explained in the *No-Passing Zone System User's Manual* also prepared for MoDOT by MRIGlobal, July 2016. These documents are available for download and use in the FDOT MUTS forms website.

(a) This system is designed to operate similarly to methods described above in which two vehicles travel a set distance apart from each other along a two-lane highway. However, the method of maintaining the desired distance relies on GPS devices and real time communication between the GPS devices. The driver in the following vehicle is continuously shown the distance along the roadway from the leading vehicle to alter travel speed as needed to maintain the correct distance. Rather than manually noting boundary locations between passing and no-passing zones, the driver of the following uses a switch to indicate the lead vehicle goes in and out of view. When the switch is flipped, the system records the point in space where this happens. The system set-up is shown in **Figure 11-1**. For further details please see the User's Manual.

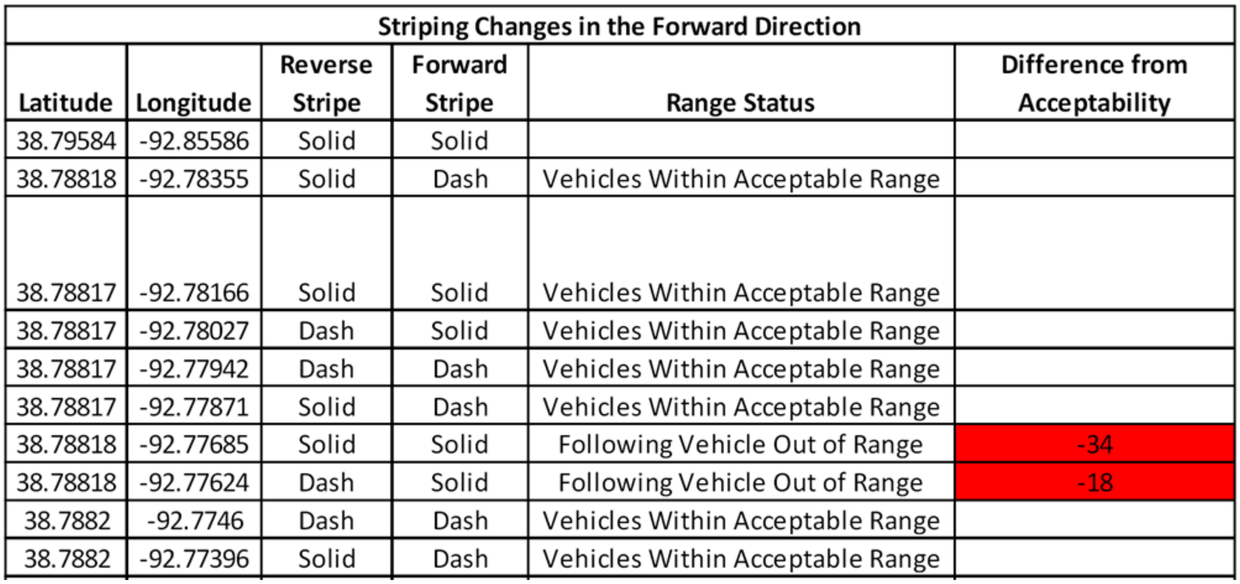
Figure 11-1. System Set-Up as Shown in the 2016 MoDOT No-Passing Zone System User's Manual



Source: No-Passing Zone System User's Manual

(b) This information is recorded on a laptop positioned in the passenger seat. The laptop should be preloaded with field data collection software (will be available for download from the FDOT MUTS website once licensing issues are resolved) so the data can be properly stored in the field. The field data can be analyzed using a second post-processing software either on the data collection laptop or separate computer. This software is also available on the FDOT MUTS website for download. The post-processing software (macro-enabled Microsoft Excel workbook) uses the data files assembled by the following vehicle to determine the location of centerline striping for both directions of travel. The following vehicle data files contain a record of latitude/longitude coordinates, location when switch is activated, distance between vehicles, and total distance traveled every 0.2 seconds. The post-processing software determines points of change in the centerline striping and reports these into a separate worksheet as the example shown in ***Table 11-3***.

Table 11-3. No-Passing Zone report sample from Worksheets



Striping Changes in the Forward Direction					
Latitude	Longitude	Reverse Stripe	Forward Stripe	Range Status	Difference from Acceptability
38.79584	-92.85586	Solid	Solid		
38.78818	-92.78355	Solid	Dash	Vehicles Within Acceptable Range	
38.78817	-92.78166	Solid	Solid	Vehicles Within Acceptable Range	
38.78817	-92.78027	Dash	Solid	Vehicles Within Acceptable Range	
38.78817	-92.77942	Dash	Dash	Vehicles Within Acceptable Range	
38.78817	-92.77871	Solid	Dash	Vehicles Within Acceptable Range	
38.78818	-92.77685	Solid	Solid	Following Vehicle Out of Range	-34
38.78818	-92.77624	Dash	Solid	Following Vehicle Out of Range	-18
38.7882	-92.7746	Dash	Dash	Vehicles Within Acceptable Range	
38.7882	-92.77396	Solid	Dash	Vehicles Within Acceptable Range	

Source: No-Passing Zone System User's Manual

(3) Use of the automated method following the referenced report's guidance must be approved by the District Traffic Operations Engineer prior to conducting the field work.

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

(1) An example of the ***No-Passing Zone Study*** (Form No. 750-020-13) is shown in ***Figure 11-2***. 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.

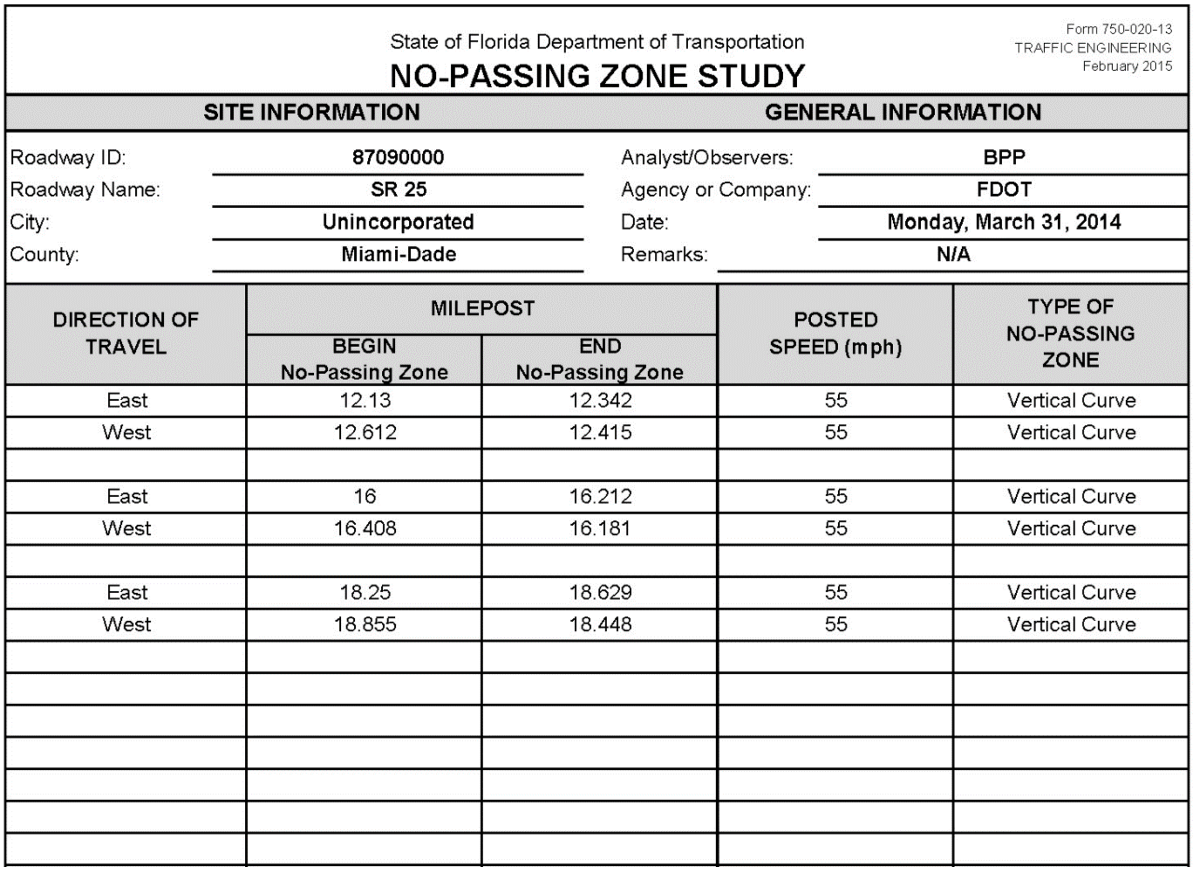
(3) Enter *Observer(s), Agency or Company* and *Date of Study* in the appropriate spaces. On the line provided for *Remarks*, include any information that may need to be considered in addition to data being collected.

(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 11-2. No-Passing Zone Study
(*Form No. 750-020-13*)



State of Florida Department of Transportation

NO-PASSING ZONE STUDY

Form 750-020-13
TRAFFIC ENGINEERING
February 2015

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, installing speed zones, and evaluating the potential need for speed management.

(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. 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*** and the FDOT Speed Zoning for Highways, Roads and Streets in Florida***, 2018, Chapter 5.***

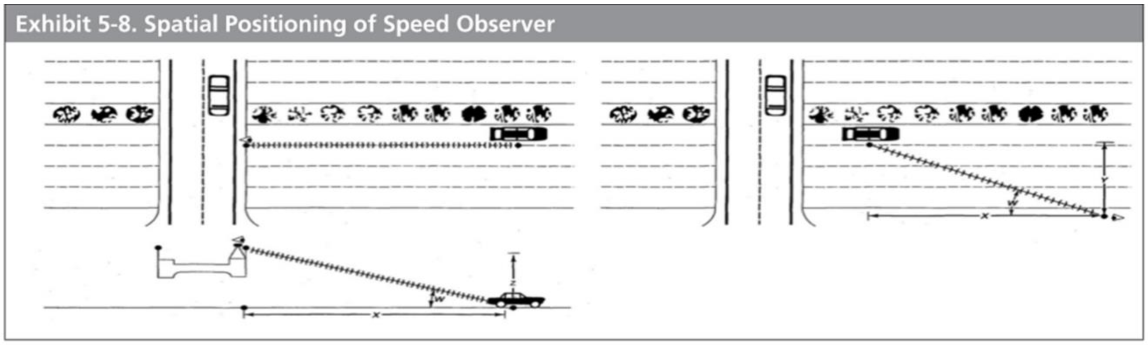
(4) Vehicle speed is determined using the direct measurement technique with radar, laser (lidar), or infrared technologies, which generally operate on the Doppler Principle. The positioning of the radar or laser unit should be determined considering the following:

- **(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. Figure 12-1*** shows below shows Exhibit 5-8 below.

Figure 12-1. Spatial Positioning of Speed Observer



Source: *Speed Monitoring Program Procedural Manual.* FHWA, 1980.

(6) For further considerations in selecting a spot speed study location review the FDOT Speed Zoning for Highways, Roads and Streets in Florida, ***2018, Chapter 5.***

(7) In the Federal Highway Administration Technical Report (FHWA-SA-12-004) ***Methods and Practices for Setting Speed Limits: An Informational Report***, it suggests that if at least one of the following is true; the recommended speed limit may be the 5-mph multiple closest to the 50th percentile speed.

- **(a)** Signals per mile >4.
- **(b)** Pedestrian/bike activity is High (see USLIMITS2 User Guide[7] for definitions in addition to meeting the high volume level criteria shown in MUTS Chapter 14; Section 14.2 (2) (b): high ≥ 100 pedestrians / bicyclists per hour per IESNA RP-8).
- **(c)** Parking activity is High (see USLIMITS2 User Guide for definitions).
- **(d)** Driveways per mile > 60.

(8) The vehicle spot speed study form provides the 50th and 85th percentile speeds.

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[7] USLIMITS2 is a web-based tool designed to help practitioners set reasonable, safe, and consistent speed limits for specific segments of roads.

12.2 VEHICLE SPOT SPEED STUDY FORM

(1) Form No. 750-010-03 is designed to allow for several options in collecting 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. An example of this option is shown in ***Figure 12-2.*** The form also provides a cumulative for both directions, **Option 2**, in which case either side of the form can be used to record data for both directions. An example of this option is shown in ***Figure 12-3.***

(2) Using the electronic format of the form as shown under Option 1, it is possible to calculate the 50th and 85th percentile speed and 10 mph pace for each direction of travel. 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.

(3) 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 50th and 85th percentile vehicles are automatically computed for each direction and shown at the bottom of the form. Those vehicles' corresponding speed categories represent the 50th and 85th percentile speeds. These speeds are computed by interpolating two *Cum Total* column values (higher and lower than the 50th and 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 the form displays at the bottom an "OK" message if a single 10 mph pace was identified. If more than one speed range has 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 ("Warning: Multiple 10 mph paces. Highest range shown").

(4) 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.

(5) The Speed Zoning for Highways, Roads, and Streets in Florida Manual 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.

(6) 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

(a) 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***.

Table 12-1. Average Standard Deviation (S) for sample-size determination

Traffic Areas	Highway Type	mph
Rural	Two-lane	5.3
	Four-lane	4.2
Intermediate	Two-lane	5.3
	Four-lane	5.3
Urban	Two-lane	4.8
	Four-lane	4.9
	Rounded value:	5.0

Source: *Exhibit 5-5 of the ITE Manual of Transportation Engineering Studies, 2nd Edition, page 83*

(b) 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.

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*

(c) 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.

(7) **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 50th and 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 12-3.***

(8) **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 12-4.*** 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)

(9) 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 the user to summarize speed data for each class of vehicle, providing that a statistically adequate number of vehicles from each class are sampled.

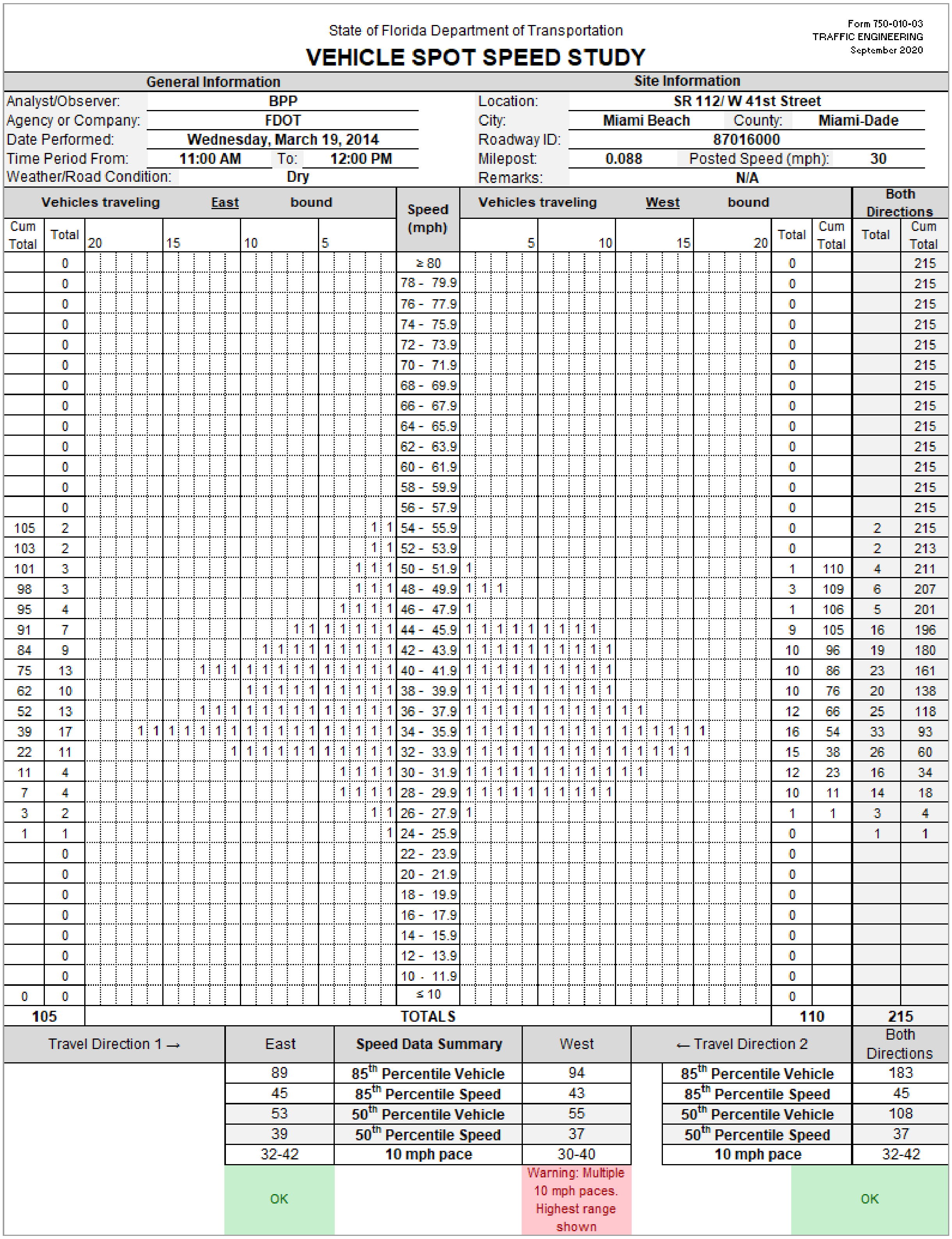
(10) The remainder of the study form computes the 50th and 85th percentile speed and 10 mph pace using the standard procedures identified in the ***Chapter 5 of the ITE Manual of Transportation Engineering Studies, 2nd Edition.***

(11) The user is referred to The Speed Zoning for Highways, Roads, and Streets in Florida for further details regarding speed data collection and analysis.

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 12-2. Vehicle Spot Speed Study - Option 1
(*Form No. 750-010-03*)



State of Florida Department of Transportation

Form 750-010-03
TRAFFIC ENGINEERING
September 2020

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**

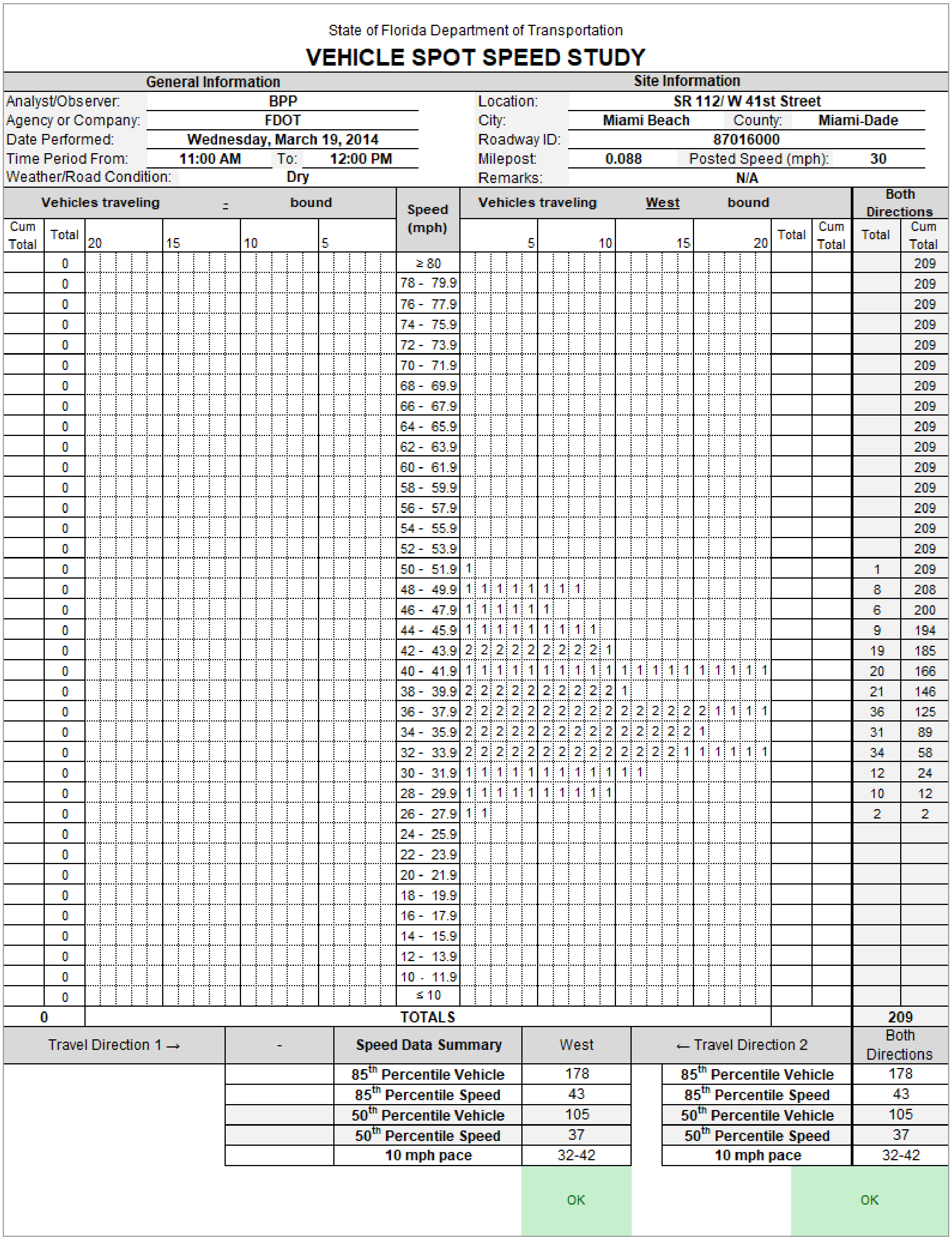
Site Information

Location: **SR 112/ W 41st Street**
City: **Miami Beach** County: **Miami-Dade**
Roadway ID: **87016000**
Milepost: **0.088** Posted Speed (mph): **30**
Remarks: **N/A**

Vehicles traveling **East** bound			Speed (mph)	Vehicles traveling **West** bound			Both Directions	
Cum Total	Total	20 15 10 5		5 10 15 20	Total	Cum Total	Total	Cum Total
	0		≥ 80		0			215
	0		78 - 79.9		0			215
	0		76 - 77.9		0			215
	0		74 - 75.9		0			215
	0		72 - 73.9		0			215
	0		70 - 71.9		0			215
	0		68 - 69.9		0			215
	0		66 - 67.9		0			215
	0		64 - 65.9		0			215
	0		62 - 63.9		0			215
	0		60 - 61.9		0			215
	0		58 - 59.9		0			215
	0		56 - 57.9		0			215
105	2	1 1	54 - 55.9		0		2	215
103	2	1 1	52 - 53.9		0		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		0		1	1
	0		22 - 23.9		0			
	0		20 - 21.9		0			
	0		18 - 19.9		0			
	0		16 - 17.9		0			
	0		14 - 15.9		0			
	0		12 - 13.9		0			
	0		10 - 11.9		0			
0	0		≤ 10		0			
105			**TOTALS**		**110**		**215**	

Travel Direction 1 →	East	Speed Data Summary	West	← Travel Direction 2	Both Directions
	89	85th Percentile Vehicle	94	85th Percentile Vehicle	183
	45	85th Percentile Speed	43	85th Percentile Speed	45
	53	50th Percentile Vehicle	55	50th Percentile Vehicle	108
	39	50th Percentile Speed	37	50th Percentile Speed	37
	32-42	10 mph pace	30-40	10 mph pace	32-42
	OK		Warning: Multiple 10 mph paces. Highest range shown		OK

Figure 12-3. Vehicle Spot Speed Study - Option 2
(*Form No. 750-010-03*)



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**

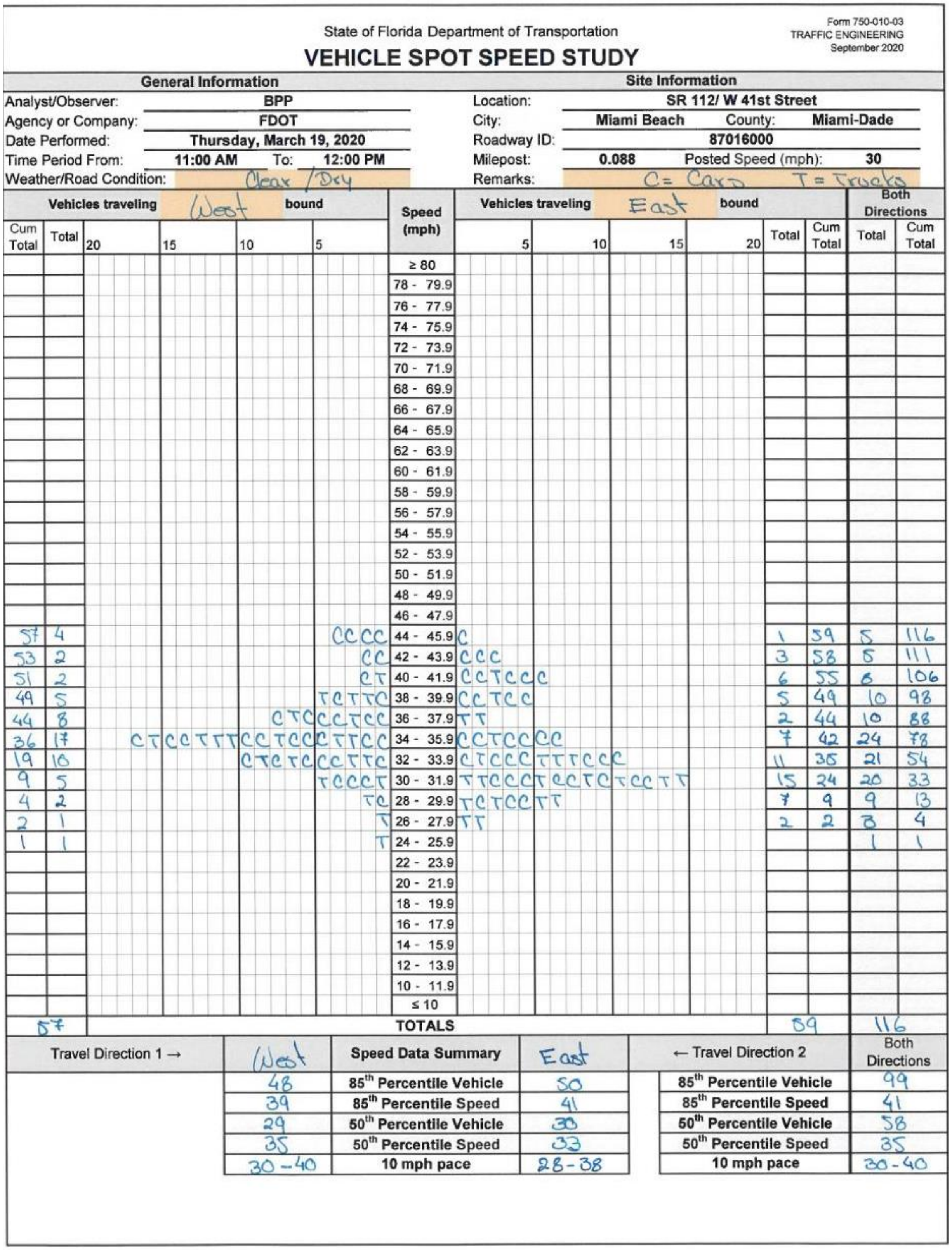
Site Information

Location: **SR 112/ W 41st Street**
City: **Miami Beach** County: **Miami-Dade**
Roadway ID: **87016000**
Milepost: **0.088** Posted Speed (mph): **30**
Remarks: **N/A**

Vehicles traveling - bound																						Speed (mph)	Vehicles traveling West bound																							Both Directions	
Cum Total	Total	20					15					10					5										5					10					15					20	Total	Cum Total	Total	Cum Total
	0																					≥ 80																								209
	0																					78 - 79.9																								209
	0																					76 - 77.9																								209
	0																					74 - 75.9																								209
	0																					72 - 73.9																								209
	0																					70 - 71.9																								209
	0																					68 - 69.9																								209
	0																					66 - 67.9																								209
	0																					64 - 65.9																								209
	0																					62 - 63.9																								209
	0																					60 - 61.9																								209
	0																					58 - 59.9																								209
	0																					56 - 57.9																								209
	0																					54 - 55.9																								209
	0																					52 - 53.9																								209
	0																					50 - 51.9	1																						1	209
	0																					48 - 49.9	1	1	1	1	1	1	1	1															8	208
	0																					46 - 47.9	1	1	1	1	1	1																	6	200
	0																					44 - 45.9	1	1	1	1	1	1	1	1	1														9	194
	0																					42 - 43.9	2	2	2	2	2	2	2	2	2	1													19	185
	0																					40 - 41.9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			20	166
	0																					38 - 39.9	2	2	2	2	2	2	2	2	2	2	1												21	146
	0																					36 - 37.9	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1			36	125
	0																					34 - 35.9	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1							31	89
	0																					32 - 33.9	2	2	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1			34	58
	0																					30 - 31.9	1	1	1	1	1	1	1	1	1	1	1	1											12	24
	0																					28 - 29.9	1	1	1	1	1	1	1	1	1	1													10	12
	0																					26 - 27.9	1	1																					2	2
	0																					24 - 25.9																								
	0																					22 - 23.9																								
	0																					20 - 21.9																								
	0																					18 - 19.9																								
	0																					16 - 17.9																								
	0																					14 - 15.9																								
	0																					12 - 13.9																								
	0																					10 - 11.9																								
	0																					≤ 10																								
0																						TOTALS																							209	

Travel Direction 1 →	-	Speed Data Summary	West	← Travel Direction 2	Both Directions
		85th Percentile Vehicle	178	**85th Percentile Vehicle**	178
		85th Percentile Speed	43	**85th Percentile Speed**	43
		50th Percentile Vehicle	105	**50th Percentile Vehicle**	105
		50th Percentile Speed	37	**50th Percentile Speed**	37
		10 mph pace	32-42	**10 mph pace**	32-42
			OK		OK

Figure 12-4. Vehicle Spot 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
September 2020

General Information

Analyst/Observer: BPP
Agency or Company: FDOT
Date Performed: Thursday, March 19, 2020
Time Period From: 11:00 AM To: 12:00 PM
Weather/Road Condition: Clear / Dry

Site Information

Location: SR 112/ W 41st Street
City: Miami Beach County: Miami-Dade
Roadway ID: 87016000
Milepost: 0.088 Posted Speed (mph): 30
Remarks: C= Cars T = Trucks

Cum Total	Total	Vehicles traveling West bound	Speed (mph)	Vehicles traveling East bound	Total	Cum Total	Both Directions Total	Both Directions Cum Total
		20 15 10 5		5 10 15 20				
			≥ 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					
57	4	CCCC	44 - 45.9	C	1	59	5	116
53	2	CC	42 - 43.9	CCC	3	58	5	111
51	2	CT	40 - 41.9	CCTCCC	6	55	8	106
49	5	TCTTC	38 - 39.9	CCTCC	5	49	10	98
44	8	CTCCCTCC	36 - 37.9	TT	2	44	10	88
36	17	CTCCTTTCCTCCCTTCC	34 - 35.9	CCTCCCC	7	42	24	78
19	10	CTCTCCCTTC	32 - 33.9	CTCCCTTTCCC	11	35	21	54
9	5	TCCCT	30 - 31.9	TTCCCTCCTCTCCTT	15	24	20	33
4	2	TC	28 - 29.9	TCTCCTT	7	9	9	13
2	1	T	26 - 27.9	TT	2	2	3	4
1	1	T	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					
57			TOTALS			59		116

Travel Direction 1 →	West	Speed Data Summary	East	← Travel Direction 2	Both Directions
	48	85th Percentile Vehicle	50	85th Percentile Vehicle	99
	39	85th Percentile Speed	41	85th Percentile Speed	41
	29	50th Percentile Vehicle	30	50th Percentile Vehicle	58
	35	50th Percentile Speed	33	50th Percentile Speed	35
	30 - 40	10 mph pace	28 - 38	10 mph pace	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 data.

(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

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 that is easily identifiable, e.g., power pole. The type and placement of control points should be as consistent as possible throughout the study corridor. 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**.**

Delay (D) - The additional travel time experienced by a user. For purposes of this chapter, delay is the length of time (in seconds) that a motorist is stopped—defined as a travel speed between 0 and 5 mph.

Distance - The length of a link or the length of a run (in feet).

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.

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:

$$RS = \frac{Distance}{TT - D}$$

Running time (RT) - The elapsed time (in seconds), excluding delay, spent driving a distance.

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.

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 one third of the target speed (***HCM 6th Edition, page 36-41***). As an example, if the target speed is 45 mph, additional stops will not be recorded until the vehicle accelerates past 15 mph.

Travel speed (TS) or average speed (AS) - The test vehicle's average speed (in miles per hour) over a distance.

Travel time (TT) - The total elapsed time (in seconds) spent driving a specified distance.

Trip length (TL) - The total corridor distance (in miles). It is the sum of the lengths of each segment (between one control point and the next).

13.3 STUDY PROCEDURES

(1) Test vehicle, vehicle observation, and probe data 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 abnormal 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) 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.

(2) 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).

(3) When conducting a ***Travel Time and Delay Study*** using the test vehicle method, there are three techniques that can be used:

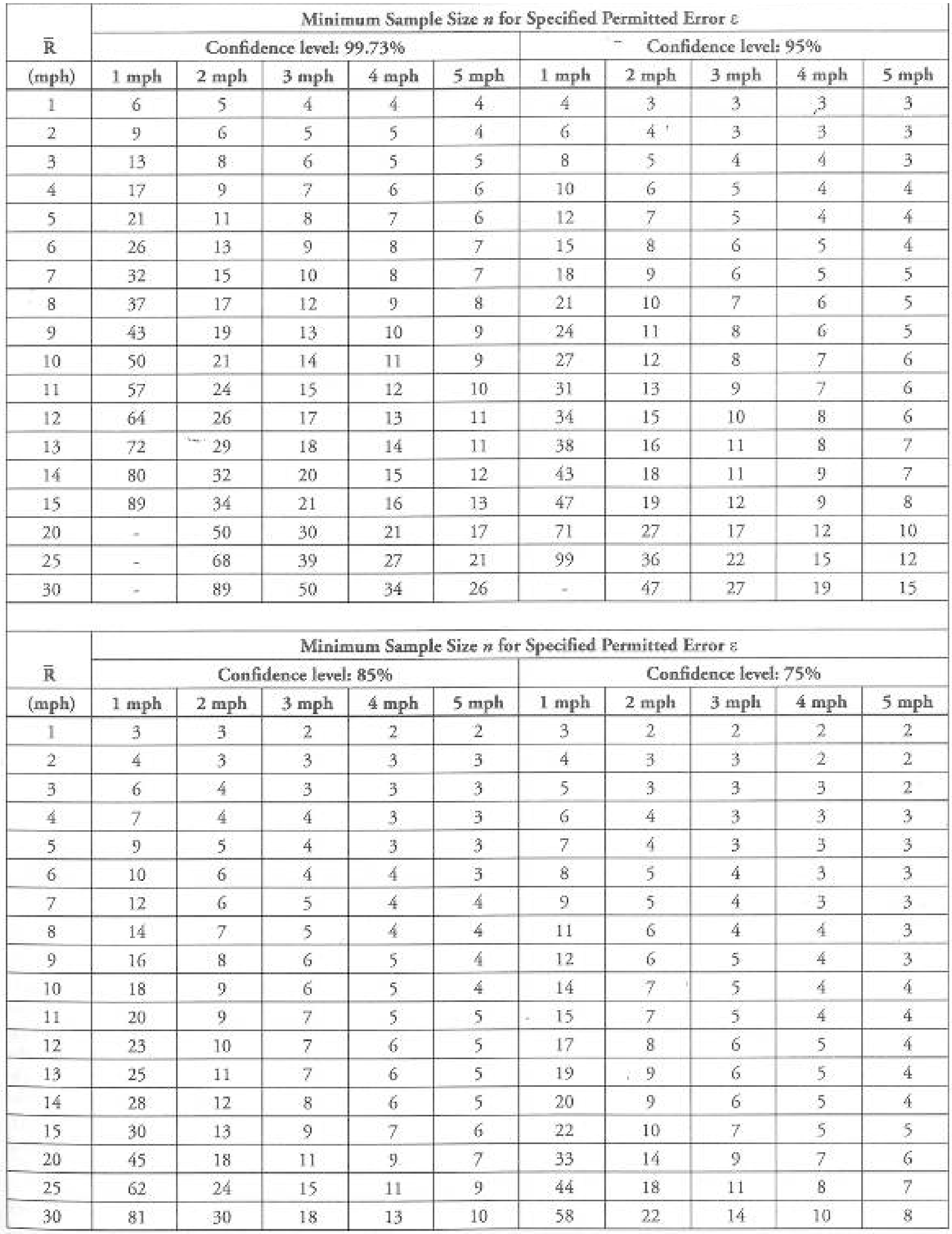
- **(a)** Average-Car: the speed of travel is determined by the driver's judgment of the average speed of the traffic stream.
- **(b)** Floating-Car: the driver floats with traffic by passing as many vehicles as pass the test car. The idea is to emulate the median driver for each section of roadway.
- **(c)** Maximum-Car: the speed of travel is the posted speed limit unless impeded by safety considerations or observed traffic conditions.

(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 confidence 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
(ITE Manual of Transportation Engineering Studies, 2nd Edition, Exhibit 9-1)



$\bar{R}$	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

(d) Using the difference in minimum and maximum running speeds $(\bar{R})$ and the desired permitted error $(\boldsymbol{\varepsilon})$ from ***Table 13-1***, again use ***Figure 13-1*** to determine the number of runs required. A sample size must 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.

Table 13-1. Suggested Ranges of Permitted Errors in the Estimate of the Mean Travel Speed Related to Study Purpose (ITE Manual of Transportation Engineering Studies, 2nd Edition, Exhibit 9-1)

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

(6) The approximate minimum sample size is selected from ***Figure 13-1*** for the calculated difference in minimum and maximum running speeds $(\bar{R})$ and the desired permitted error $(\boldsymbol{\varepsilon})$. 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. The representative lane should be consciously chosen by taking into consideration any prevailing queues, parking maneuvers, or transit stops in the corridor. If unknown, start with the second lane from median for roadways that have two lanes in the direction of travel and with the middle lane for roadways with three lanes in the direction of travel. The test vehicle driver may change lanes as necessary to meet the intent of the chosen test vehicle technique (see Section 13.3.1). 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 GPS system	

13.3.1.2 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) The program's outputs must then be reviewed and analyzed. If problem areas are identified, then the appropriate corrective action must be determined.

13.3.1.3 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. Completed form examples are 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:

Agency or **Company** - Name of the responsible agency or company of conducting study.

City - City where study is being conducted.

Control point - Describe each control point by intersection name or physical feature.

County - County where study is being conducted.

Date - Date of study.

Location - The cumulative distance of each control point from the begin control point.

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.

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).

Time period - Time period range for data collection.

Weather - General description of weather conditions during study.

(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.

Delay (D) - The time in seconds of delay experienced from one control point to the next.

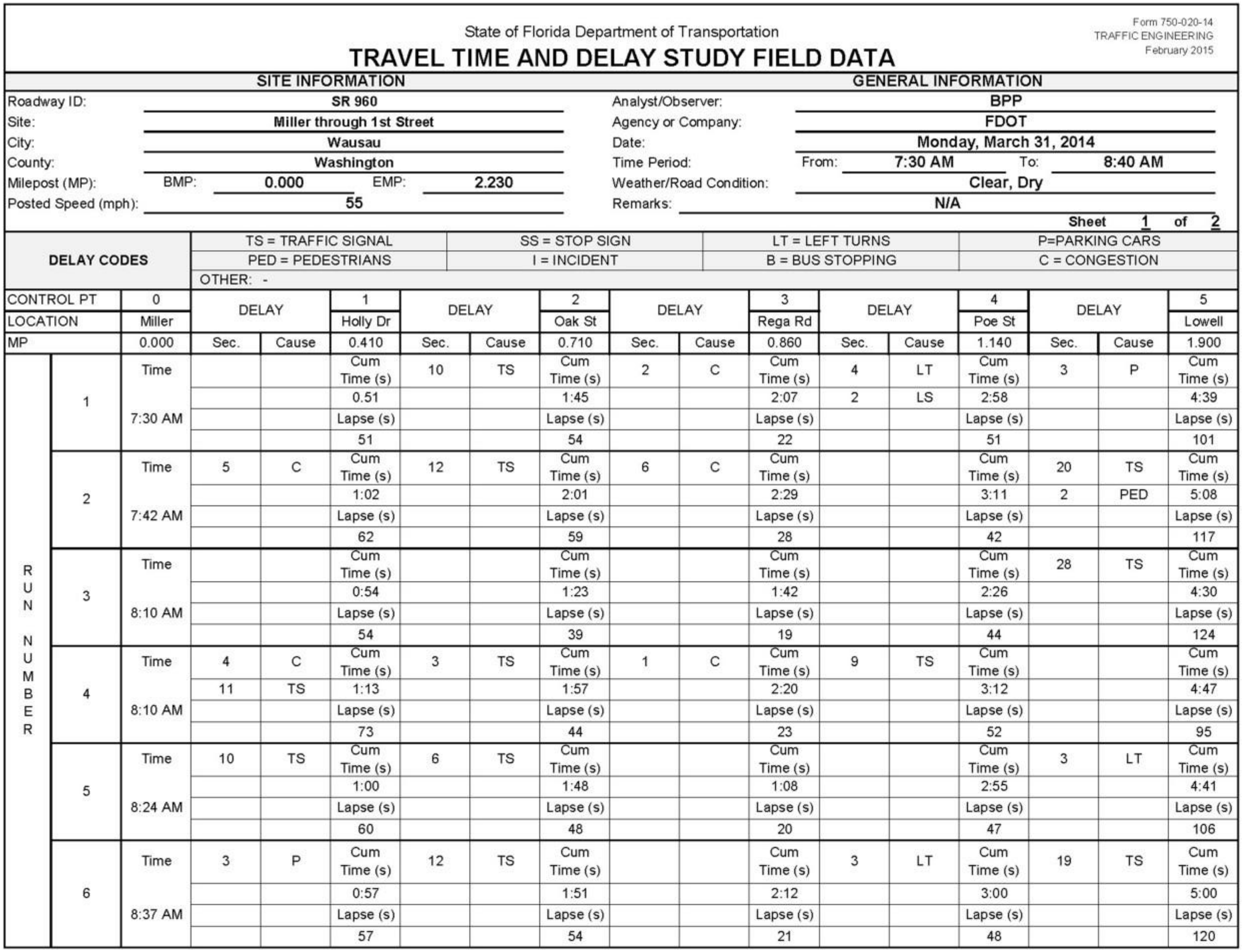
Miles (M) - Distance in miles from one control point to the next.

Running time (RT) - Total travel time minus total delay for each run.

Totals - The miles, travel time, and delay are summed vertically and written in the *Totals* area.

Travel Time (TT) -Time in seconds from one control point to the next.

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

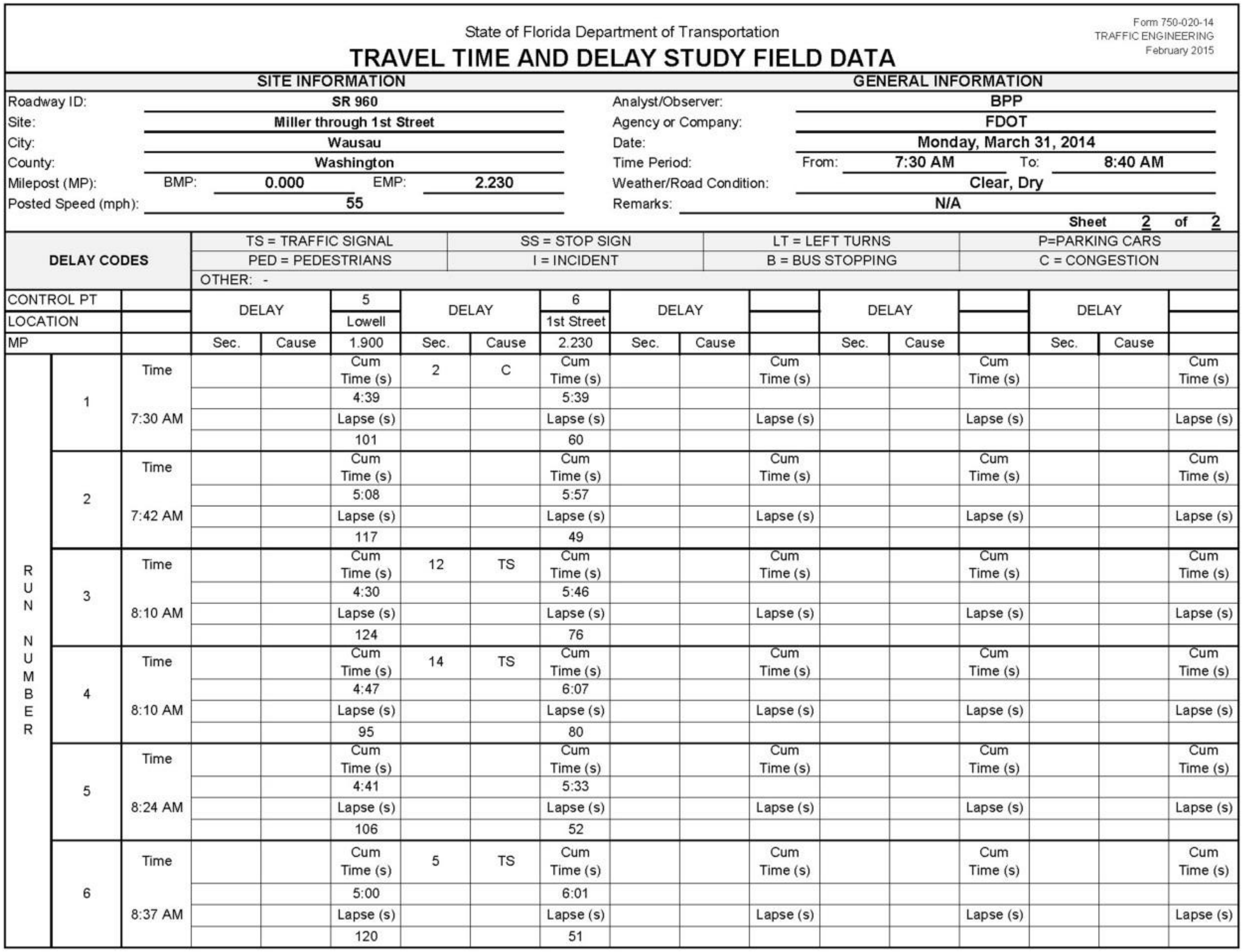
Analyst/Observer: **BPP**
Agency or Company: **FDOT**
Date: **Monday, March 31, 2014**
Time Period: From: **7:30 AM** To: **8:40 AM**
Weather/Road Condition: **Clear, Dry**
Remarks: **N/A**

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*)



State of Florida Department of Transportation

Form 750-020-14
TRAFFIC ENGINEERING
February 2015

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									

13.3.1.4 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)

$$Average\ Travel\ Time\ (ATT) = \frac{Sum\ of\ TT}{Total\ No.of\ Runs}$$

$$Average\ Travel\ Speed\ (ATS) = \frac{Segment\ Length\ (miles) \times 3600\ seconds\ per\ hour}{ATT}$$

$$Average\ Delay\ (AD) = \frac{Sum\ of\ Delay}{Total\ No.of\ Runs}$$

$$Average\ Running\ Time\ (ART) = ATT - AD$$

$$Average\ Running\ Speed\ (ARS) = \frac{Miles \times 3600\ seconds\ per\ hour}{ART}$$

(b) Calculated Route Averages (Bottom of Summary Sheet)

$$Total\ Trip\ Length\ (TTL)\ =\ Total\ distance\ between\ all\ control\ points\ (miles)$$

$$Total\ Travel\ Time\ (TTT) \\ =\ Sum\ of\ \ travel\ times\ between\ control\ points\ for\ an\ individual\ run$$

$$Average\ Total\ Travel\ Time\ (ATTT) = \frac{Sum\ of\ all\ TTT's}{Total\ No.of\ Runs} = Sum\ of\ ATT's$$

$$Average\ Total\ Travel\ Speed\ (ATTS) = \frac{TTL\ x\ 3600\ seconds\ per\ hour}{ATTT}$$

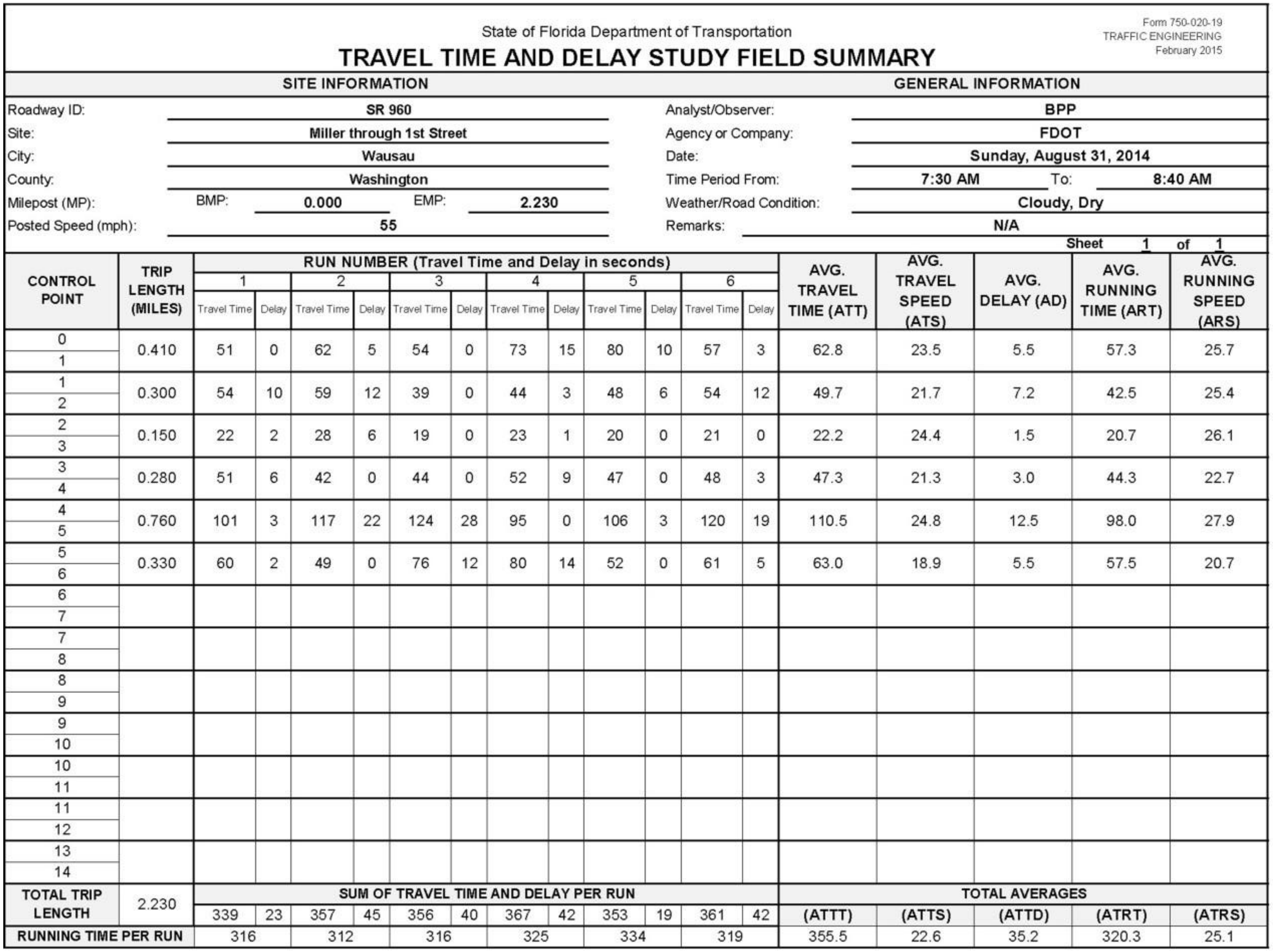
$$Average\ Total\ Trip\ Delay\ (ATTD) = \frac{Sum\ of\ Delay\ Totals}{Total\ No.of\ Runs} = Sum\ of\ AD's$$

$$Average\ Total\ Running\ Time\ (ATRT) = \frac{Sum\ of\ RT's}{Total\ No.of\ Runs} = Sum\ ART's$$

$$Average\ Total\ Running\ Speed\ (ATRS) = \frac{TTL\ x\ 3600\ seconds\ per\ hour}{ATRT}$$

(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 non-intrusively study the movements of individual vehicles.

(2) Two methods that have become more popular in recent years with the rise in telematics and mobile connectivity:

- **(a)** Wireless Technology Method

- **(b)** Cellular Telephone Observation Method

(3) The **Wireless Technology Method** uses time and position data from GPS-enabled vehicles operated by third parties (e.g., taxi fleets). This method may also be suitable for obtaining travel time and delay statistics for non-auto modes.

- **(a)** For example, transit agencies with automated vehicle location (AVL) technology can use the data to pinpoint locations contributing to delayed buses.

- **(b)** Similarly, GPS data from bikeshare and scootershare may be used to identify intersections with high crossing delays for these users.

(4) To apply the Wireless Technology Method, the analyst must first obtain a GPS dataset. Care should be taken to ensure that the dataset obtained reflects the mode being studied. These may be available from the agencies operating the mode being studied or from commercial vendors that collect and sell fleet data (e.g., INRIX). The minimum data collection period should be determined based on the volume of the roadway and the data source being used. ***Table 7-4*** in MUTS Chapter 7 contains guidance on the minimum number of weeks needed for wireless technology data collection.

(5) Once the dataset is obtained, the analyst should become familiar with its metadata. GPS datasets vary widely in their reporting frequencies, spatial accuracy, and sample size. Some datasets are already “snapped” to a roadway or transit route, while others are simply sets of timestamped latitude-longitude coordinates. Although the level of pre-processing and analysis will vary, the analyst should be able to compute most of the measures available from the test vehicle method.

(6) The **Cellular Telephone Observation Method** relies on collecting Bluetooth and/or Wi-Fi “addresses” from travelers passing by roadside readers. Mobile devices, including cell phones and wearable electronics, constantly broadcast their Bluetooth and Wi-Fi addresses (i.e., MAC addresses) to enable wireless connectivity with other devices, such as headsets or speakers. These broadcasted “pings” may be collected and archived by hardware available from vendors such as BlueMAC or BlueTOAD.

(7) To compute average travel time metrics, at least two readers are needed. In essence, the readers act as the special control points (SCP) at the beginning and end of each study segment. Additional readers may be used to increase the granularity of the dataset. Because there is no information on the movement of devices between the readers, care should be taken to filter out excessively long travel times. These are usually due to travelers making stops between reader locations (e.g., stops for gas or coffee).

(8) The penetration rate of Bluetooth devices is approximately 5%, which provides adequate sample sizes for volumes greater than 600 vehicles per hour. Readers able to capture Bluetooth Low Energy (BLE) devices—such as most wearable electronics and headsets—can see penetration rates in the 25-30% range, enabling estimates at volumes greater than 100 vehicles per hour. Actual capture rates vary by site. ***Table 7-4*** in MUTS Chapter 7 contains guidance on the minimum number of weeks needed for probe data collection.

(9) Other methods are explained in greater detail in the ITE Manual of Transportation Engineering Studies 2nd Edition, Chapter 9, Section 3.1.

  (a) License Plate Method

  (b) Interview Method

  (c) Extrapolation Method

  (d) Signpost-based Method

  (e) AVI Transponders

  (f) Ground-based Radio Navigation

13.3.3 Probe Data

(1) The **Probe Data** approach refers to the use of aggregated location data—usually from commercial vendors (e.g., INRIX, HERE, Google Maps, StreetLight Data, etc.). The probe data is aggregated to the link or zone level to protect user privacy.

(2) For roadways on the National Highway System (NHS), probe data may be obtained free of charge via the Federal Highway Administration's National Performance Measures Research Data Set (NPMRDS) program. The NPMRDS data consists of average travel times for short segments of roadway (i.e., Traffic Message Channels or TMCs) at a five-minute resolution.

(3) Because the probe data is already aggregated, detailed vehicle movement information (such as number of stops) is not readily available. However, the availability of end-to-end travel times at different times of days and days of week can be used to develop a general understanding of corridor travel speeds and delays as experienced by the motorist.

(4) When using probe data, the analyst should first filter the data to the study's scope. For example, if only midweek peak periods are of interest, data from other time periods should be excluded from the analysis.

(5) Obtaining the median travel time first—and then converting to travel speeds—helps reduce the effect of outliers and most closely reflects the space-mean speeds obtained via floating cars.

(6) If free-flow conditions are used to develop delay metrics, the analyst may use the 15th percentile travel time across the entire dataset (all times and days of week) or compute the median travel time within a time period when free-flow conditions are expected (e.g., midnight to 6 AM).

(7) The minimum data collection period should be determined based on the volume of the roadway and the data source being used. ***Table 7-4*** in MUTS Chapter 7 contains guidance on the minimum number of weeks needed for probe data collection.

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 the HSM 1st Edition ***- Part C*** and ***NCHRP 17-58***, Safety Prediction Models for Six, Seven and Eight-Lane and One-Way Urban and Suburban Arterials 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 August 2012 FHWA Lighting Handbook***, Section 4*** 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 FDM Part 2, Section 231.4, 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 ***FDM, Part 2, Section 213.11***, lighting is required at all roundabouts on the state highway system.

(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) Classification factors listed in ***Figure 14-1*** are defined as follows:

(a) **Geometric Factors** – Includes key geometric factors listed for the roadway's length to which the analysis is being applied. These include:

- Number of lanes
- Lane width
- Number of median openings per mile
- Driveways and entrances per mile
- Horizontal curve radius
- Vertical curve
- Sight distance
- Parking

The worst-case rating factors (R) given in ***Figure 14-1*** shall apply for the entire length of the road being considered. If there is significant variation in factors over the length of the road, the analyst may want to consider segmenting the analysis. The weighted value is very high for sharp horizontal curve radii even though it may only be a short section of the roadway length being considered.

(b) **Operational Factors** – Includes operational factors for the roadway's entire length to which the analysis is being applied. These include:

- Signalized Intersections – percentage is based upon intersections with full median access. The percentage ranges are included in ***Figure 14-1***.
- Left turn lanes - As a general guide, the following left turn lane

definitions may be applied. A major intersection is defined as an intersection with full access.

- All major intersections or one-way - Would typically be areas where left turn lanes are applied along the major roadway at all major intersections, One-way roadways also meet this definition.
- Substantial Number of Major Intersections - Would typically be areas where left turn lanes are applied at 76% to 99% of major intersection’s major roadway approaches,
- Most Major Intersections - Would typically be areas where left turn lanes are applied at 56% to 75% of major intersection’s major roadway approaches.
- Half of the intersections - Would typically be areas where left turn lanes are applied at 45% to 55% of major intersection’s major roadway approaches.
- Infrequent Number or TWLT - Would typically be areas where left turn lanes are applied at 44% or fewer of major intersection’s major roadway approaches. It also applies to roadways with two-way left turn (TWLT) lanes.

- Median width – The ranges are shown in ***Figure 14-1***.
- Operating or posted speed – Use 85^{th} percentile speed if available otherwise use posted speed.
- Pedestrian and bicycle activity (conflict) levels (ref to IESNA RP-8 for definition of high, medium, or low activity). This refers to the number of pedestrians and bicycles present in the roadway, either crossing or walking parallel to the roadway. These are:
  - High - > 100 pedestrians/bicyclists per hour
  - Moderate – 10 to 100 pedestrians/bicyclists per hour
  - Low - < 10 pedestrian/bicyclists per hour

The worst-case rating factors (R) shall apply for the entire length of the road being considered. If there is significant variation in factors over the length of the road, the analyst may want to consider segmenting the analysis. The weighted value is very high for pedestrian and bicycle activity level.

(c) **Environmental Factors** – Includes environmental factors for the roadway's entire length to which the analysis is being applied. These include:

- Percentage of development adjacent to the roadway. Adjacent development must be a reasonable distance from the roadway and must tie into the roadway for which the analysis is being undertaken via a driveway of intersection which generates a reasonable amount of traffic.

- Area classification

- Distance from development to roadway

- Ambient Lighting - Determining the amount of ambient lighting present is an area depends on the judgement of the individual performing the analysis. As a general guide, the following ambient lighting definitions may be applied.

    - *Sparse* – Would typically include rural freeways or highways with little or no development outside of city boundaries.

    - *Moderate* – Would typically include rural or urban roads with some building lighting and development outside of commercial areas. Areas with residential and industrial development will typically have moderate ambient lighting.

    - *Distracting* – Would typically be downtown commercial areas with well-lighted building exteriors adjacent to the roadway. Distracting lighting can also include that from fuel stations, automotive sales lots, and other commercial development where lighting is used to attract attention to businesses.

    - *Intense* – Would typically be areas with large advertising signs, sports lighting, and other intense light sources adjacent to the roadway. Intense sources can be found in both rural and urban areas.

- Raised median curb – As a general guide, the following raised curb median definitions may be applied. Raised curb median can be either curb and gutter such as Type E or F or concrete curb such as Type A or B.

- Continuous – Would typically be areas where raised curb median is applied at all intersections, median openings, and the segment between intersections/median openings.
- At All Intersections (100%) – Would typically be areas where raised curb median is applied at all intersections and median openings but not the segment between intersections/median openings.
- At Most Intersections (51% to 99%) - Would typically be areas where raised curb median is applied at most intersections and median openings (51% to 99%) but not the segment between intersections/median openings.
- At Few Intersections (<51%) - Would typically be areas where raised curb median is applied at few intersections and median openings (<51%) but not the segment between intersections/median openings.

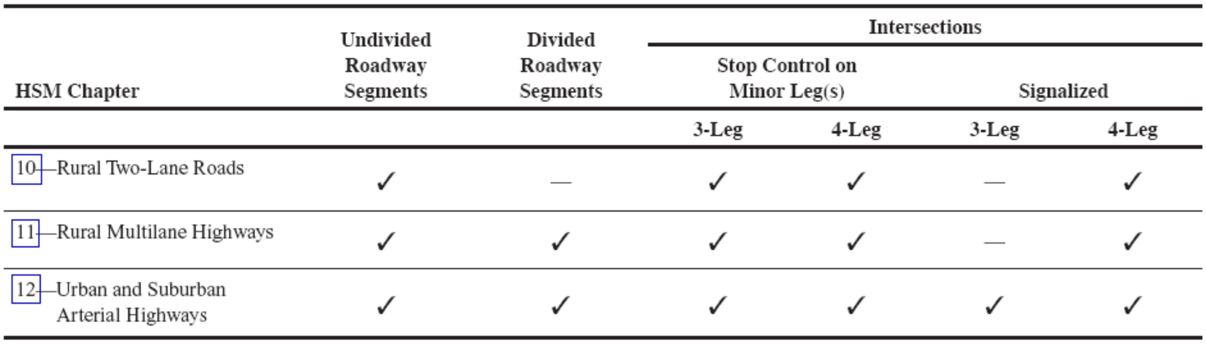
The worst-case rating factors (R) shall apply for the entire length of the road being considered. The weighted value is very high for ambient lighting.

(d) **Collision Factors** – If the night-to-day crash ratio is 2:1 or greater, lighting is automatically warranted regardless of the overall point score. Crashes reported as dawn or dusk should be considered as night crashes.

(4) 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. Currently, crash reduction due to lighting can be predicted for rural two-lane roadways, rural multi-lane roadways up to four through lanes, urban/suburban arterials up to eight through-lanes and one-way streets. The urban/suburban arterials analysis can also be conducted for five and seven 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 14-1***.

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 ***HSM Part D, Section 13.13*** should be applied. Should the FHWA CMF Clearinghouse be used, only CMFs having four or five stars are acceptable.

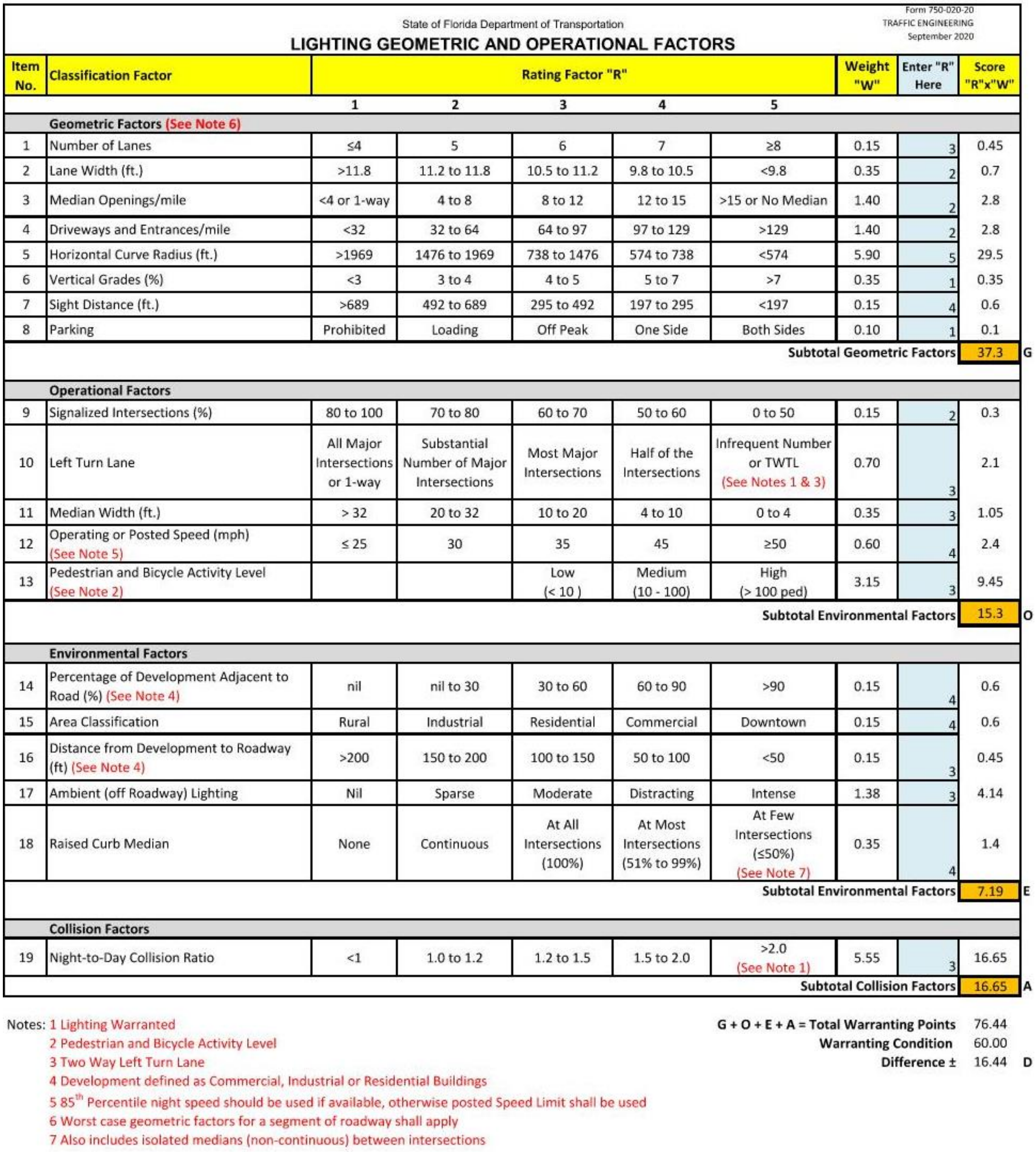
Table 14-1. Facility Types and Site Types Included in the HSM Predictive Method (*HSM, 2010, Table 3-2*)



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	✓	✓	✓	✓	✓	✓

(5) The difference in crash frequency can then be converted to dollars using FDOT crash costs provided in FDM, Section 122.6. Data needs and additional details for applying the HSM Predictive Method are provided in MUTS Chapter 5 for surface streets. After reviewing MUTS 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
September 2020

State of Florida Department of Transportation

LIGHTING GEOMETRIC AND OPERATIONAL FACTORS

Item No.	Classification Factor	Rating Factor "R"					Weight "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 and Bicycle Activity Level (See Note 2)			Low (< 10)	Medium (10 - 100)	High (> 100 ped)	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	3	0.45	
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	7.19	**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**

G + O + E + A = Total Warranting Points	76.44	
Warranting Condition	60.00	
Difference ±	16.44	**D**

Notes: 1 Lighting Warranted
2 Pedestrian and Bicycle 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

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 crash cost reduction resulting from adding lighting 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. First the existing roadway is analyzed with lighting and using actual crash data. This analysis is done using the Empirical Bayes method *(**Highway Safety Manual, Section C.6.6**)* to obtain an expected crash value. The without lighting analysis is then done by using the expected crash value and changing the lighting crash modification factor (CMF) to be no lighting.

(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 using HSM methodology 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. The user should note there are two separate spreadsheets. One supports HSM 1 crash prediction methodologies and is also known as the ***NCHRP 17-38*** spreadsheets for 2 through 5 lanes. The second is newer based upon ***NCHRP 17-58*** research for 6, 7 and 8 lane roadways and one-way streets. These spreadsheets calculate life cycle crash costs with and without lighting. NPV computations can be conducted using a six-step process, outlined as follows:

- **(a)** Step 1: Identify or compute crash frequencies for NO LIGHTING CONDITIONS
- **(b)** Step 2: Quantify monetary cost of crashes for NO LIGHTING CONDITIONS

(c) Step 3: Identify or compute crash frequencies for LIGHTED CONDITIONS

(d) Step 4: Quantify monetary cost of crashes for LIGHTED CONDITIONS

(e) Step 5: Compute difference: BENEFIT = Monetary cost of crashes for NO LIGHTING CONDITIONS – Monetary cost of crashes for LIGHTED CONDITIONS

(f) 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 each year in the project's design life. 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 the MUTS Chapter 5. Crashes are distributed by severity using the default severity distributions found in FDM Table 122.6.4, HSM Crash Distribution for Florida. The table below illustrates a $N_{predicted}$ value being the predicted number of crashes computed using the HSM Predictive Method. When crash data is available, the Empirical Bayes method ***(HSM, Section C.6.6)***. should be conducted and $N_{expected}$ should be applied to the distribution. This value is then distributed by severity per the KABCO scale using HSM default severity distribution values in FDM Table 122.6.4.

Year	AADT	TOTAL	K	A	B	C	O
		$N_{predicted}$ (crashes/year)	Fatal	Inc. Injury	Non Inc. Injury	Pos. Injury	PDO
2018	17300	3.15	0.025	0.144	0.447	0.737	1.799
2019	17676	3.22	0.026	0.148	0.457	0.754	1.839

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 FDM Table 122.6.2, FDOT KABCO Crash Costs and shown in the table below. The following tables below illustrate the computation for two years of data, 2018 and 2019 on a 4-lane divided urban and suburban arterial. This process is repeated for each year in the design life of the project.

Crash Severity	Comprehensive Crash Cost
Fatal (K)	$10,670,000
Severe Injury (A)	$872,612
Moderate Injury (B)	$174,018
Minor Injury (C)	$106,215
Property Damage Only (O)	$7,700

Year		**K**	**A**	**B**	**C**	**O**	**TOTAL**
		Fatal	**Inc. Injury**	**Non Inc. Injury**	**Pos. Injury**	**PDO**	**$N_{predicted}$ (crashes/ year)**
2018	Crashes	0.025	0.144	0.447	0.737	1.799	3.15
	Cost per Crash Type	$10,670,000	$872,612	$174,018	$106,215	$7,700	
	Total Cost per Crash Type	$266,750	$125,656	$77,786	$78,280	$13,582	
	Total Cost for 2018	**$562,324**					

Year		**K**	**A**	**B**	**C**	**O**	**TOTAL**
		Fatal	**Inc. Injury**	**Non Inc. Injury**	**Pos. Injury**	**PDO**	**$N_{predicted}$ (crashes/ year)**
2019	Crashes	0.026	0.148	0.457	0.754	1.839	3.22
	Cost per Crash Type	$10,670,000	$872,612	$174,018	$106,215	$7,700	
	Total Cost per Crash Type	$277,420	$129,147	$79,526	$80,086	$14,160	
	Total Cost for 2019	**$580,339**					

↓

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 FDM Section 122.6.

$$Present\ worth = \frac{Final\ Value}{(1+0.04)^{years}}$$

$$For\ 2019\ Present\ Worth = \frac{\$580{,}339}{(1+0.04)^2} = \$536{,}556$$

Year	AADT	$N_{predicted}$ (crashes/year)	Total Cost	Present Worth of Cost
2018	17300	3.15	$562,324	$562,324
2019	17676	3.22	$580,339	$536,556
Total Present Worth of Cost				$1,098,880

(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	$1,098,880
BUILD	$702,000
Savings for LIGHTED conditions	$396,880

(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 $146,880.

(4) Examples of ***Present Worth Analysis for Rural-Two Lane Road*** (Form 750-020-21a), ***Present Worth Analysis for Rural-Multilane Road*** (Form 750-020-21b), ***Present Worth Analysis for Urban/Suburban Arterial (2 to 5 Lanes)*** (Form 750-020-21c), and ***Present Worth Analysis for Urban and Suburban Arterials (6 to 8 Lanes and One-Way Streets)*** (Form 750-020-21d) completed spreadsheets providing crash cost calculations are shown in ***Figure 14-2***, ***Figure 14-3, Figure 14-4***, and ***Figure 14-5,*** respectively.

Figure 14-2. Rural Two-Lane Road Example
(*Form No. 750-020-21a*)

Form 750-020-21a
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

Present Worth Analysis
Rural Two Lane Road
Build Alternative

General Information

Analyst: BPP
Date: 3/9/2020
Agency or Company: FDOT

Site Information

Location ID: N/A
County: Miami-Dade
City: Homestead
M.P. - M.P. 3.258 - 5.258

Manual Input from Analysis

Growth Rate = 1.0%
Current Year AADT = 16,000
Segment Length = 2
Current Year = 2020
Rate of Return = 4.0%
Segment = Segment1
Crash Data Used = Yes
roject Opening Year = 2022
Analysis Period = 10
P
1.968843

Default Distribution for Crash Severity Level (2010-2014 Florida HSM Crash Distribution)

Fatality = 3.2%
Incapacitating = 11.6%
Non-Incapacitating = 19.6%
Possible Injury = 19.5%
Property Damage Only = 46.1%
100.0%

			Annual Number of Crashes						Annual Cost						
	Year		Site Specific ($N_{predicted / expected}$)	Fatality	Incap.	Non-Inc.	Possible Injury	PDO	Fatality	Incap.	Non-Inc.	Possible Injury	PDO	Total Cost	Present Value
	2020	16,000		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0
	2021	16,160		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0
1	2022	16,322	17.0	0.545	1.976	3.339	3.322	7.853	$5,576,624	$1,146,757	$524,773	$324,379	$59,684	$7,632,217	$7,338,670
2	2023	16,485	17.2	0.551	1.996	3.372	3.355	7.932	$5,632,390	$1,158,224	$530,021	$327,623	$60,281	$7,708,539	$7,126,977
3	2024	16,650	17.4	0.556	2.016	3.406	3.389	8.011	$5,688,714	$1,169,806	$535,321	$330,899	$60,884	$7,785,624	$6,921,392
4	2025	16,816	17.6	0.562	2.036	3.440	3.423	8.091	$5,745,601	$1,181,505	$540,674	$334,208	$61,493	$7,863,480	$6,721,736
5	2026	16,984	17.7	0.567	2.056	3.474	3.457	8.172	$5,803,057	$1,193,320	$546,081	$337,550	$62,108	$7,942,115	$6,527,840
6	2027	17,154	17.9	0.573	2.077	3.509	3.491	8.254	$5,861,088	$1,205,253	$551,542	$340,925	$62,729	$8,021,536	$6,339,537
7	2028	17,326	18.1	0.579	2.098	3.544	3.526	8.336	$5,919,699	$1,217,305	$557,057	$344,335	$63,356	$8,101,752	$6,156,666
8	2029	17,499	18.3	0.584	2.119	3.580	3.561	8.420	$5,978,896	$1,229,478	$562,628	$347,778	$63,990	$8,182,769	$5,979,069
9	2030	17,674	18.4	0.590	2.140	3.616	3.597	8.504	$6,038,685	$1,241,773	$568,254	$351,256	$64,630	$8,264,597	$5,806,596
10	2031	17,851	18.6	0.596	2.161	3.652	3.633	8.589	$6,099,071	$1,254,191	$573,936	$354,768	$65,276	$8,347,243	$5,639,098
	2032	18,029		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0
	2033	18,209		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0
	2034	18,392		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0

Shaded cell indicates the AADT is outside the limits

Total Present Value **$64,557,581**

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] x 100

where ADT$_f$ = Average Daily Traffic for Future Year

ADT$_i$ = Average Daily Traffic for Initial Year

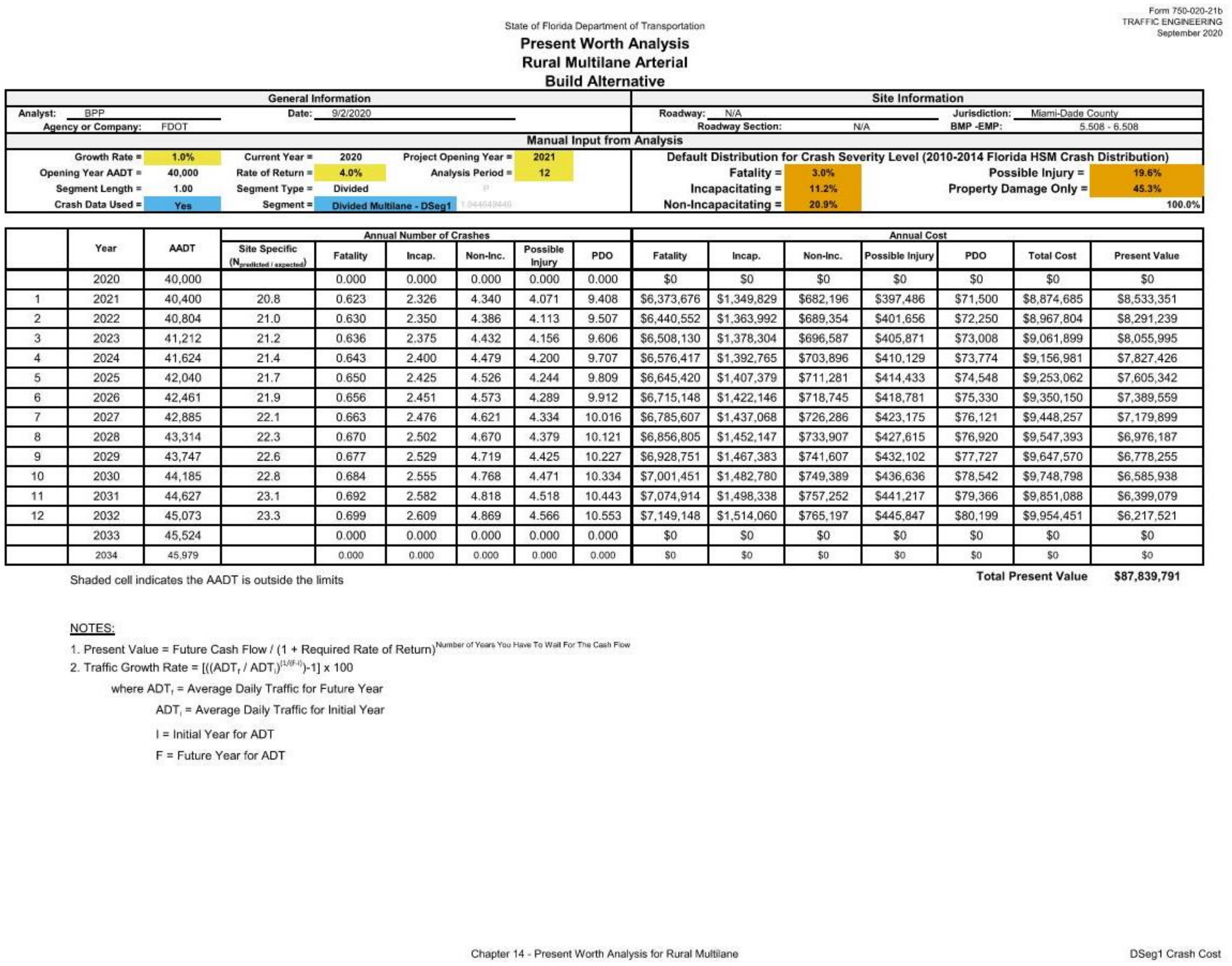
I = Initial Year for ADT

F = Future Year for ADT

Chapter 14 - Present Worth Analysis for Rural Two Lane Roads

Segment1 Crash Cost

Figure 14-3. Rural-Multilane Road Example
(Form No. 750-020-21b)



Form 750-020-21b
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation
Present Worth Analysis
Rural Multilane Arterial
Build Alternative

General Information

Analyst: BPP
Date: 9/2/2020
Agency or Company: FDOT

Site Information

Roadway: N/A
Jurisdiction: Miami-Dade County
Roadway Section: N/A
BMP -EMP: 5.508 - 6.508

Manual Input from Analysis

Growth Rate = 1.0%
Opening Year AADT = 40,000
Segment Length = 1.00
Crash Data Used = Yes
Current Year = 2020
Rate of Return = 4.0%
Segment Type = Divided
Segment = Divided Multilane - DSeg1
Project Opening Year = 2021
Analysis Period = 12

Default Distribution for Crash Severity Level (2010-2014 Florida HSM Crash Distribution)

Fatality = 3.0%
Incapacitating = 11.2%
Non-Incapacitating = 20.9%
Possible Injury = 19.6%
Property Damage Only = 45.3%
100.0%

			Annual Number of Crashes						Annual Cost						
	Year	**AADT**	**Site Specific ($N_{predicted\ /\ expected}$)**	**Fatality**	**Incap.**	**Non-Inc.**	**Possible Injury**	**PDO**	**Fatality**	**Incap.**	**Non-Inc.**	**Possible Injury**	**PDO**	**Total Cost**	**Present Value**
	2020	40,000		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0
1	2021	40,400	20.8	0.623	2.326	4.340	4.071	9.408	$6,373,676	$1,349,829	$682,196	$397,486	$71,500	$8,874,685	$8,533,351
2	2022	40,804	21.0	0.630	2.350	4.386	4.113	9.507	$6,440,552	$1,363,992	$689,354	$401,656	$72,250	$8,967,804	$8,291,239
3	2023	41,212	21.2	0.636	2.375	4.432	4.156	9.606	$6,508,130	$1,378,304	$696,587	$405,871	$73,008	$9,061,899	$8,055,995
4	2024	41,624	21.4	0.643	2.400	4.479	4.200	9.707	$6,576,417	$1,392,765	$703,896	$410,129	$73,774	$9,156,981	$7,827,426
5	2025	42,040	21.7	0.650	2.425	4.526	4.244	9.809	$6,645,420	$1,407,379	$711,281	$414,433	$74,548	$9,253,062	$7,605,342
6	2026	42,461	21.9	0.656	2.451	4.573	4.289	9.912	$6,715,148	$1,422,146	$718,745	$418,781	$75,330	$9,350,150	$7,389,559
7	2027	42,885	22.1	0.663	2.476	4.621	4.334	10.016	$6,785,607	$1,437,068	$726,286	$423,175	$76,121	$9,448,257	$7,179,899
8	2028	43,314	22.3	0.670	2.502	4.670	4.379	10.121	$6,856,805	$1,452,147	$733,907	$427,615	$76,920	$9,547,393	$6,976,187
9	2029	43,747	22.6	0.677	2.529	4.719	4.425	10.227	$6,928,751	$1,467,383	$741,607	$432,102	$77,727	$9,647,570	$6,778,255
10	2030	44,185	22.8	0.684	2.555	4.768	4.471	10.334	$7,001,451	$1,482,780	$749,389	$436,636	$78,542	$9,748,798	$6,585,938
11	2031	44,627	23.1	0.692	2.582	4.818	4.518	10.443	$7,074,914	$1,498,338	$757,252	$441,217	$79,366	$9,851,088	$6,399,079
12	2032	45,073	23.3	0.699	2.609	4.869	4.566	10.553	$7,149,148	$1,514,060	$765,197	$445,847	$80,199	$9,954,451	$6,217,521
	2033	45,524		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0
	2034	45,979		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0

Total Present Value **$87,839,791**

Shaded cell indicates the AADT is outside the limits

NOTES:

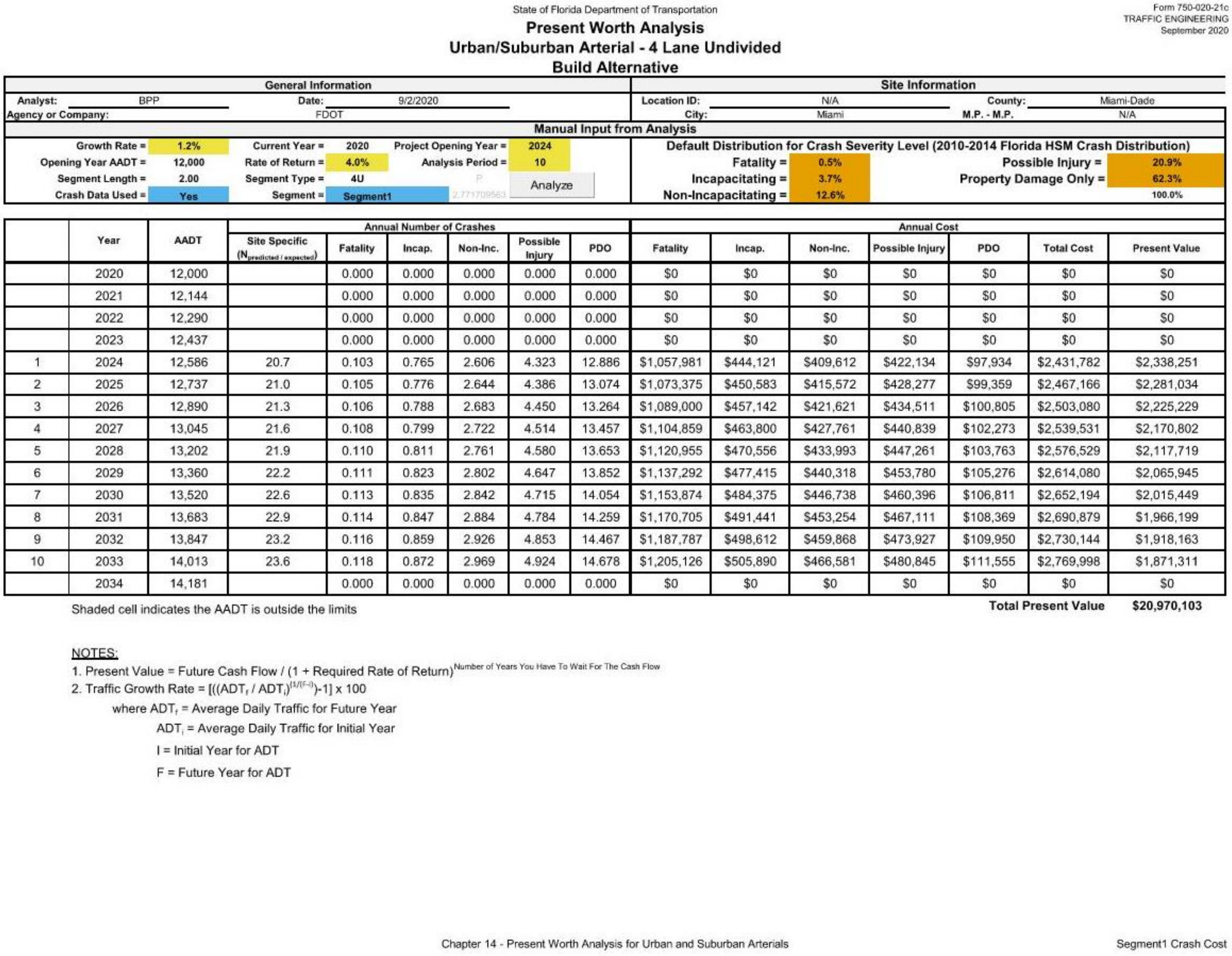
1. Present Value = Future Cash Flow / (1 + Required Rate of Return)$^{\text{Number of Years You Have To Wait For The Cash Flow}}$
2. Traffic Growth Rate = $[((ADT_f / ADT_i)^{(1/(F-I))})-1] \times 100$

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

Chapter 14 - Present Worth Analysis for Rural Multilane

DSeg1 Crash Cost

Figure 14-4. Urban/Suburban Arterial (2 to 5 Lanes) Example (Form No. 750-020-21c)



Form 750-020-21c
TRAFFIC ENGINEERING
September 2020

State of Florida Department of Transportation

Present Worth Analysis
Urban/Suburban Arterial - 4 Lane Undivided
Build Alternative

General Information

Analyst: BPP
Date: 9/2/2020
Agency or Company: FDOT

Site Information

Location ID: N/A
County: Miami-Dade
City: Miami
M.P. - M.P. N/A

Manual Input from Analysis

Growth Rate = 1.2%
Opening Year AADT = 12,000
Segment Length = 2.00
Crash Data Used = Yes
Current Year = 2020
Rate of Return = 4.0%
Segment Type = 4U
Segment = Segment1
Project Opening Year = 2024
Analysis Period = 10
P
2.771709563
Analyze

Default Distribution for Crash Severity Level (2010-2014 Florida HSM Crash Distribution)

Fatality = 0.5%
Incapacitating = 3.7%
Non-Incapacitating = 12.6%
Possible Injury = 20.9%
Property Damage Only = 62.3%
100.0%

			Annual Number of Crashes						Annual Cost							
	Year	AADT	Site Specific ($N_{predicted / expected}$)	Fatality	Incap.	Non-Inc.	Possible Injury	PDO	Fatality	Incap.	Non-Inc.	Possible Injury	PDO	Total Cost	Present Value
	2020	12,000		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0
	2021	12,144		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0
	2022	12,290		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0
	2023	12,437		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0
1	2024	12,586	20.7	0.103	0.765	2.606	4.323	12.886	$1,057,981	$444,121	$409,612	$422,134	$97,934	$2,431,782	$2,338,251
2	2025	12,737	21.0	0.105	0.776	2.644	4.386	13.074	$1,073,375	$450,583	$415,572	$428,277	$99,359	$2,467,166	$2,281,034
3	2026	12,890	21.3	0.106	0.788	2.683	4.450	13.264	$1,089,000	$457,142	$421,621	$434,511	$100,805	$2,503,080	$2,225,229
4	2027	13,045	21.6	0.108	0.799	2.722	4.514	13.457	$1,104,859	$463,800	$427,761	$440,839	$102,273	$2,539,531	$2,170,802
5	2028	13,202	21.9	0.110	0.811	2.761	4.580	13.653	$1,120,955	$470,556	$433,993	$447,261	$103,763	$2,576,529	$2,117,719
6	2029	13,360	22.2	0.111	0.823	2.802	4.647	13.852	$1,137,292	$477,415	$440,318	$453,780	$105,276	$2,614,080	$2,065,945
7	2030	13,520	22.6	0.113	0.835	2.842	4.715	14.054	$1,153,874	$484,375	$446,738	$460,396	$106,811	$2,652,194	$2,015,449
8	2031	13,683	22.9	0.114	0.847	2.884	4.784	14.259	$1,170,705	$491,441	$453,254	$467,111	$108,369	$2,690,879	$1,966,199
9	2032	13,847	23.2	0.116	0.859	2.926	4.853	14.467	$1,187,787	$498,612	$459,868	$473,927	$109,950	$2,730,144	$1,918,163
10	2033	14,013	23.6	0.118	0.872	2.969	4.924	14.678	$1,205,126	$505,890	$466,581	$480,845	$111,555	$2,769,998	$1,871,311
	2034	14,181		0.000	0.000	0.000	0.000	0.000	$0	$0	$0	$0	$0	$0	$0

Shaded cell indicates the AADT is outside the limits

Total Present Value **$20,970,103**

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

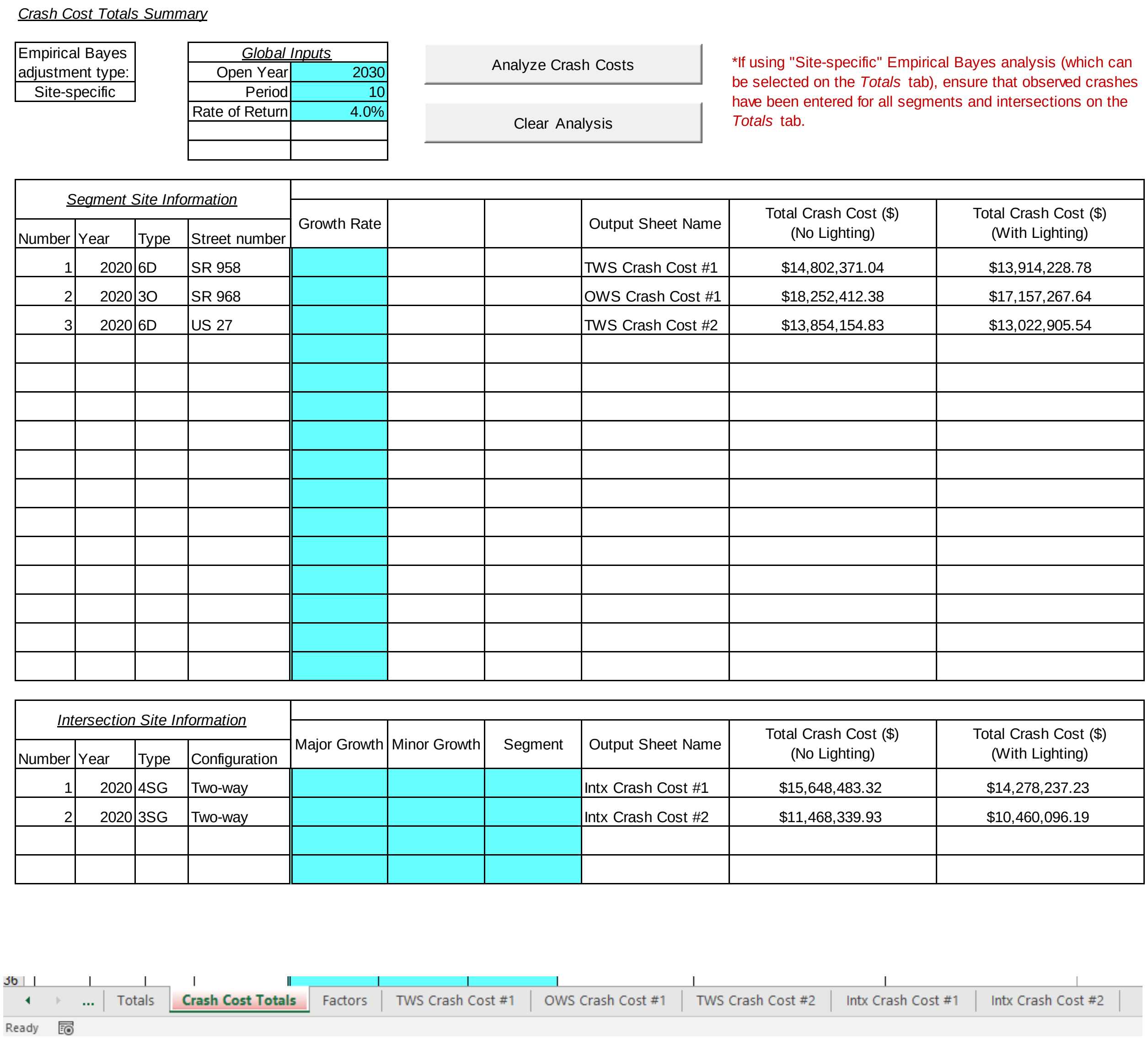
I = Initial Year for ADT

F = Future Year for ADT

Chapter 14 - Present Worth Analysis for Urban and Suburban Arterials

Segment1 Crash Cost

Figure 14-5. Urban/Suburban Arterial (6 to 8 Lanes and One-Way Streets) Example (Form No. 750-020-21d)



Crash Cost Totals Summary

Empirical Bayes adjustment type:
Site-specific

Global Inputs	
Open Year	2030
Period	10
Rate of Return	4.0%

*If using "Site-specific" Empirical Bayes analysis (which can be selected on the *Totals* tab), ensure that observed crashes have been entered for all segments and intersections on the *Totals* tab.

Segment Site Information									
Number	Year	Type	Street number	Growth Rate			Output Sheet Name	Total Crash Cost ($) (No Lighting)	Total Crash Cost ($) (With Lighting)
1	2020	6D	SR 958				TWS Crash Cost #1	$14,802,371.04	$13,914,228.78
2	2020	3O	SR 968				OWS Crash Cost #1	$18,252,412.38	$17,157,267.64
3	2020	6D	US 27				TWS Crash Cost #2	$13,854,154.83	$13,022,905.54

Intersection Site Information									
Number	Year	Type	Configuration	Major Growth	Minor Growth	Segment	Output Sheet Name	Total Crash Cost ($) (No Lighting)	Total Crash Cost ($) (With Lighting)
1	2020	4SG	Two-way				Intx Crash Cost #1	$15,648,483.32	$14,278,237.23
2	2020	3SG	Two-way				Intx Crash Cost #2	$11,468,339.93	$10,460,096.19

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 FDM, Section 122.6.1. 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 FDM, Section 122.6.1. 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.

$$Present\ Worth\ of\ Cost\ LIGHTED = N_{lighted} * CC$$

(e) **Step 5:** Compute the difference in cost between lighted and unlighted conditions.

$$\begin{aligned} Cost\ Difference \\ &= Present\ Worth\ of\ Cost\ UNLIGHTED \\ &- Present\ Worth\ of\ Cost\ LIGHTED \end{aligned}$$

(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 Section 122.6 of FDM)

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 HSM or the CMF Clearinghouse.

14.4 DETERMINING OPERATIONAL STATUS OF EXISTING LIGHTING: FREEWAYS

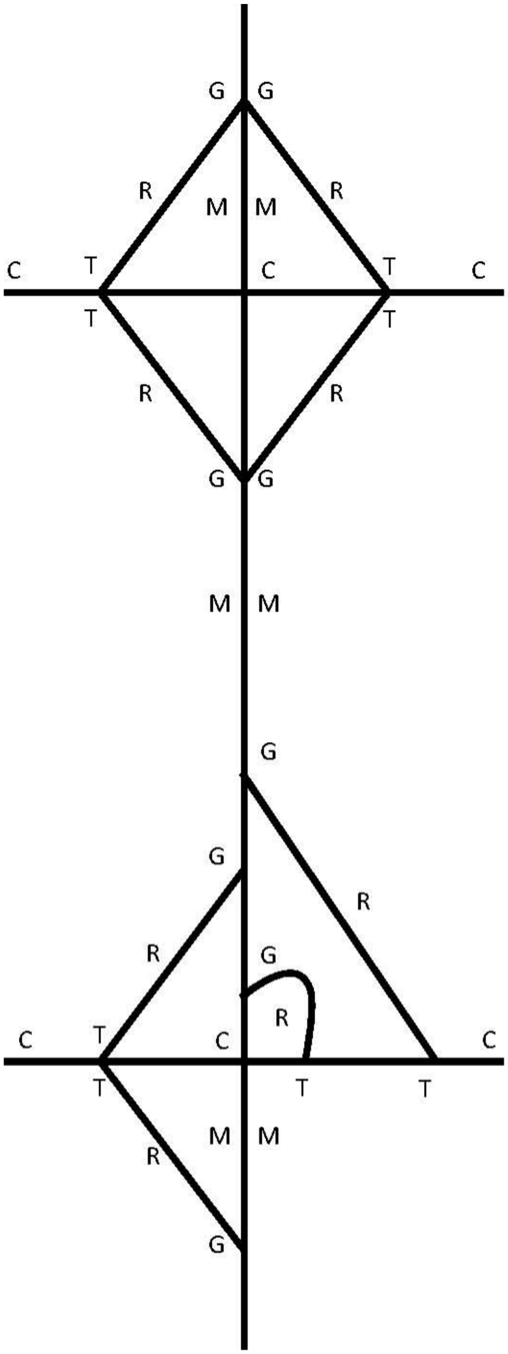
(1) Existing highway lighting systems are subject to various causes of electrical or mechanical malfunction. Pole knockdowns, lightning strikes, damaged circuits, blown fuses, burned-out bulbs, and other causes result in an operational status almost always less than 100 percent.

(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

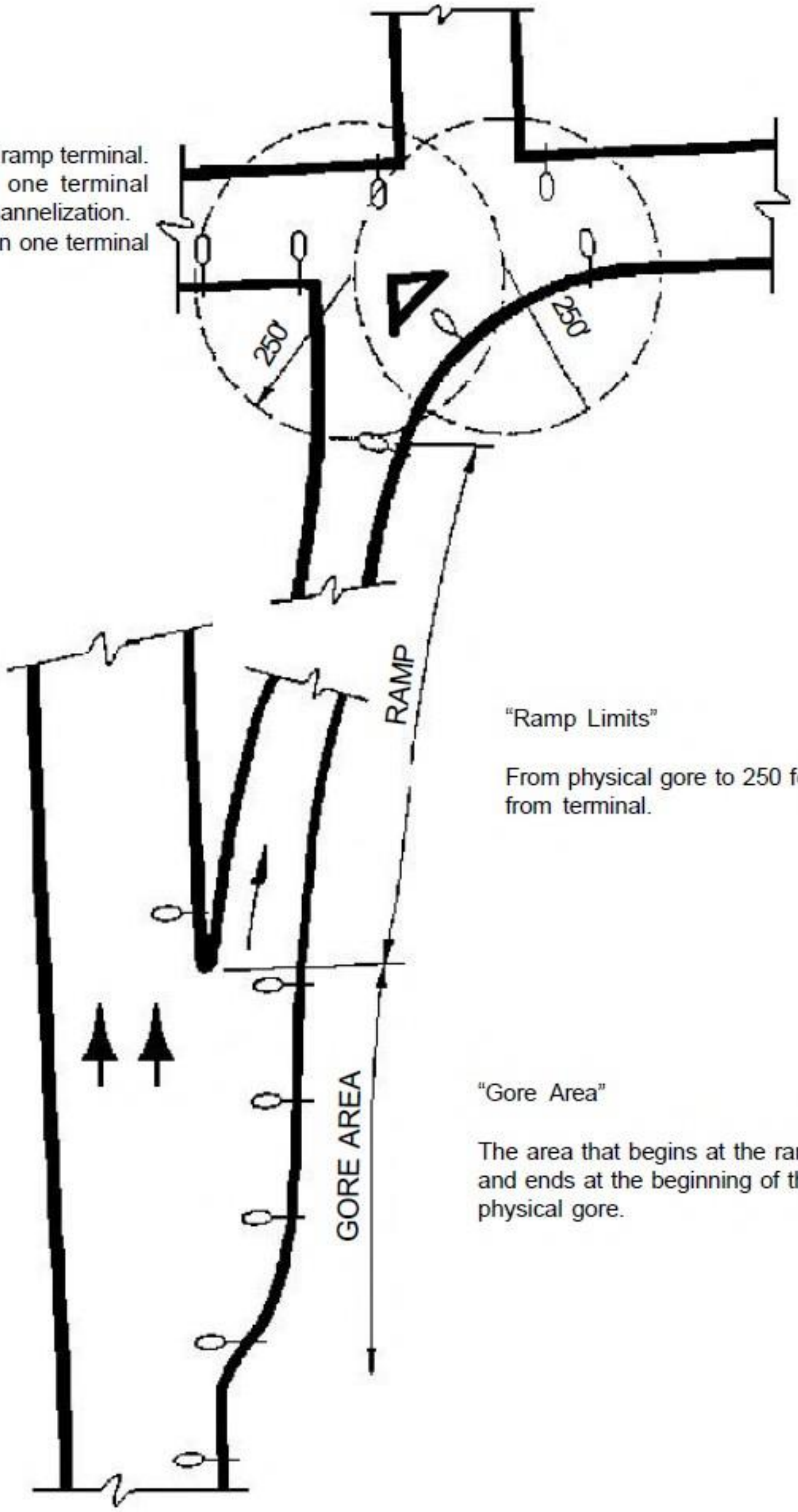
Example Calculation of Numerical Base Lighting Operational Level for configuration shown at left:

	#	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.

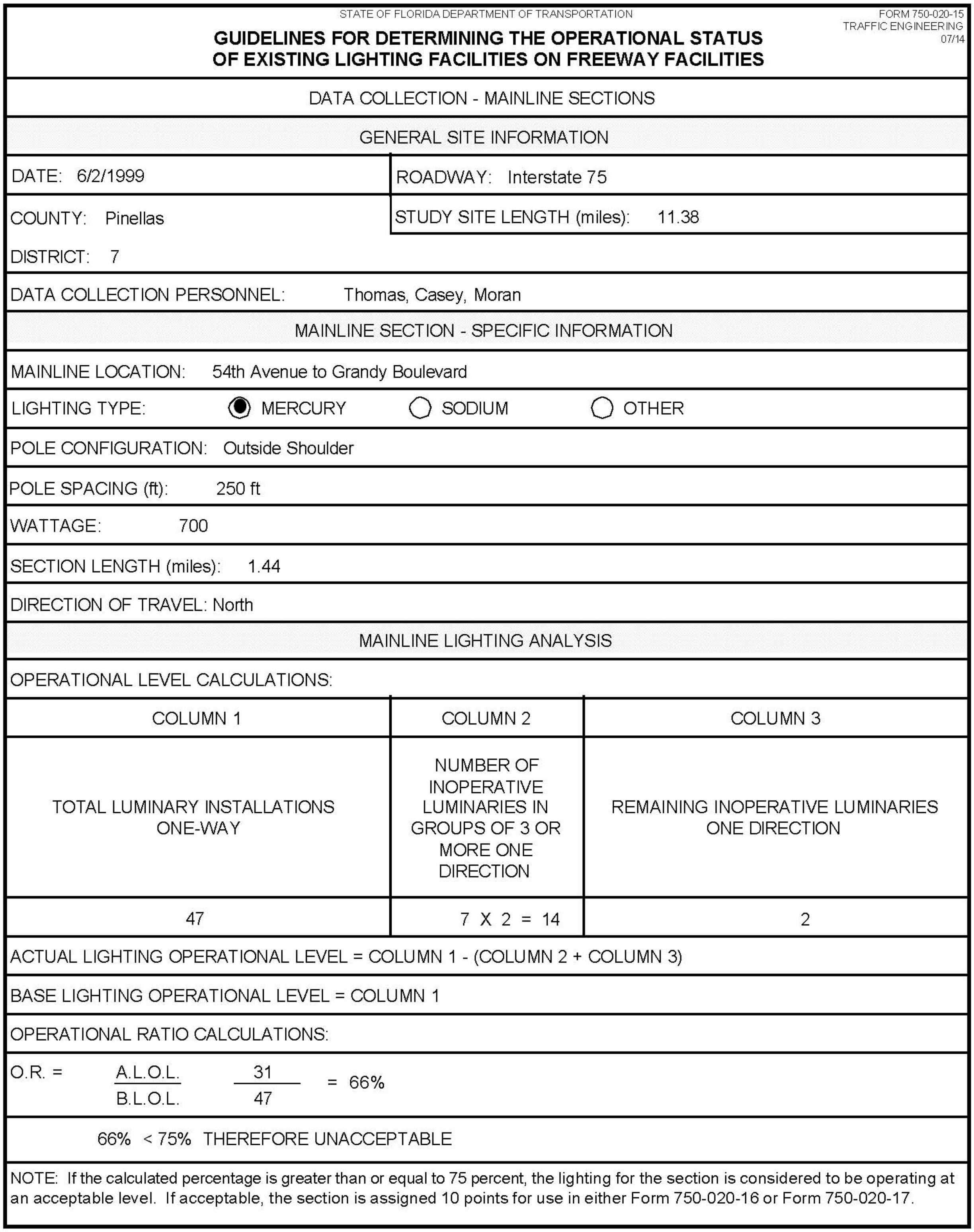
*If the sum is greater than 25 percent of the total number of luminaires, then the section is unacceptable.

(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 Nos. 750-020-21-a*,* 750-020-21-b*,* 750-020-21-c and 750-020-21-d) 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

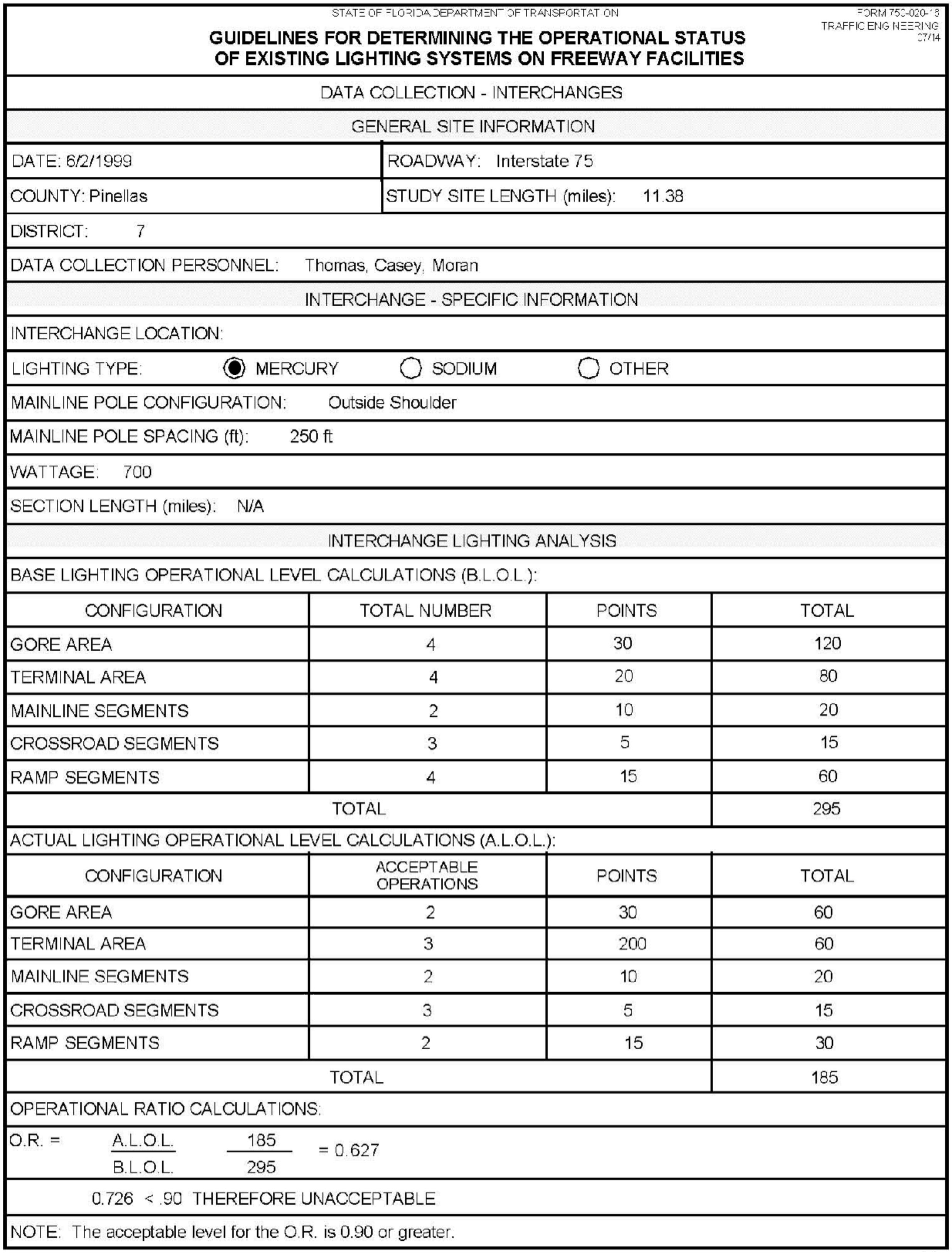
OPERATIONAL RATIO CALCULATIONS:

$$\text{O.R.} = \frac{\text{A.L.O.L.}}{\text{B.L.O.L.}} \quad \frac{31}{47} = 66\%$$

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

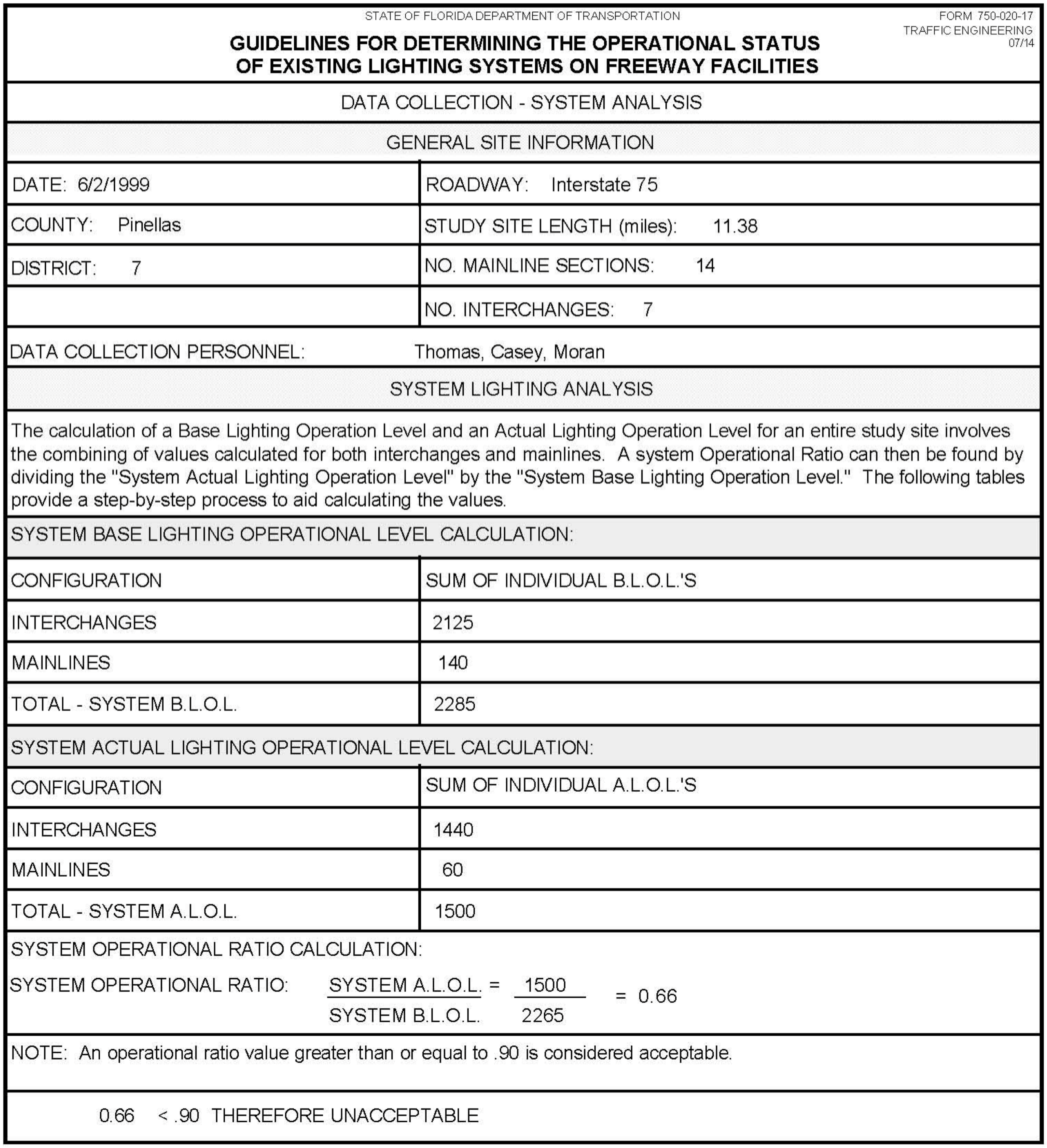
OPERATIONAL RATIO CALCULATIONS:

$$\text{O.R.} = \frac{\text{A.L.O.L.}}{\text{B.L.O.L.}} \quad \frac{185}{295} = 0.627$$

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