Chapter 2

TRAFFIC SIGNAL STUDY PROCEDURE

2.1 PURPOSE

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

(2) This manual is not all-inclusive in addressing traffic signal study situations; rather, it is a general guide for the traffic engineer to follow while investigating conditions and circumstances regarding the installation of a new traffic signal or improvement of the operation of an existing traffic signal. This manual will begin with an alleged problem concerning traffic control at a particular location. The observation of the problem symptoms, establishment of areas of concern, collection and analysis of data, and preparation of a traffic signal study report will be outlined in subsequent chapters.

(3) This chapter provides a logical and systematic data collection procedure for investigating traffic signal requirements which allows the traffic engineer to use judgement to analyze local conditions and interpret data as effectively and efficiently as possible with resources available. By following this chapter it is intended to minimize the collection of unnecessary or inappropriate data and/or to reduce the number of trips to the field to collect additional data. Figure 2-1 presents a flow chart of the procedure outlined in the following text. Figure 2-2 is a detailed version of Figure 2-1 showing the various steps of some of the major processes.

2.2 LEARNING OF THE PROBLEM

(1) The problem facing traffic engineers at this point has yet to be defined. This is the stage during which the traffic engineer receives notice from the public, a civic organization, business, etc., regarding their desire or need for a traffic signal to be installed or modified at a given site. Often, the traffic engineer or one of his/her staff has observed the problem, or another governmental agency has brought it to their attention.

(2) Regardless of the source, the traffic engineer is obligated to respond. However, to respond in a professional manner requires some systematic investigation of the situation. Before a full scale investigation is launched requiring a large
Figure 2-1. Flow Chart of Study Procedure

1. Alleged Problem
   - Observation Process
   - Initial Interpretation Incorrect
     - Signal Not Warranted
     - Warrant Analysis and Report Process
     - Conceptual Design and Report Process
     - Traffic Regulation Approval Process
     - Plans Preparation Process
     - Education/Information Dissemination Process
     - Implementation
Figure 2-2. Detail of Study Procedure

ALLEGED PROBLEM

OBSERVE PROBLEM SYMPTOMS

APPARENT PROBLEM EXISTS

YES

ESTABLISH BASIC AREAS OF CONCERN

VEHICLE PEDESTRIAN CRASH

DEVELOP SCOPE OF STUDY

DATA COLLECTION, REDUCTION AND SUMMARIZATION

DATA ANALYSIS AND INTERPRETATION

PREPARE TRAFFIC SIGNAL STUDY REPORT

SIGNAL NOT WARRANTED

YES

APPROVE TRAFFIC SIGNAL STUDY REPORT

NO

YES

DEVELOP CONCEPTUAL DESIGN

PREPARE CONCEPTUAL DESIGN REPORT

APPROVE CONCEPTUAL DESIGN REPORT

NO

YES

TRAFFIC REGULATION APPROVAL PROCESS

PLANS PREPARATION PROCESS

EDUCATION/ INFORMATION DISSEMINATION

IMPLEMENTATION

INITIAL INTERPRETATION INincorrect
amount of manpower and equipment, the traffic engineer should conduct an observation of the site. If a great deal of delay is encountered, the engineer should contact the reporting party about the action to be initiated.

2.3 OBSERVATION OF PROBLEM SYMPTOMS

(1) During the initial observation or field investigation of the site, a number of items should be noted. The preparation of a Condition Diagram (Chapter 5) should be made at this time if none exists for the site. The Condition Diagram shows the location of traffic control devices, intersection geometry, and other physical features. If the engineer has an existing Condition Diagram, it should be updated if necessary. Note that it is not necessary for this diagram to be drawn to scale.

(2) In addition to preparing a Condition Diagram, the engineer should observe the operational characteristics of the location and note any unusual or significant circumstances. Ideally, this observation should be made during the hours of the day when the operational problems were reported to have occurred. Color photographs of each approach often save subsequent trips back to the study location.

(3) With an understanding of the operation and a representation of conditions at the location, the engineer is in a position to determine if a real problem exists or no further investigation is warranted. If it is decided after the field investigation that no problem exists, the engineer should respond either in writing or verbally to that person responsible for the initial contact regarding the site. However, should it be determined that further investigation is warranted, the engineer should continue the investigation. At this point, the engineer should notify the concerned party(ies) of his/her intention to investigate the site for possible signalization and inform them of an approximate completion date.

2.4 ESTABLISHING BASIC AREAS OF CONCERN

(1) Establishing the basic area(s) of concern draws a great deal from the traffic engineer’s experience and judgement. Some cases can be easily diagnosed, such as excessive vehicle delays. Other cases are more subtle in nature. Of course, the problem under consideration may be the result of more than one basic area of concern.

(2) Decisions made by the traffic engineer at this point will provide the basis for data collection efforts to be made during the investigation. The areas of concern can be grouped into three basic categories: vehicle, pedestrian, and crashes and are addressed in this section. Warrants for signal installation, taken from the MUTCD, will be correlated with the studies indicated. This manual will be of
assistance in conducting many of the studies indicated as we have noted the appropriate chapter or section.

2.4.1 Vehicle

(1) A vehicle problem can normally be diagnosed during the field observation without great difficulty. Some of these characteristics are: excessive queue lengths, slow queue dissipation rates, and/or large traffic volumes using the intersection, etc.

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

(a) Hourly approach volumes for the highest 8 hours of an average day, as required for MUTCD Warrants 1, 2, 6, and 8 (Sections 3.5, 3.6, 3.10, and 3.12)

(b) Progressive Movement - distance to nearest signal greater than 1000 feet as required for MUTCD Warrant 5 (Section 3.9)

(c) Travel Time and Delay Study (Chapter 14)

(d) Intersection Delay and Queue Length Studies (Chapter 7)

2.4.2 Pedestrian

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

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

(a) Pedestrian Volume Count (Chapter 9) as required for MUTCD Warrants 3, 6, and 8 (Sections 3.7, 3.10, and 3.12)

(b) Pedestrian Group Size (Chapter 10) as required for MUTCD Warrant 4 (Section 3.8)

(c) Vehicle Gap Size (Chapter 8) as required for MUTCD Warrant 4 (Section 3.8)

(d) Distance to nearest crosswalk, or signalized intersection is greater than 300 feet as required for MUTCD Warrant 3 (Section 3.7)
2.4.3 Crashes

(1) The determination of an intersection’s crash potential during a short field observation is difficult. Some obvious features of a high crash location may be damaged sign supports or excessive tire skid marks, however, the number of crashes is not normally shown by the previous features. The quickest and cheapest method of determining if crashes are a problem, e.g., significantly higher than average for similar intersections, is to review past crash records for a minimum of one but preferably three years. Crashes many times can also be related to the previously described problems of vehicle and pedestrian delay, yet, poor geometric design may be the overriding factor.

(2) The following information can be used to further define a crash problem:

(a) Hourly approach volumes for the highest 8 hours as required for MUTCD Warrants 1, 2, 6, and 8 (Sections 3.5, 3.6, 3.10, and 3.12)

(b) Crash records/rates as required for MUTCD Warrant 6 (Section 3.10)

(c) Collision Diagram (Chapter 6)

(d) Pedestrian Volume Count (Chapter 9) as required for MUTCD Warrants 3, 6, and 8 (Sections 3.7, 3.10, and 3.12)

(e) Vehicle Spot Speed Study (Chapter 13) may be required for MUTCD Warrants 1, 2, 9, and 11 (Sections 3.5, 3.6, 3.13, and 3.15)

(f) Sight distances

(g) Geometries: vertical and horizontal

(h) Pavement condition for skid resistance

(i) Roadside hazards

(j) Existing positive guidance through signing and marking
(k) Existing highway lighting

(l) Traffic conflict investigation and analysis

(3) This list of data to be collected for each of the three basic areas of concern are neither all inclusive nor suggested as a minimum effort. Keep in mind that a database is required for justification (warrant analysis) and another database is required for design and operation. Data included in one database; however, is not mutually exclusive of the other.

(4) The engineer should not attempt to collect any of the data elements listed unless he is certain it will ultimately be required for the study. In fact, certain elements should not be collected until others have been reviewed. For example, hourly approach volumes (preferably fifteen minute volumes) should be counted for analysis of traffic signal warrants, which is generally necessary for each of the three areas of concern. Once the warrant analysis has been completed and the problem(s) has been identified (and before any turning volumes are counted), the machine counts should also be examined carefully to determine the control periods of interest. These periods of interest are the peak and off-peak periods for which the various signal operation plans will be designed.

2.5 DATA COLLECTION, REDUCTION, AND SUMMARIZATION

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. (A convenient manner in which to summarize and thus facilitate interpretation of the data required for the MUTCD signal warrants is to complete the Traffic Signal Warrant Summary, Form 750-020-01, in Chapter 3). For more information regarding data collection, reduction, and summarization, see the individual chapters contained herein.

2.6 DATA ANALYSIS AND INTERPRETATION

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

(2) Application of the Traffic Signal Warrant Summary can be made in a straightforward manner and provides the traffic engineer with information concerning the minimum conditions for justifying signal installation. Instructions for use of the Traffic Signal Warrant Summary (Form 750-020-01) are included in Chapter 3. Further explanation of the individual warrants can be found in Part IV of the MUTCD.
Engineering judgement plays an important role in the decision to signalize an intersection. The traffic engineers need a thorough knowledge and understanding of any local conditions which may, or may not, support the need for signalization. Situations may arise when a traffic signal is best not installed even though one of the eleven 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 to insure that installation of a signal does not create a greater problem. These considerations include, but are not limited to the following:

(a) Development of excessive queues on the major street
(b) Queue dissipation rates
(c) Spacing between adjacent signalized intersections
(d) Highway and intersection geometry (turn lanes)
(e) Location of stops/turnouts for public transportation
(f) Distance to pedestrian crossings and distance pedestrians have to cross

Conversely, local conditions may, on rare occasions, dictate installation of a signal when the minimum volume warrants are not met for eight hours. An example of this situation is the entrance to a plant or office complex which generates sufficient traffic such as work trips, to meet volume warrant criteria for several hours of the day (but less than the full eight hours) for at least each weekday. These locations should be designed with an operation plan which may include flashing operation during hours when full signal control is not justified. See Warrants 9, 10, and 11 (Section 3.13) in Chapter 3.

It is very important to note that even when a traffic signal is justified, e.g., it satisfies one or more warrants, it may not contribute to the safety and efficiency of the roadway. Closely spaced intersections in high volume corridors would all meet volume warrants, but signals are not desirable at every cross street. Signals can be poorly designed, ineffectively placed, improperly operated, and poorly maintained. Any of these conditions can negate the benefits intended by the traffic signal installation. The traffic engineer should also be increasingly aware of energy conservation and include these thoughts when signalization is considered.
2.7 PREPARATION AND APPROVAL OF TRAFFIC SIGNAL STUDY REPORT

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

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

(b) Description and map of intersection being considered

(c) Existing conditions and a diagram (sketch)

(d) Crash analysis and Collision Diagram

(e) Warrant analysis
   · Statement of use of 70 or 100 percent requirements
   · Analysis discussion of Warrants 1-8 (only those applicable)
   · Discussion of Warrants 9-11 (if applicable)
   · Discussion of delay study and/or SOAP, SIGNAL 94, SIDRA, SYNCHRO, CORSIM analysis with Highway Capacity Manual as a base definition source and documentation
   · Discussion of capacity analysis

(f) Recommendations (including sketch if applicable)

(g) Supplemental information or data to be submitted
   · Completed Warrant Analysis Sheets 1-8 (if applicable)
   · Completed Warrant Sheets 9-11 (if applicable)
   · Turning movement counts for the existing intersection (8 hour - A.M., P.M., and off-peak)
   · Projected turning movement counts for the proposed intersection (A.M., P.M., and off-peak) (if applicable)
   · 24-hour machine counts
   · Pedestrian counts (8 hours)
   · Color photos of each approach
   · Projected traffic data for new intersection (if applicable)
   · Pertinent supplemental information if needed
   · Computer program outputs
Guidelines for the content and format of this report are necessary to insure uniform report preparation procedures and to expedite report review time.

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

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

2.8 DEVELOPMENT OF CONCEPTUAL DESIGN

The conceptual design stage includes all activities that take place after justification of a new traffic signal installation has been made or the modification of the operation of the existing signal is required. These activities, which lead 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) Design improvement

For the installation of a new traffic signal the additional data collection will generally be limited to the turning volume counts for 15-minute time periods required for developing the signal operating plan and controller timings. Data collected for the signal warrants are of course available if needed. For modification of an existing signal the data available is often dated, so it may also be necessary to collect some of the data elements outlined previously in addition to the turning volumes. An example is an update of pedestrian volume and group
size data. In any event it is advisable to develop alternative concepts prior to the collection of additional data.

(3) The alternative development, evaluation, and selection steps are significant steps in themselves and are, therefore, only addressed in general terms in this manual. However, the basic approach is presented in order to provide the user with guidelines necessary to insure proper conduct of the traffic signal study.

(4) All reasonable alternative concepts should be considered by the engineer. These concepts should then be 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 isolated intersection analysis. SOAP, SIGNAL 94, SYNCHRO, or SIDRA are valuable programs with a Highway Capacity Manual interface that can be used for design, analysis, and evaluation of isolated intersections. By specifying appropriate commands and parameters, these programs can select optimal phase patterns and timings (cycle lengths and splits). Each alternative can be analyzed by the measures of effectiveness included in the output reports. Several alternatives can also be evaluated by comparative analysis to determine the best alternative. The Engineer of Record should be responsible for any model result.

(6) If the intersection is included in a linear arterial highway under study for progression, a PASSER II analysis should be conducted. PASSER II optimizes signal progression and is capable of design and analysis of multiphase, as well as two phase, fixed time signal control. TRANSYT-7F may also be used on an arterial (to verify or minimize) delay and stop.

(7) In cases where the intersection is part of a grid network, the TRANSYT-7F program should be used. This program is capable of modeling and optimizing grid networks composed of fixed-time intersections with two to seven phases. It also includes fuel consumption and environmental measures of effectiveness.

(8) When examining traffic signal control of a diamond interchange, the PASSER III program should be used. PASSER III is designed to optimize the coordinated signal timing of two intersections located at the ramp terminal of a diamond interchange. It is also capable of optimizing progression of adjacent frontage roads. PASSER III outputs include phasing patterns, timings, overlaps, offsets, and appropriate measures of effectiveness.

(9) It is advisable to utilize the isolated signalized intersection computer programs to examine all legitimate 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 model output can be used to
determine input values and ranges necessary to run PASSER II, TRANSYT-7F,
and PASSER III more effectively and more efficiently.

(10) A corridor network or freeway simulation program, CORSIM 1, should be used to
calculate system impact of signalized intersections with unsignalized
intersections. An economic analysis (cost effectiveness) should be conducted in
conjunction with the computer analyses and before proceeding to the
implementation stage. Unfortunately, constraints beyond the engineer’s control
may sometimes not permit implementation of the best alternative (i.e., limited
maintenance capability).

(11) 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. This report should include the following
elements as a minimum:

(a) All elements of the traffic signal study report. (show report in the
Appendix)

(b) Additional data collected, if any

(c) Description of alternatives

(d) Description of analyses (including appropriate output from SOAP, SIGNAL
94, SYNCHRO, SIDRA, PASSER II, TRANSYT-7F, PASSER III, and
CORSIM/NETSIM)

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

### 2.10 IMPLEMENTATION

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

2. Following implementation, the engineer should always visit the site to determine if the traffic signal is operating as designed. As a minimum, he 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. It is always a good idea to drive through the intersection from all approaches and to make any critical turning maneuvers.

3. In some cases, data collection may be necessary to determine if and how well the improvement is operating. This is particularly true for the after condition of a before and after study, where crash data, travel time and delay data, etc., are required.

4. It is also advisable to follow through on the implementation of a traffic signal with an educational program, preferably before any ground is broken, to increase public awareness of the change. This should result in improved safety and efficiency during the transition, and it draws attention to the traffic engineering activities, particularly safety and energy efficiency, that benefit the area.

### 2.11 TRAFFIC REGULATION APPROVAL PROCESS

1. The traffic regulation approval process is the significant stage of the improvement process; and, therefore it will not be addressed in this document. The user should refer to *Topic Number 750-010-011, Traffic Regulation Approval Process*, for specific procedural requirements.