Traffic Engineering Studies Reference

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TRAFFIC ENGINEERING STUDIES REFERENCE
SDDCTEA PAMPHLET 55-8

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Military Surface Deployment and Distribution Command
Transportation Engineering Agency

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GENERAL

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INTRODUCTION

Background

An efficient, safe and multimodal transportation system is vital to the operation of military installations. It provides a means for personnel and visitors to effectively travel onto and within an installation to access housing, employment, training, shopping and recreation. The transportation network needs to support a wide range of vehicle types including automobiles, trucks, buses, emergency equipment, motorcycles, and specialized military vehicles, as well as provide safe amenities for nonmotorized modes of transportation, i.e. pedestrians and bicycles. Various traffic studies have been developed to evaluate components of the current transportation system and plan for future operation conditions. The studies need to address the range of military installation aspects including, but not limited to, access gates; arterial and minor streets; signalized controlled intersections; and, training and recreation areas. A poorly functioning transportation network on an installation can lead to traffic congestion and delay, safety and security concerns, health risks, and environmental issues. Understanding existing and potential problems relating to the movement of people within the base facility is critical. The development of sound transportation improvements requires collecting factual information and employing recognized traffic study methods to analyze the data and recommend system enhancements.

Military installations are unique in that their physical size, and operating budgets limit the magnitude and speed with which transportation problems can be treated. In many cases, personnel trained specifically in traffic issues cannot be readily employed, and base funds and space are limited. These factors frequently prevent the implementation of proper corrective action, particularly since general motor vehicle operation is considered secondary to the base mission. This pamphlet is designed for technical and nontechnical persons who have been tasked to provide early remedy to the more basic traffic oriented problems, or to provide assistance to others who are so assigned.

In accordance with the Code of Federal Regulations (CFR)-Title 23: Highways, Chapter I, Subchapter G. Part 555, subpart f: Traffic Control Devices on Federal-Aid and other streets and highways 655.603-Standards, The Manual on Uniform Traffic Control Devices (MUTCD) is the national standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel. All roads within an installation are considered to be open to public travel, therefore, installations are required to meet the requirements referenced in the MUTCD as set forth by CFR-Title 32 National Defense, Subtitle A, Chapter V, subchapter I, Part 634.

Installation officials are encouraged to cultivate and maintain contact with representatives of the state and local highway authorities. Roads open to the public that provide vehicular access for the installation can affect its safety, capacity and security. Access roads adjacent to the installation with high volumes, especially at peak travel periods or have poor operation characteristics can cause congestion issues that may reduce the entrance gate throughput. Coordinating with regional transportation agencies is important to alleviate potential issues. For assistance with public highway matters, contact Surface Deployment and Distribution Command Transportation Engineering Agency (SDDCTEA).

Types of Studies

This pamphlet describes a variety of the most common traffic engineering studies that can provide the objective data and analysis needed to assist in the evaluation of traffic conditions and development of projects to improve the safety and mobility of the installation travel network. *Traffic volume studies* provide the basic counts of the number of vehicles, bicycles, or pedestrians at specific points of interest. *Intersection capacity studies* help determine the traffic flow through a corridor and provide potential alternatives to reduce congestion and delay. *Crash studies* provide the data necessary to identify the type, severity, and patterns of crashes within the installation to help develop appropriate safety measures to prevent future crashes. *Signing and pavement marking studies*, and *traffic signal management studies* identify where improvements can be implemented to increase traffic flow and ensure appropriate and required lane markings and instructional signs are in place. *Travel time and delay studies*, and *origin and destination studies* help evaluate the intensity of certain travel patterns within the installation and identify measures to reduce congestion and unnecessary travel delay. *Spot speed studies* help determine the appropriate speed limit postings and potential traffic calming improvements. *Public transportation studies*, and *bicycle and pedestrian studies* serve to highlight the need for safe integration of transit and non-motorized travel and encourage an increase in multi-modal travel users that can reduce vehicle usage, increase health benefits and improve the environment.

Military installations may occasionally undergo changes to population and land use as a result of differences in day-to-day activities or a major re-evaluation and deployment of the installation's mission. Traffic problems can increase significantly with increases in military forces, civilian staff, contractor personnel and visitors, or due to changes in installation duty hours. A comprehensive evaluation of the transportation network within the installation may be advantageous in adjusting to variations in travel needs of the base. Consideration of long-term transportation needs is important to adequately prepare for future traffic capacity increases and system operation management requirements. Traffic problems will develop as missions increase, and more traffic is added to already overburdened transportation systems.

It is not uncommon for installations to experience large amounts of growth. To support existing and future demands, installations must not only identify capacity enhancements but also consider capacity management and demand management strategies. Traffic studies can be conducted individually or in combination to provide the base planners comprehensive transportation data with which to evaluate many aspects of the installation network. The systematic collection and analysis of traffic data throughout the installation will provide the objective measures that can be used to assess travel quality and evaluate system performance. The results of conducting traffic studies over time, can provide a more comprehensive view of the installation's transportation system, help maintain existing operations, and prepare for potential impacts of increased travel needs.

The SDDCTEA staff are available to assist in the analysis and development of the traffic study information provided in this pamphlet; as well as aid installation personnel in recognizing and addressing problems relating to the design, use, or maintenance of transportation facilities and systems. SDDCTEA can be contacted and in some cases should be contacted in preparation for the implementation of transportation studies.

Purpose

The multi-service regulation AR 55-80, OPNAVINST 11210.2, AFMAN 32-1017, MCO 11210.2D, and DLAR 4500.19 implements Department of Defense (DoD) Directive 4510.11 (DoD Transportation Engineering) and DoD Instruction 6055.04 (DoD Traffic Safety Program). Accordingly, SDDCTEA is the designated DoD executive agent in public highway matters. SDDCTEA is delegated traffic engineering support responsibilities for all of DoD. This SDDCTEA pamphlet is intended for use by personnel responsible for vehicular traffic engineering analyses and control at DoD installations. It is not intended to replace published manuals and criteria or to be used as a substitute for formal training, but rather to provide supplemental assistance to those who have need for immediate guidance on the basic considerations in analysis and remedy of traffic-related problems. It identifies what information is important, how it can be assembled, and its significance. It also provides some of the more widely used methods for alleviation of traffic problems. This pamphlet identifies the more common problems experienced in connection with traffic operation on military installations, the types of studies most frequently used in determining solutions to the problems, and those aspects of each study type that concern data collection, analysis, and interpretation. It includes sufficient illustrations of formats, diagrams, and calculations to insure a logical process in the conduct of the studies and the presentation of related analyses and findings.

The information in the pamphlet will also assist local personnel in the coordination and assembly of data for the more complex studies conducted by SDDCTEA, and will enable them to deal directly with many of the day-to-day traffic problems.

This pamphlet is designed for use by installation personnel in the treatment of the day-to-day problems that cause traffic crashes and congestion. The primary variances in study scope will be as dictated by the size of the installation, the length and use of roadways, the volume of activities, and the nature and magnitude of transportation problems. Additional information for transportation studies can be referenced in the Institute of Transportation Engineers' (ITE) *Manual of Transportation Engineering Studies (MTES)*. Other reference material include the *Highway Capacity Manual (HCM), Highway Safety Manual (HSM)*, *Manual on Uniform Traffic Control Devices (MUTCD)* and other SDDCTEA Pamphlets.

HOW TO USE THIS PAMPHLET

General

This pamphlet is intended for use as an aid in both the selection and conduct of the type of study required to provide information to solve a localized problem or to clarify for installation personnel the type and degree of assistance required by professionals in the study of the more complex situations. It is a primary need to limit study effort to the minimum by selection of appropriate study type. In some cases this may mean only a sampling of data whereas in others it may result in the conduct of more than one study type. It is unlikely that an installation would have a need to perform every study listed in this pamphlet, particularly, since the more complex problems should be solved by professional traffic engineering personnel. As an example, the design of a modern traffic signal system requires professional expertise. Blank field data sheets developed for use in the collection and recording of the various types of data necessary to conduct the studies in the pamphlet are provided in Appendix C.

Study Selection

The user of this pamphlet should first determine the scope and magnitude of the problem and the apparent involvements. The Engineering Study Reference Guide presented in Exhibit G.1 combines the more common problems and symptoms under the heading of "Study Generator". It is used to determine which study(ies) will provide the information required to permit analysis of the problem and determination of appropriate remedial action. Review is made of the details provided in the pamphlet chapter for the applicable study prior to study commencement.

Exhibit G.1: Engineering Study Reference Guide

STUDY GENERATOR	TRAFFIC STUDIES REQUIRED												
	TRAFFIC VOLUME STUDIES	INTERSECTION CAPACITY STUDY	CRASH STUDY	SIGN MANAGEMENT STUDY	PAVEMENT MARKING STUDY	TRAFFIC SIGNAL STUDY	TRAVEL TIME & DELAY STUDIES	SPOT SPEED STUDIES	ORIGIN & DESTINATION STUDY	PUBLIC TRANSPORTATION STUDY	PARKING STUDY	BIKE / PEDESTRIAN STUDIES	ECF STUDY
Accidents	P		P	P	P	P		P		S		S	
Bicycles	P		S	S	S							P	
Building Program	P	P									P		S
Bus Service	S								S	P			
Capacity, Traffic	P	P					P			S			P
Car Pooling	S						S		P	P	S		
Congestion	P	P					P		S	S		S	P
Construction Projects	P								P				
Control, Traffic	S	S		P	P	P							P
Counts	P	P	P				P	P	P	P	P	P	P
Delay, Traffic	P	P					P						S
Driver Confusion				P	P	P							
Energy Conservation								S		S			
Entrance Gate	P								S				P
Flow, Traffic	P	P				S							S
Generators, Traffic	P	P							P	S	S		
Intersection	S	P	P	S	S	S	S						
Land Use									P				
Law Enforcement			P			S		P					
Mode, Transportation	P									P		P	
MUTCD				P	P	P							

Legend: P = Primary Importance
S = Secondary Importance

Exhibit G.1: Engineering Study Reference Guide (continued)

STUDY GENERATOR	TRAFFIC STUDIES REQUIRED												
	TRAFFIC VOLUME STUDIES	INTERSECTION CAPACITY STUDY	CRASH STUDY	SIGN MANAGEMENT STUDY	PAVEMENT MARKING STUDY	TRAFFIC SIGNAL STUDY	TRAVEL TIME & DELAY STUDIES	SPOT SPEED STUDIES	ORIGIN & DESTINATION STUDY	PUBLIC TRANSPORTATION STUDY	PARKING STUDY	BIKE / PEDESTRIAN STUDIES	ECF STUDY
Origin & Destination	S						S		P				S
Parking Congestion	P								S		P		
Pavement Marking			S		P								
Pedestrians	P		P							S		P	
Personnel	S												P
Planning, Master	P	S							P	S		S	S
Population Changes	P								P		S		P
Public Approach Rds	P	P	S						P				P
Regulations, DoD				P	P	P							P
Safety	P	S	P	S	S	S		S				S	S
Signals	S	S	S			P							
Signs	S			P									S
Speed, Spot Speed			P					P					
Through Traffic	P	S							P				
Traffic Control	S	S		P		P							
Transit Service	P									P			
Travel Desires	S						S		P				
Travel Time	S	S					P						
Trucks	P	S											
Turning Movements	P	P		S	S	P							
Vehicle Occupancy	S						P			S			
Volume, Traffic	P	P	S							S	S		S

Legend: P = Primary Importance
S = Secondary Importance

CONDUCTING A TRAFFIC STUDY

General

Traffic engineering studies are conducted to develop factual information necessary to effect intelligent solutions to traffic problems, to provide guidance for the planning of transportation systems and facilities, and to assist authorities in developing the most desirable land-use patterns. Accurate knowledge of travel desires, constraints, and operational problems is a primary element in any decision involving transportation. Information obtained by application of procedures contained in this reference will assist personnel in correcting many of the more frequently experienced traffic problems and will prove invaluable when assisting SDDCTEA in the conduct of the more complex studies that require professional expertise.

Use of Traffic Studies

Each chapter in this pamphlet relates to conducting a particular type of study and provides explanations of basic purpose and application. Sufficient guidance and illustrations are included to ensure adequacy in the conduct of each type of study. Questions concerning the conduct or application of any study contained herein should be directed to SDDCTEA.

Format

Each section of this pamphlet deals with an individual type of study and is generally organized as follows:

- ✓ **Objective** of study
- ✓ **Information Needed**
- ✓ **Methods** of data collection
- ✓ **Analysis** of data
- ✓ **Interpretation** of processed data
- ✓ **Application** of study results

Planning a Traffic Study

Planning a traffic study is as important as the study itself. Improper techniques, excessive data collection, or even conducting an unnecessary study can be a waste of manpower and/or make it difficult to determine the correct solution to a problem. It is essential that the engineer/technician has sufficient information to conduct the analysis, but frequently this can be obtained by sample observation or survey of traffic movements and desires. Compliance with the following procedure will make it easier to conduct a study and will help to preclude excessive use of personnel time:

- ✓ Examine records and assemble available related data
- ✓ Determine how much additional data is required
- ✓ Select location(s) and time(s) for data collection
- ✓ Review study procedures
- ✓ Establish personnel and equipment needs

- ✓ Prepare survey forms
- ✓ Arrange for and brief survey personnel on study procedures
- ✓ Collect field data
- ✓ Perform analyses and interpret data
- ✓ Determine alternate solutions
- ✓ Select solutions that best fit the dictates of effectiveness, economy, and ease of implementation

Traffic Engineering Study Contracts

Whenever traffic studies cannot be readily undertaken and accomplished by the installation staff because of insufficient staffing levels, time constraints, the need for specialized technical services, or other cause, contracting with consulting traffic engineers may be necessary to carry out the study. A well-written scope of work should be prepared that outlines the required work efforts to properly conduct the study. Appropriate contracting procedures should be followed to select and secure the consulting services. The SDDCTEA staff can provide example scopes of work and procedures for contracting consulting services and is available to provide assistance in the preparation and review of the contracting documents. Refer to Appendix A for example contract language.

General References

The contractor shall fully consider and ensure studies and plans comply with the most recent and current country, federal, state, and local laws and regulations, and SDDCTEA directives and instructions. Examples include:

- ✓ SDDCTEA Pamphlet 55-8, *Traffic Engineering Study Reference*
- ✓ SDDCTEA Pamphlet 55-15, *Traffic and Safety Engineering for Better Entry Control Facilities*
- ✓ SDDCTEA Pamphlet 55-17, *Better Military Traffic Engineering*
- ✓ American Association of State Highway and Transportation Officials (AASHTO)—*A Policy on Geometric Design of Highways and Streets*, 2011
- ✓ AASHTO—*Roadside Design Guide*, 4th Edition, 2011
- ✓ Institute of Transportation Engineers (ITE)—*Traffic Engineering Handbook*—Washington D.C., 2009
- ✓ U.S. Department of Transportation, Federal Highway Administration (FHWA)—*Manual on Uniform Traffic Control Devices* (*MUTCD*) Washington, D.C., 2009
- ✓ Transportation Research Board—*Highway Capacity Manual*, 2010
- ✓ ITE—*Manual of Traffic Signal Design*
- ✓ ITE—*Design and Safety of Pedestrian Facilities*
- ✓ ITE—*Traffic Calming, State of the Practice*
- ✓ ITE—*Parking Generation*
- ✓ All applicable Unified Facilities Criteria (UFCs)
- ✓ State and Department MUTCD Supplements
- ✓ DoD Supplement to The National Manual on Uniform Traffic Control Devices (MUTCD) 2015

Common Deliverables

- ✓ Contractor Points of Contact
- ✓ Project Schedule
- ✓ In-Brief Presentation/Meeting
- ✓ Out-Brief Presentation/Meeting
- ✓ In/Out-Brief Meeting Minutes
- ✓ Draft Report
  (Shall include adequate text, illustrations, and data to thoroughly document existing conditions & deficiencies; as well as to support the recommended improvements. Recommendations for all necessary improvements shall be shown.)
- ✓ Draft-Final Report
  (Shall include all necessary changes due to installation out-brief comments and the implementation of remaining data.)
- ✓ Final Report

COMMON ACRONYMS

For ease of reference, the common acronyms and abbreviations used throughout this pamphlet are listed below in alphabetical order.

AADT–Average Annual Daily Traffic

ABA–Architectural Barriers Act

ACP–Access Control Point

ADT–Average Daily Traffic

APC–Automatic Passenger Counters

ATR–Automatic Traffic Recorder

AVL–Automatic Vehicle Location

DA–Deployment Adjustment

DHV–Design Hourly Volume

DMI–Distance Measuring Instruments

ECF–Entry Control Facility

FG–Future Growth

FHWA–Federal Highway Administration

GIS–Geographic Information System

GPS–Geopositioning Satellite

ICU–Intersection Capacity Utilization

IRRIS–Intelligent Road/Rail Information Server

LOS–Level of Service

MUTCD–Manual on Uniform Traffic Control Devices

OD–Origin-Destination

PHF–Peak Hour Factor

PROWAG–Public Right-of-Way Accessibility Guidelines

RSA–Road Safety Assessment

SCAT–Signal Coordination and Timing

SMS–Sign Management Study

TGIS–Temporal Geographic Information System

VMT–Vehicle Miles Traveled

GFA–Gross Floor Area

CHAPTER 1—TRAFFIC VOLUME STUDIES

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CHAPTER 1—TRAFFIC VOLUME STUDIES

Understanding how traffic flows throughout the military installation is critical to the efficient movement of vehicles. Improving safety and security for both vehicles and pedestrians, and reducing traffic congestion are two main objectives in providing an effective transportation system. Collecting and analyzing traffic data through traffic volume studies is the primary tool to evaluate, improve and monitor the performance of the transportation network. The ITE MTES is the primary reference source for traffic volume studies.

1.1. OBJECTIVE

The objective of performing traffic volume studies is to count the number of persons or vehicles at a given location, including the movements and classification of roadway vehicles. The amount of traffic in vehicles per unit of time is called the traffic volume. A count may be classified by the time of day, direction of travel, types of vehicles, and number of vehicle occupants. Traffic counts should be taken on an average weekday Tuesday, Wednesday or Thursday of a non-holiday week during normal operations. If weekend volumes are of interest, such as at a guard facility, counts should be taken on the highest volume day. The scope of a count may range from a count of the number of cars passing through an intersection in a single hour to a comprehensive survey of traffic flow on all major roadways of an installation. Additional counts for pedestrian and bicycle movement may also be included. Volume data are used as basic input in all operations-based procedures as it describes the vehicular or pedestrian exposure at each location. Typical types of traffic volume data and their usage are:

ADT—Average Daily Traffic (ADT) or Annual Average Daily Traffic (AADT) is an average of 24-hour volumes over a stated period of time. Traditionally, the AADT is the total volume of vehicle traffic of a highway or roadway for a year divided by 365 days. It is a useful measurement of how busy the road is. AADT and ADT data are used to estimate growth trends, to calculate crash rates, to decide construction priorities, to plan roadway maintenance, and to design future street networks. The ADT can be estimated based on one 24 hour count.

Peak-hour Volumes—Peak hour volumes are needed to determine when the peak traffic movements occur during the day and the number and direction of these movements at a given location. Typically, there are one or more peak periods in daily travel. The dominant weekday peak periods are in the morning (a.m. peak period) and in the late afternoon (p.m. peak period). The peak period can also occur during the mid-day. The peak hour is the hour of the day during which the highest traffic volume occurs. The peak hour can occur during any of the typical three peak periods of the day when traffic volumes are higher and usually coincide with the normal weekday work schedule. The peak hour volumes are typically referring to intersection counts, but can also refer to the peak hour of a roadway. These are used to determine changes to traffic-control devices, such as traffic signals, as well as the basis for evaluating intersection capacity.

These data are also used to determine the number of lanes necessary to accommodate known or projected traffic demands, to allocate right-of-way, to appropriate traffic flows, and to design and locate streets and installation gates.

Vehicle Classification—Vehicle classification is used to identify a road in terms of the traffic it serves. The classes typically include passenger cars, various types of trucks and buses, motorcycles, and bicycles. Vehicle-classification data are used primarily in the design of pavement thickness and in calculating highway capacities.

The vehicle classification can also help identify the appropriate design vehicle which is typically used for evaluating turning movements through an intersection. A typical design vehicle for an installation is a WB 67 in areas where truck traffic is prevalent, a single unit truck (SU) or passenger vehicle (P) where trucks are not prevalent, or a school bus in areas where truck traffic is not expected.

1.2. INFORMATION NEEDED

The most commonly counted location in an installation traffic system is an intersection. A general intersection approach would have three possible vehicle turning movements: left (including U-turn), through, and right. Separate counts can be taken for passenger cars, trucks, and buses. Intersections can be either unsignalized or signalized. Unsignalized intersections are usually controlled by STOP and YIELD signs. Signalized intersections are controlled by alternating signal phasing. The types of traffic-volume counts needed will be determined by the ultimate usage of the data. In any volume-counting program, you must determine:

- ✓ Locations where counts will be taken
- ✓ Overall length of time the data collection will last
- ✓ Intervals at which information will be recorded (for example, every 15 minutes, or hourly)
- ✓ What will be counted (for example, total vehicles, trucks, pedestrians, or a combination of these and other categories)

1.3. METHODS

The techniques used to collect traffic volume data will be determined by the purpose of the traffic count. The basic techniques for obtaining traffic volume data involve either the use of an automatic (mechanical/electronic) counter or a manual count. Manual counts can be conducted by using electronic intersection traffic volume recorders, or by hand tally. Manual counts require significant time and resources. Manual counting is sufficient for most installation locations where counting times may be limited to peak hour periods. However, advances in technology and available counting equipment such as, loop detectors, video counters, and GPS transponders are shifting the balance from manual to automatic counting methods. New technologies for more long term traffic counts and classification includes, magnetic in-road sensors, radar, microwave, Bluetooth, infrared, and video imaging.

When using traffic data, including turning movement count data or ATR data, is it important to ensure that the data is reflective of actual demand. Arrival counts are reflective of actual demand. Arrival counts are the counts that approach a facility, such as an intersection, bottleneck, or entry control facility. These differ from departure counts, which are a function of the facility's capacity. Departure counts are the counts that leave the facility and are based on that facility's capacity. If arrival counts are greater than the departure counts, queues form. If arrival counts are less than departure counts, queues dissipate. In under-capacity conditions, arrival counts and departure counts would be equal.

When performing data collection, it is often difficult to directly obtain the arrival counts due to positioning of the counter. If an intersection is manually counted by observation, the observer must count all approaches, and is frequently located toward the center of the intersection where they can see all approaches. If queues form, it may be difficult to observe vehicles as they arrive particularly if the queue is extensive, and it would be difficult to keep track of which vehicles were counted. Instead, a queue adjustment should be made. Standing queues for each movement should be recorded every interval of data collection, while the counting of vehicles is departure-based. The change in queue for each interval should be added to the departure counts for that movement to obtain the actual demand for that interval. If the queue is building, a positive number is added to the departure-based count. If the queue is dissipating, a negative number is added (or simply subtracted) to the departure-based count. If there is no queue present, no adjustment is made.

A similar method can be used when ATRs are obtaining departure-based counts, and an observer is recording queues. Common locations where this would occur is at Entry Control Facilities (ECFs) or bottlenecks.

Note that platoons that may result from multiple vehicles traveling from a signal which are cleared shortly after they arrive are typically not considered to be queues since they are not reflective of the capacity of the facility.

Automatic Traffic Recorders—Automatic Traffic Recorders (ATRs) are traffic counting devices that are installed on or adjacent to the roadway to count, classify or measure vehicle speeds. ATRs store traffic data in a timestamp or interval fashion that can be downloaded onto a computer and viewed/analyzed through proprietary software.

ATRs can record traffic data for a variety of time intervals (1 minute to 60 minutes). The most commonly used interval for traffic analysis and simulation purposes is 15 minutes. ATRs that cannot record traffic data in 15 minute or less intervals are not recommended.

Manual Counts—Manual counting requires field personnel to observe and record each vehicle as it passes the study point by hand tally or using an electronic device.

Hand tallying—When conducting manual counts by hand tallying, observers must have a pencil, clock, clip board, and a sufficient supply of appropriate field data sheets. Laptop computers can be used in lieu of handwritten tally sheets. Spreadsheets can be used to manually record and summarize the traffic data. Hand tallying, whether using paper or a laptop, is not recommended for high volume intersection counts or gate counts. Exhibit 1.2 shows a typical vehicle turning movement count field sheet.

Electronic count boards—Electronic count boards (as illustrated in Exhibit 1.1) greatly increase the total number of vehicles that one person can count in a given period, since the user only has to indicate the passing of a vehicle by depressing a key. They are lightweight with buttons dedicated to each intersection movement. Data can be transferred to a computer where analysis software can examine and present the results in appropriate formats. Most electronic count boards are capable of handling several types of common traffic studies including, volume, turning movement, classification, gap, stop delay, saturation flow rate, stop sign delay, spot speed and travel-time studies.

Exhibit 1.1: Typical Turning Movement Counter

Hand-held web-based computer devices—Advances in computer technology and data transmittal has greatly reduced the size of personal computing devices. Laptops, tablets, and “smart” cell phones are convenient devices that allow web-based internet access. Many applications (apps) are now available on the web market for these devices and provide user friendly traffic volume counting and analysis programs that can be downloaded onto any web-based device for use. Some examples of these web-based apps currently on the market are “CarCounter”, “TurnCount”, and “Crosstown Traffic”.

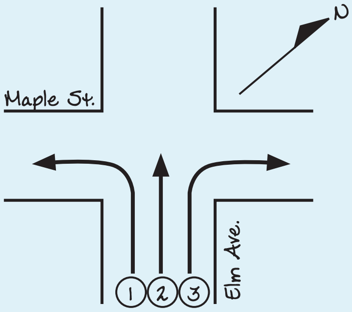
Exhibit 1.2: Typical Turning Movement Count Field Sheet (Sample)

Location Maple St. & Elm Ave

Date July 21, 2015

Time 0645 to 0815

Observer LR Smith



Time	① ↰	Vehicle Queue	② ↑	Vehicle Queue	③ ↱	Vehicle Queue
0645 to 0700	𝍸 𝍸 𝍸 ⑮		𝍸 || ⑦		𝍸 𝍸 𝍸 𝍸 || ㉒	
0700 to 0715	𝍸 𝍸 𝍸 𝍸 | ㉑		𝍸 |||| ⑨		𝍸 𝍸 𝍸 𝍸 𝍸 |||| ㉙	
0715 to 0730	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ㉚		𝍸 𝍸 𝍸 ||| ⑱		𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 | ㊻	
0730 to 0745	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 | ㊶		𝍸 𝍸 𝍸 𝍸 𝍸 || ㉗		𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||| (88)	
0745 to 0800	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 || ㊷		𝍸 𝍸 𝍸 𝍸 𝍸 ||| ㉘		𝍸 ||| (133)	
0800 to 0815	𝍸 𝍸 𝍸 𝍸 || ㉒		𝍸 𝍸 | ㉑		𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||| ㊳	

Not all computer web apps for traffic analysis provide adequate data for the required traffic volume studies. The SDDCTEA does not endorse any particular web application for use, however, these applications may provide a sufficient, convenient and economical means to collect and evaluate traffic study data. It is recommended to investigate the various apps to determine the most beneficial app for the type of traffic study and analysis data required. As technology is always changing, new and improved versions of these applications will continue to be made available.

Manual traffic counting requires trained observers with a sufficient amount of personnel available to obtain accurate data. At very busy intersections, it may be necessary to provide one observer for each approach. Less busy intersections can be counted by two observers; or even one, if an intersection electronic counting device is utilized. When all day counts are undertaken, it will be necessary to provide extra personnel so that the observers may have periodic breaks. The safety and protection of all observers is paramount when performing manual traffic counts or installing automatic counting devices. Proper safety equipment and procedures should be maintained and followed at all times during the counting sessions.

Count Periods—Traffic counts are made over a time period long enough to provide the data desired. For example, a peak period count should include sufficient time to ensure the peak hour is covered. Most traffic volume counts, including Intersection counts, should be recorded in terms of 15 minute intervals to permit identification of the highest volume count within the hour. Normally it is desirable to count a minimum of 15 minutes before and after the peak hour. Traffic volume counts are typically collected during the morning peak, evening peak, noon peak, and/or off-peak periods. For example, an intersection capacity study usually would require directional counts during the AM, PM, and mid-day periods to determine if turning lanes are warranted. AM traffic volumes may dictate the need for a turning lane in one direction at the intersection, whereas the PM traffic volumes may dictate a turning lane in the other direction. For ECFs, the AM period may dictate the number of ID check lanes needed for uncongested flow through the installation entrance gate. For traffic signal warrants, data should be collected during the 10 busiest hours of the day, where automatic traffic recorders can be used for several of these hours. Automatic counters can be left in place for extended periods or even be permanently installed to determine daily, weekly, or seasonal variation in traffic volumes.

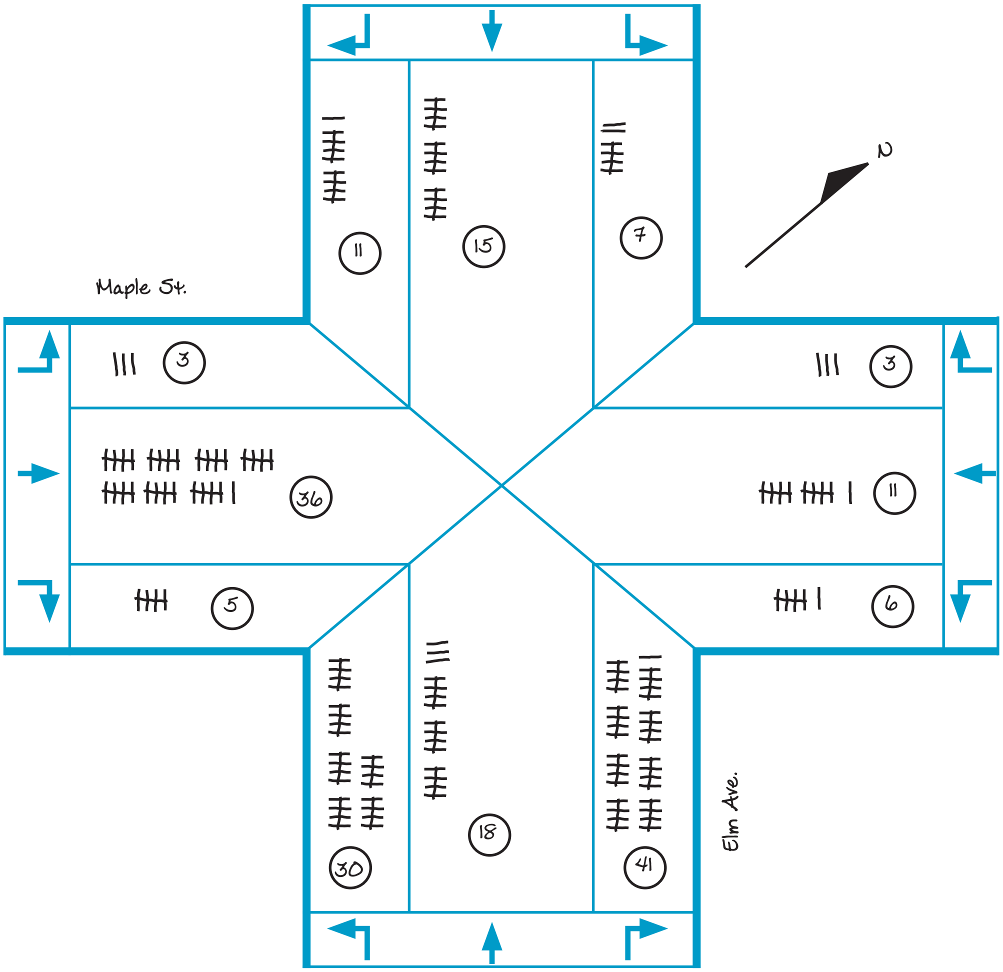
Volume Study Types—The typical types of volume studies performed at military installations are the turning-movement count, traffic volume count, and vehicle classification count. Other more specialized counts include vehicle parking, U-turns, weaving or right turn on red signals where applicable.

Turning-movement count—This type of count is typically performed at the major intersections of interest in the overall study area in order to determine the peak hour volumes and associated turning movements at the intersection. The counts are made during morning- and evening-peak periods, and if possible, during noon-peak and several off-peak periods. Personnel are assigned to the entire intersection if possible, or specific approaches of the intersection. The counting period should be divided in 15 minute intervals. Traffic counts are typically performed with an electronic count board. If not available, an alternate field-data sheet such as Exhibit 1.3 shows a typical turning movement count field sheet that may be used when two or more low-volume approaches are counted by one person. The observer conducting the counts should be positioned at the optimum location with an unobstructed view of the intersection movements and traffic queues.

Exhibit 1.3: Typical Abbreviated Turning Movement Count Field Sheet (Sample)

Location Maple St. & Elm Ave Date July 21, 2015

Time 0715 to 0730 Weather Fair Observer L.R. Smith



Traffic volume count—A traffic volume count is usually performed at an intersection or at midblock locations along a street. The count may be done manually on a simple tally sheet or may be performed using ATRs. In most cases, the count is taken in each direction of travel to provide the total bi-directional ADT for the location. The total duration of the count is often 24 hours, which includes the morning and evening peak hours. An ATR can be installed at the same location for 1 week or more. This provides a profile of day-to-day variations during the week, which may then be averaged to calculate the average daily traffic ADT.

Typically, the average of a 1- to 3-day count (24 hours) utilizing ATRs and collecting both directions of travel in 15 minute intervals will accommodate the needs of most installations requiring ADT data.

Vehicle-classification counts—These can be obtained from typical automatic recorder data, but can also be performed by manual counts. Manual counts may be performed during any period of interest but should attempt to sample typical traffic conditions with representative percentages of trucks. A classification count may be performed as an integral part of other traffic-volume counts. Exhibit 1.4 shows a typical turning movement vehicle classification field sheet.

In accordance with AASHTO, four general classes of vehicles have been established:

- ✓ **Passenger cars** include compacts, subcompacts, sedans, pick-up trucks, sport/utility vehicles (SUVs), minivans, full-size vans, and motorcycles.
- ✓ **Buses** include inter-city (motor coaches), city transit, school, and articulated buses.
- ✓ **Trucks** include single-unit trucks, truck tractor-semitrailer combinations, and truck tractors with semitrailers in combination with full trailers.
- ✓ **Recreational vehicles** include motor homes, cars with camper trailers, cars with boat trailers, motor homes with boat trailers, and motor homes pulling cars. Additionally, the bicycle should also be considered a design vehicle when its use on a roadway is permitted.

Records should also be made of any tracked vehicles, forklifts or other unconventional military vehicles that pass the count location. Vehicle classifications are different when collected with ATRs. When using ATRs, vehicles are classified based on vehicle length and number of axles, not the four AASHTO classifications given above.

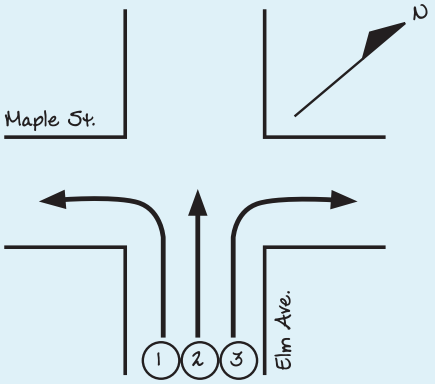
Exhibit 1.4: Turning Movement Vehicle Classification Count Field Sheet (Sample)

Location Maple St. & Elm Ave

Date July 21, 2015

Time 0645 to 0815

Observer LR Smith



Legend:

Group	Vehicle Type
1	Passenger cars (including Recreational Vehicles)
2	Buses
3	Trucks
4	Bicycles

Time	① ↰				② ↑				③ ↱			
	1	2	3	4	1	2	3	4	1	2	3	4
0645 to 0700	𝍸 𝍸 𝍸 | ⑯		||| ③	| ①	𝍸 ⑤	|| ②	|| ②	𝍸 𝍸 ⑩	𝍸 𝍸 𝍸 ⑮		𝍸 ⑤	|| ②
0700 to 0715	𝍸 𝍸 𝍸 ⑮	|| ②	𝍸 ⑤	|| ②	𝍸 || ⑦		|| ②	⓪	𝍸 𝍸 ||| ⑬		|| || ④	𝍸 ⑤
0715 to 0730	𝍸 𝍸 𝍸 𝍸 𝍸 | ㉖		||| ③	| ①	𝍸 𝍸 𝍸 | ⑯	|| ②	| ①	| ①	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 || ㊲		||| ③	| ①
0730 to 0745	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||| ㉝	| ①	𝍸 | ⑥	|| ②	𝍸 𝍸 𝍸 𝍸 𝍸 ㉕	| ①	| ①	| ①	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 (70)		𝍸 | ⑥	𝍸 ⑤
0745 to 0800	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||| ㊳		||| ③	| ①	𝍸 𝍸 𝍸 𝍸 𝍸 | ㉖		| ①	| ①	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 ||| (68)		𝍸 𝍸 ⑩	𝍸 ⑤
0800 to 0815	𝍸 𝍸 𝍸 𝍸 ⑳		| ①	| ①	𝍸 |||| ⑨		| ①	⓪	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 |||| ㉞		||| ③	| ①

Pedestrian counts—Pedestrian counts are usually taken at intersection crosswalks, midblock crossings, or along sidewalks and walking paths. These are performed whenever there is a question about pedestrian flow. Problems could arise where there is a conflict between pedestrian and vehicle traffic, such as at a midblock crossing or at a circulation road within a large parking lot. Pedestrian counts are used for traffic signal and crosswalk warrant studies, safety improvements, capacity analysis, crash studies, traffic control devices, and other planning applications. Pedestrian movements are more vulnerable and require special consideration when evaluating their travel conditions and barriers to travel. They should also be considered as important for accessing other modes of transportation within the installation including transit service.

Bicycle Counts—Bicycle counts are usually taken at intersections or when entering and exiting an installation. Since bicyclists are required to follow the traffic regulations for motor vehicles, typically they will be traveling within the vehicle travel lane. Conflicts can arise between bicyclists and vehicles and identifying volumes can help determine needed accommodations such as bike lanes, to provide a safer travel mode or the location of bike racks for secure storage location.

Entry Control Facility (ECF) counts—The efficient movement of vehicles entering and exiting the military installation through the ECF is critical to the overall operation of the installation. Maintaining security for both military and civilian personnel is the main function of the ECF. Traffic volume counts and vehicle classification counts can be taken within the roadway approach to the ECF to determine traffic flow into and out of the gate facility. Data collected can be analyzed to determine the level of throughput of the facility, number of lanes required to efficiently process the peak hour vehicle entrance and exit demand, level of congestion, length of queuing, delay, and capacity issues to assist in maintaining the required level of security. Refer to Chapter 13 for calculating the existing Demand Volume, as well as the Design Demand Volume, at an ECF. SDDCTEA Pamphlet 55-15 *Traffic and Safety Engineering for Better Entry Control Facilities* provides more in-depth information regarding ECFs.

1.4. ANALYSIS

Data Reduction—The first step is to convert the raw data to a more convenient form. The turning movements for an entire intersection are summarized on a summary data sheet such as the one shown in Exhibit 1.5. This form can also show pedestrian, bicycle, or other classification data relevant to the type of study. The movements for the various time periods are then studied to find the highest “peak” hour (highest four consecutive 15 minute periods) and the highest 15 minute volume, v_{15}, within that peak hour for each approach (See Exhibit 1.6 Peak Hour Turning Movement Diagram).

Exhibit 1.5: Intersection Turning Movement Count Summary (Sample)

Intersection: Liberty Street and US 1

Date: January 21, 2015

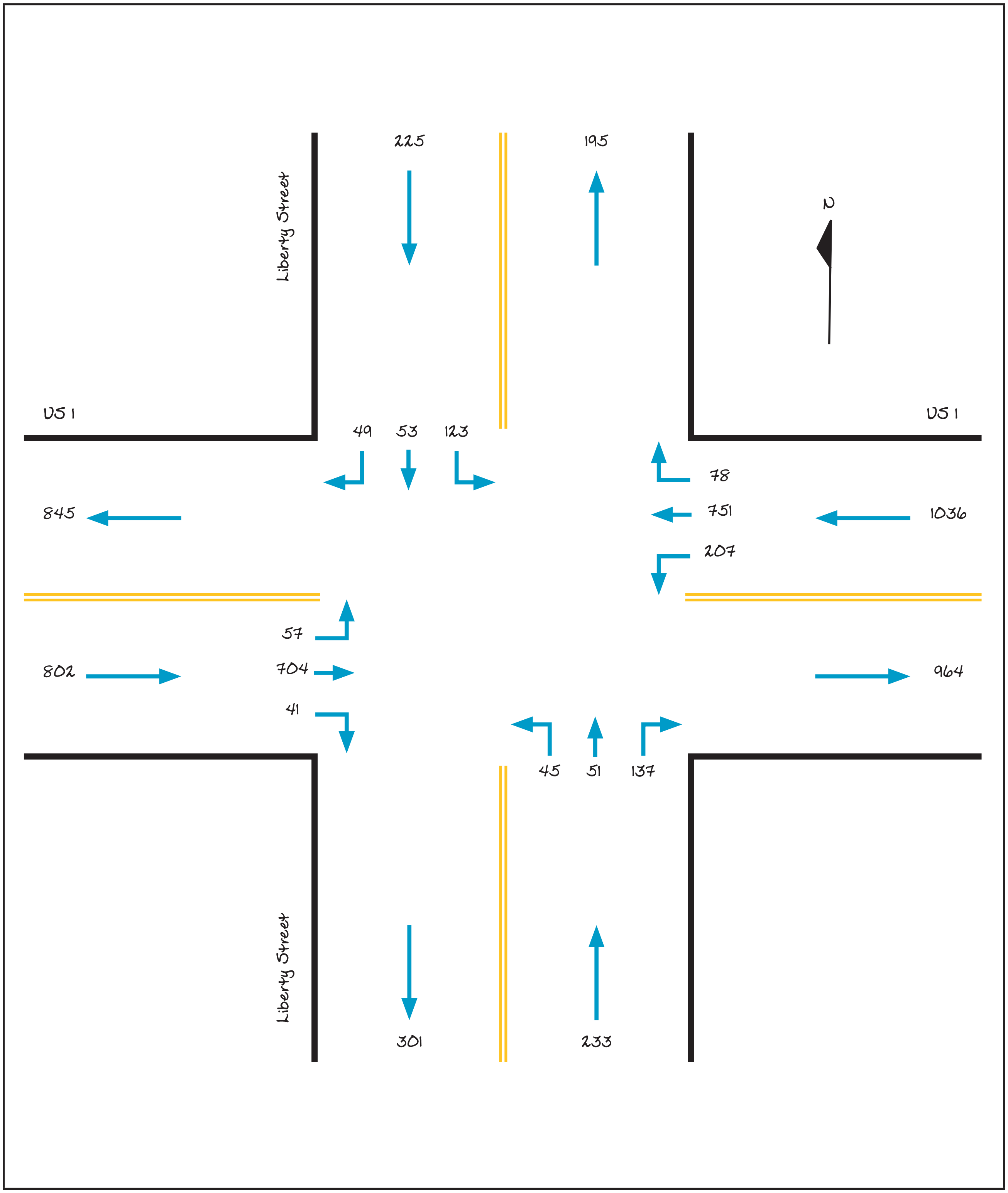
Weather: Dry

Peak hour period = 0630-0730

V, Peak hour volume (vph) = 524

Begin Time	Eastbound				Westbound				Northbound				Southbound				Total
	Oak Street				Oak Street				Apple Avenue				Apple Avenue				
	Left	Thru	Right	Peds	Left	Thru	Right	Peds	Left	Thru	Right	Peds	Left	Thru	Right	Peds	
6:00 AM	3	12	2		7	18	2		1	2	4		2	1	3		57
6:15 AM	3	24	3		16	35	4		3	2	8		8	2	3		111
6:30 AM	8	78	6		29	98	10		5	5	16		15	6	5		281
6:45 AM	10	123	8		32	109	12		8	6	21		21	10	6		366
7:00 AM	9	171	6		34	150	11		9	12	24		23	9	8		466
7:15 AM	6	145	4		27	147	13		6	8	18		23	8	6		411
7:30 AM	4	96	3		19	78	7		5	5	10		11	4	4		246
7:45 AM	3	23	2		15	65	4		2	3	10		8	4	3		142
8:00 AM	3	12	2		8	32	4		2	3	6		4	2	2		80
8:15 AM	3	13	2		7	10	3		3	2	5		2	2	2		54
8:30 AM	3	5	2		5	5	5		1	2	8		3	3	4		46
8:45 AM	2	2	1		8	4	3			1	7		3	2	3		36
Total	57	704	41		207	751	78		45	51	137		123	53	49		

Exhibit 1.6: Peak Hour Turning Movement Diagram (Sample)



Design Hourly Volume Calculation

The highest four consecutive 15 minute interval counts are added together to determine the total peak hour volume. The peak hour factor (PHF) is the ratio of the total hourly volume to the peak flow rate within the hour; where the volume represents the total number of vehicles observed passing a given point, and the flow rate represents the highest number of vehicles passing a point during the 15 minute time interval.

Peak Hour Factor (PHF) is calculated using the following formula:

$PHF = V / (4 \times v_{15})$

Where

V = peak hour volume (vph) (total of the four 15 minute interval counts)

v_{15} = highest peak 15 minute volume (veh/15 min)

Peak-hour factors in urban areas generally range between 0.80 and 0.98. Lower values signify greater variability of flow within the subject hour, and higher values signify little flow variation. The closer the PHF is to 1.00 means that the traffic volumes are constant throughout the peak hour. Peak-hour factors over 0.95 are often indicative of high traffic volumes, sometimes with capacity constraints on flow during the peak hour.

The PHF is used to convert the hourly traffic volume into the flow rate that represents the busiest 15 minutes of the peak travel period. If 15 minute counts are not available, the Highway Capacity Manual (HCM) recommends a PHF of 0.88 for rural roads and 0.92 for urban roads be applied to the hourly volume count data to determine the peak 15 minute period. Using hourly volumes, instead of 15 minute counts, assumes that the arrival rate of vehicles is constant throughout the period of study. Therefore, the use of hourly counts may result in a less accurate determination of the peaking within the hour and risks underestimating the delay actually incurred.

TYPICAL PEAK HOUR FACTORS USING HOURLY VOLUMES

ROAD TYPE	PHF
Rural Roads	0.88
Urban Roads	0.92
High Congestion Roads	0.95

Design Hourly Volume (DHV) is used to determine lane capacity and is calculated from the following formula:

DHV = V / PHF, or
DHV = 4 X v_{15}

Example: Traffic vehicle volume counts were taken during a typical peak hour period at an intersection as indicated in Exhibit 1.7. The four-15 minute interval counts were as follows: 205, 220, 190, and 185. The total peak hour volume is 800 vph.

Exhibit 1.7: Total Peak Hour Volume

TIME (PM)	VOLUME (VEH)
5:00–5:15	205
5:15–5:30	220
5:30–5:45	190
5:45–6:00	185
TOTAL	**800 VPH**

V = the sum of the four 15 min count periods = 800 vph
v_{15} = the highest 15 minute interval volume = 220 veh/15 min (Between 5:15 and 5:30 PM)
PHF = 800 / (4 x 220) = 0.91
DHV = 800 / 0.91 ≈ 880 vph or, DHV = 4 X 220 = 880 vph

Typically, a PHF is calculated for each intersection approach and applied in the analysis software. Therefore, the example given would apply to one approach of an intersection. If necessary, for excessively high volume or extraordinary movements, a PHF can be applied on a per movement basis.

The DHV can be used to determine the number of lanes required at an intersection. Refer to Chapter 13 for calculating the Design Demand Volume (DDV) at an ECF. DHV and DDV are similar in that they both are design volumes.

Data Validation—After the highest hour or peak hour has been determined on the summary sheets, traffic data recorded along the same street and at adjacent intersections are checked for accuracy. For example, if 500 more vehicles were counted at one intersection than at another intersection a block away, there should be an intermediate driveway that caused the variance. If that is not the case, suspect either a counter malfunction or the credibility of the manual count. A recount may be necessary unless there is a viable reason for the discrepancy.

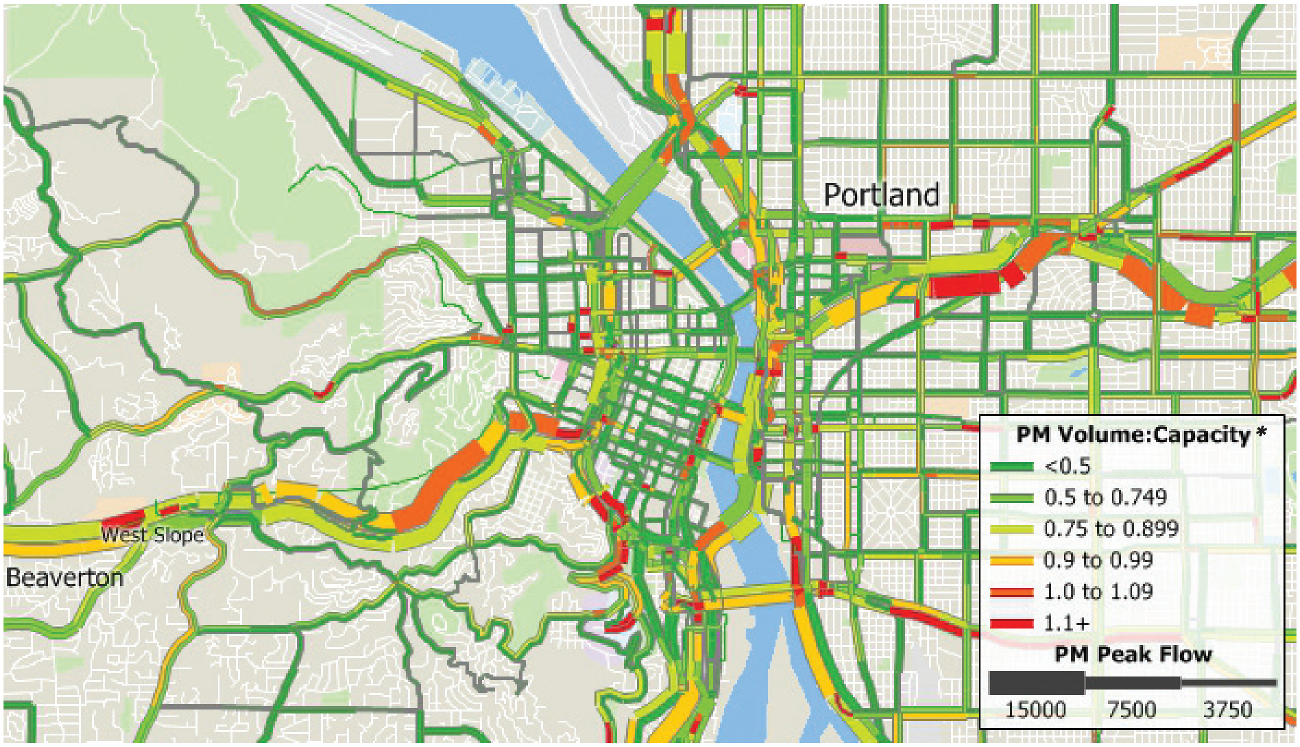
Additional information regarding traffic volume studies can be found in the HCM as well as the ITE MTES. SDDCTEA staff are available and should be contacted for discussion and assistance in conducting necessary intersection capacity studies.

Adjustment Factors—The purpose of an adjustment factor is to modify a volume count to reflect average daily traffic movement for the site in question. The count period should represent the time of day, day of week, or month of year that is of interest in the study. Traffic volumes usually exhibit a predictable day-to-day variation. Typically, traffic counts are conducted on Tuesday, Wednesday and Thursday of non-holiday weeks, as they represent consistent travel period days for the week. Traffic counts taken on highest volume days need not be adjusted. Adjustments may be required when school is not in session, or local troop levels are below their normal levels.

1.5. INTERPRETATION

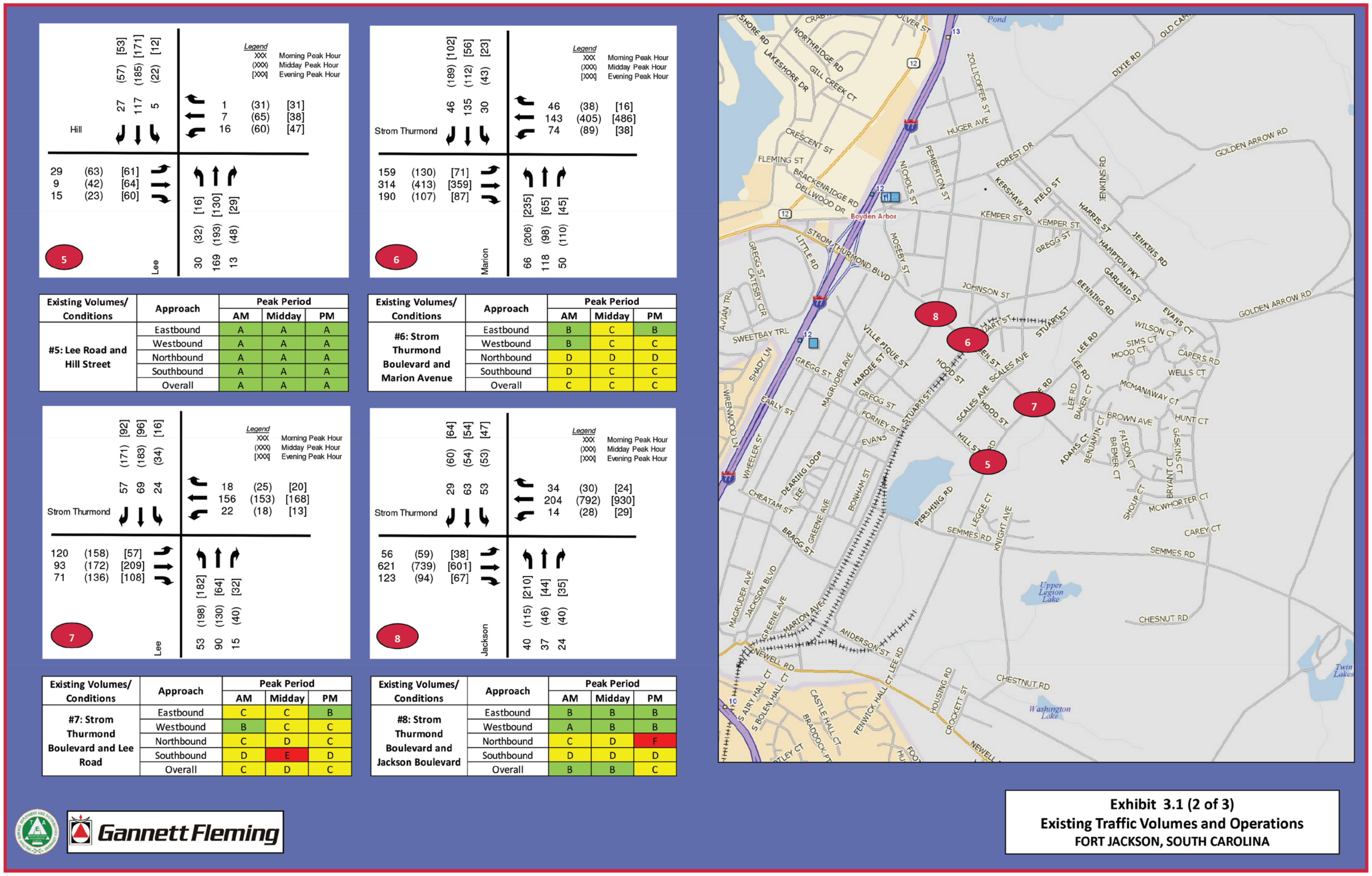
Convenient graphic displays can be developed from the results to assist with interpretation. One such display is shown in the traffic volume flow map, illustrated in Exhibit 1.8, where the band width for each street is proportional to the traffic volume. This type of map simplifies the determination of which routes are more heavily traveled, signifying their importance. A flow map may be prepared showing 24-hour or peak-hour volumes. Exhibit 1.9 illustrates a simpler method for preparing a flow map which utilizes peak-hour volumes and consists of a composite turning-movement diagram. This form lacks the visual emphasis of the Exhibit 1.8 flow map but provides the convenience of showing the turning movements at every intersection.

Exhibit 1.8: Traffic Volume Flow Map



Volume/capacity (v/c ratio) is indicated by the roadway color. The v/c ratio indicates the quality of operation of the roadway. A v/c ratio greater than one indicates volume exceeds the capacity of the roadway.

Exhibit 1.9: Composite Turning-Movement Diagram



Existing Volumes/ Conditions	Approach	Peak Period		
		AM	Midday	PM
#5: Lee Road and Hill Street	Eastbound	A	A	A
	Westbound	A	A	A
	Northbound	A	A	A
	Southbound	A	A	A
	Overall	A	A	A

Existing Volumes/ Conditions	Approach	Peak Period		
		AM	Midday	PM
#6: Strom Thurmond Boulevard and Marion Avenue	Eastbound	B	C	B
	Westbound	B	C	C
	Northbound	D	D	D
	Southbound	D	C	C
	Overall	C	C	C

Existing Volumes/ Conditions	Approach	Peak Period		
		AM	Midday	PM
#7: Strom Thurmond Boulevard and Lee Road	Eastbound	C	C	B
	Westbound	B	C	C
	Northbound	C	D	C
	Southbound	D	E	D
	Overall	C	D	C

Existing Volumes/ Conditions	Approach	Peak Period		
		AM	Midday	PM
#8: Strom Thurmond Boulevard and Jackson Boulevard	Eastbound	B	B	B
	Westbound	A	B	B
	Northbound	C	D	F
	Southbound	D	D	D
	Overall	B	B	C

Exhibit 3.1 (2 of 3)
Existing Traffic Volumes and Operations
FORT JACKSON, SOUTH CAROLINA

Usually peak hours carry about 10 to 15 percent of the day's total traffic. When a higher percentage is observed, it may be an indication that staggered duty hours may help spread the traffic load and reduce congestion.

1.6. APPLICATION

Volumes are basic traffic data and are used in conjunction with other types of data to support all traffic improvement decisions. The following are typical uses for collecting traffic volumes within base installations:

- ✓ To justify installation (or removal) of a traffic signal by comparison with the volume warrants stated in the MUTCD; also, to time the traffic signal cycle correctly and to determine the type of signal equipment required.
- ✓ To evaluate the size or capacity requirements of an intersection.
- ✓ To indicate the need for traffic control signs according to the requirements stated in the MUTCD.
- ✓ To assist in the evaluation of crash data and study the relationship of turning movements to crashes and congestion.
- ✓ To assist in determining the need for use of reversible lanes at ECFs.
- ✓ To compare day and night traffic volumes with their associated crash rates to determine the need for street lighting.
- ✓ To help in the development of a street-classification system such as primary, secondary, and tertiary streets.
- ✓ To evaluate the need for additional capacity to handle high traffic volumes.
- ✓ To facilitate assignment of traffic control police for intersection duty during certain time periods.
- ✓ To indicate long-term growth trends for vehicle usage and for traffic volumes in general.
- ✓ To help establish construction and maintenance priorities.
- ✓ To determine the need for pavement markings, as well as, the required frequency for repainting traffic-worn lines.
- ✓ To help with the analysis of parking demands and to assess the impact of new traffic generators on the surrounding streets.
- ✓ To determine the ideal locations for residential, commercial or military facilities whose location is influenced by passing traffic (service stations, banks, or retail stores, etc.).
- ✓ To determine pedestrian crosswalk warrants/removal.

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CHAPTER 2—INTERSECTION CAPACITY STUDY

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CHAPTER 2—INTERSECTION CAPACITY STUDY

Controlled intersections can greatly impact the desired traffic flow thorough a corridor on a military installation by interrupting vehicle travel rates causing increased congestion and delay. In many cases, improvements to intersection controls (i.e., adjustment of signal timing, additional signing, adding a turn lane, or other specific intersection capacity improvements) will eliminate the need to increase general corridor roadway capacity, thereby improving safety and mobility while saving costs.

In order to perform an intersection capacity analysis, a Turning Movement Count as (presented in Chapter 1) is required to determine the peak hour volume of the subject intersection.

2.1. OBJECTIVE

Intersection capacity studies are commonly used to evaluate traffic flow and to help design and implement improvements. An analysis of intersection capacity throughout the installation can provide information to determine: traffic control devices warranted, intersection congestion, traffic signal timing, site development impacts, and safe speeds. Elements that can influence intersection capacity include: length of queue, turning movement counts, delay, sight distance, pedestrians and signal timing.

Intersection capacity studies can be used for:

- ✓ Identification of points of congestion and their relative severity
- ✓ Determination of the need for and effectiveness of specific improvements to increase capacity
- ✓ Establishment of priorities for street improvements based upon capacity considerations
- ✓ Derivation of criteria for the planning and design of new streets and the modification of existing streets to meet future needs

Intersection capacity can also be used as a performance measure of the effectiveness and quality of installation roadways to serve traffic.

Most traffic delay along roadways is the result of intersections.

2.2. INFORMATION NEEDED

The subject of roadway capacity is complex and involves many factors. It has been the subject of continuing study and research by traffic engineers for many years. This pamphlet provides a general overview of the intersection capacity analysis. The primary reference source is the HCM. Contact SDDCTEA staff for additional guidance on conducting an intersection capacity study.

There are two categories of traffic flow based on the type of facility being analyzed:

- ✓ **Uninterrupted traffic flow** is a condition in which a vehicle traveling a section of road is not required to stop by any cause external to the traffic stream. This type of flow might be found on freeway or expressway facilities, on roads through essentially rural areas, or on roads to ranges and maneuver areas.

- ✓ **Interrupted traffic flow** is a condition more likely to apply to a military installation in which a vehicle traversing a section of roadway is required to stop by a cause outside the traffic stream such as signs and signals or pedestrians. This condition usually occurs at or near intersections.

Although mid-block interruptions and interferences may become so significant that they control traffic flow and capacity, intersections are the usual cause of interruption on most roadways.

There are many physical features that can affect intersection capacity. Data pertaining to the following elements should be collected at a minimum:

Roadway Data

- ✓ Lane width and total approach width
- ✓ Lateral (side) clearance and width of shoulder
- ✓ Auxiliary lanes used for parking, speed change, turning, bus stops, and storage
- ✓ Intersection utilization
- ✓ Surface conditions
- ✓ Alignment
- ✓ Grades
- ✓ 85th percentile speed

Traffic Count Data

- ✓ Percentage of trucks, buses and bikes in the traffic stream
- ✓ Turning movements
- ✓ Variations in traffic flow during peak hours
- ✓ Control measures such as one-way operation, parking restrictions, and turning-movement controls
- ✓ Weaving and merging of traffic flows
- ✓ Traffic interruptions
  - Traffic signals, military police control, and STOP and YIELD signs
  - Volume of cross traffic at intersections
  - Entrance /exit gates

Demographic Data

- ✓ Installation population
- ✓ Characteristics of the study location such as near central business district or in fringe, residential, suburban, or rural areas.

2.3. METHODS

One of the most important elements limiting and often interrupting the flow of roadway traffic is the at-grade intersection. To a large extent, intersections control the capacity of the installation arterial streets. They also seriously affect the ability of installation access roads to perform at maximum efficiency. The capacity of an intersection approach street is the maximum number of vehicles per hour that it can handle under existing physical design conditions, traffic characteristics, and controls.

Intersection delay is a fundamental element in the evaluation of intersection capacity. Intersection delay data can be used to measure the quality of traffic flow at a controlled intersection (i.e., stop sign, roundabout or signalized) and to evaluate the need for traffic signals. Determination of the length of vehicle queue at an intersection, turning movements, traffic counts, and signal timing sequence are data that can be collected for analysis. Data for intersection capacity analysis can be collected manually, or with the more prevalent use of electronic counting boards or other computerized devices (i.e., laptops, tablets or smart phones).

Level of Service—Intersection delay can be used to determine the general level of service of an intersection. There are many factors and combinations of conditions that may occur on a given roadway. Level of service (LOS) is a descriptive measure of the effect that these factors and conditions have on the flow of traffic. The different levels of service reflect the relative differences in traffic interruptions, speed and travel time, freedom to maneuver, safety, driving comfort and convenience, and operating costs that may occur on a roadway under given conditions. LOS can be characterized for the entire intersection, each intersection approach and each lane group. There are six LOS classifications, “A” through “F.” LOS A represents the best case and LOS F represents the worst case.

- ✓ LOS A describes intersection traffic flow with a delay of 10 sec/veh or less. This level is typically assigned when most vehicles consistently move through the controlled intersection within the cycle times. It represents the best intersection traffic flow and would suggest no intersection improvement needed.
- ✓ LOS B describes intersection traffic flow with a vehicle delay between 10 and 20 sec/veh. In LOS B, more vehicles would be stopped causing limited delay. Generally, it is adequate for intersection traffic flow with no improvement needed.
- ✓ LOS C describes intersection traffic flow with a vehicle delay between 20 to 35 sec/veh. It represents more limited traffic flow with some significant delay at times. A LOS C would indicate potential improvements may be warranted to improve intersection capacity.
- ✓ LOS D describes intersection traffic flow with a vehicle delay between 35 and 55 sec/veh. It represents very constrained traffic flow due to inconsistent traffic interruptions and longer vehicle queues. LOS D would signify a need to improve the intersection operations.
- ✓ LOS E describes intersection traffic flow with a vehicle delay between 35 and 80 sec/veh. It represents significant traffic flow interruptions with lengthy vehicle queues. LOS E indicates a strong need to improve the intersection capacity.
- ✓ LOS F describes intersection traffic flow with a vehicle delay exceeding 80 sec/veh. It represents an unacceptable operating condition for most drivers. LOS F would indicate significant intersection operational improvement needed to provide adequate capacity.

Generally, the peak hour traffic flow in urban areas should be designed for intersection LOS D or above and the peak hour traffic flow in rural areas should be designed for intersection LOS C or above. LOS D is for the future 20 year, or so projected, operation. In all cases, no individual lane group of "F" will be accepted.

Intersections within installations should be designed for LOS D or above.

The HCM is the most recognized reference source used to analyze intersection capacity based on delay. The HCM contains material to be used for determining the effect (individually or collectively) of the above-mentioned factors on the capacity of a given roadway. The current HCM (2010) relies on capturing traffic data with electronic recording devices and the use of computer software packages to analyze the traffic information. Older versions of the HCM presented formulas for manually calculating LOS, but this was acknowledged as being obsolete with the current version. Formulas for calculating LOS are no longer provided in the HCM. Software, such as *Synchro* and *Highway Capacity Software* (*HCS*), or other capacity software is readily available to provide various results for consideration of intersection improvement alternatives. Both of these software programs are updated frequently; however, the current versions as of the publication date of this pamphlet are Synchro 9 and HCS 6.5.

Intersection Capacity Utilization (ICU) is another method of evaluating the capacity of an existing intersection and is intended to provide information for transportation planning purposes; such as future roadway design, traffic impact studies, and congestion management programs. The ICU method provides a value that can be used to draw macro level conclusions on the remaining capacity, or reserve capacity, that is available or how much the intersection is overcapacity. The ICU uses a grading system to rank the intersection being studied on a scale of A to H, with A being a condition of no congestion and a large capacity and H being over capacity with long periods of congestion. The ICU is not intended for operations and signal timing design. The data needed for the ICU analysis includes volumes, number of lanes, saturated flow rates, signal timings, cycle length, minimum green time and intersection geometry. The calculation and grading of ICU is best provided by computer software utilizing common software programs that are available such as Synchro.

This material presents a relatively simple method for determining intersection capacity which is of sufficient accuracy for use in traffic studies that require this type of analysis, and represents typical conditions that generally prevail on a military installation. Additional information regarding intersection capacity analysis can be found in the HCM, as well as the ITE MTES. SDDCTEA staff are available and should be contacted for discussion and assistance in conducting necessary intersection capacity studies.

2.4. ANALYSIS

There are various types of intersection delay used to evaluate the capacity of both signalized and stop controlled intersections. The primary reference source for computing intersection delay is the 2010 HCM. Delay can be measured in relation to the LOS of the intersection to help determine capacity issues. Control delay is the component of delay that results when an intersection control (i.e. signals or stop signs) causes vehicles in a lane to reduce speed or to stop. It is considered a measure of the quality of the intersection service. Control delay is measured by comparison with the uncontrolled condition and quantifies the increase in travel time due to intersection control. It is defined as the difference between the time a vehicle joins the rear of a queue and the time the vehicle clears the intersection including the incremental time due to deceleration and acceleration. The estimation of delay is complex due to random arrival of vehicles, lost time due to stopping of vehicles, over saturated flow conditions and driver behavior. Delay measures can be stated for a single vehicle, as an average for all vehicles over a specified time period, or as an aggregate total value for all vehicles over a specified time period. It can be measured for single intersection approach, a combination of intersection approaches, or the overall intersection. Control delay at an intersection is measured in vehicle-seconds.

Overall intersection delay cannot be calculated at a 2-way stop controlled intersection since the through movement and right-turn movement for the non-stopping roadway does not have any delay. Delay on stopped approaches is calculated based on gap acceptance. Based on the HCM, control delay at a stop-controlled intersection is calculated using the following formula:

$$d = t_s + 900T\left[(x-1) + \sqrt{(x-1)^2 + \frac{h_d x}{450T}}\right] + 5$$

Where:

d = average control delay (sec/veh)
$x = vh_d/3600$ = degree of utilization
ts = service time (sec)
h_d = departure headway (sec)
T = length of analysis period (hr)

Control Delay at a signalized intersection is the sum of following delay components:

Control Delay (d) (sec/veh) = Uniform Delay (d_1) + Incremental Delay (d_2) + Initial Queue Delay (d_3)

Where:

Uniform Delay (d_1) is the delay that occurs when arrival vehicle demand in the lane group is uniformly distributed over time.

Uniform Delay can be calculated though the following formula:

$$d_1 = \frac{0.5C(1-g/C)^2}{1-\left[min(1,X)g/C\right]}$$

Where:

c = lane group capacity (veh) = s / (g/C)
s = adjusted saturation Flow Rate (veh/hr/lane)
g = effective green length (sec)
C = cycle length (sec)
X = volume/capacity (v/c) ratio for lane group

Incremental Delay (d_2) is the delay that occurs when vehicle arrivals are random.

Incremental Delay can be calculated through the following formula:

$$d_2 = 900T\left[(X-1)+\sqrt{(X-1)^2+\frac{8kIX}{cT}}\right]$$

Where:

T = duration of analysis Period (hrs)
K = delay adjustment factor that is dependent of signal controller mode
I = adjustment factor

Initial Queue Delay (d_3) is the delay that occurs due to signal cycle failures.

Initial Queue Delay can be calculated through the following formula:

$$d_3 = \frac{3,600}{vT}\left(t_A\frac{Q_b+Q_e-Q_{eo}}{2}+\frac{Q_e^2+Q_{eo}^2}{2c_A}-\frac{Q_b^2}{2c_A}\right)$$

Where:

t_A = adjusted duration of unmet demand in the analysis period (h)
v = demand flow rate (veh/hr)
C_A = lane group capacity (veh)
Q_b = initial queue at start of analysis period
Q_e = queue at the end of the analysis period (veh)
Q_{eo} = queue at the end of the analysis period when v, C_A and $Q_b = 0.0$ (veh)

Note that these formulas are shown here to highlight the complexity of the calculations. In practice, software is used to perform capacity analyses. Additional information to derive the components of control delay are referenced in the 2010 HCM, Signalized Intersections (pg. 18-1), and All-Way Stop Control Intersections (pg. 20-1).

Control Delay can be used to estimate the LOS for a single lane group, i.e. a right or left turn lane, or multiple lanes within a signalized intersection or an all-way stop-controlled intersection. The calculated control can be related to thresholds established for the various LOS designations, as shown in Exhibit 2.1, and used to determine the general LOS for an intersection. As noted earlier, intersections within installations should be designed for LOS D or above for the future 20-year (or so projected) operation.

Exhibit 2.1: Thresholds for Control Delay at Intersections

CONTROL DELAY (SEC/VEH)	LOS
LESS THAN 10	A
10-20	B
20-35	C
35-55	D
55-80	E
GREATER THAN 80	F

Source: HCM 2010

Data collection to capture intersection delay should be performed during periods of congestion. Typically, the peak delay occurs during the peak hour, which can be identified from the traffic counts. The peak delay may occur during the major street's peak hour or during the minor street's peak hour, so care should be taken when determining the study time period. In some cases, both time periods need to be studied to determine the peak delay hour. It may be desirable to start the delay study 30 minutes before the beginning of the peak hour and end it 30 minutes afterwards to ensure that the peak delay is recorded.

Additional information regarding intersection capacity analysis can be found in the HCM. SDDCTEA staff are available and should be contacted for discussion and assistance in conducting necessary traffic volume and intersection capacity studies.

2.5. APPLICATION

Several practical improvement alternatives resulting from intersection capacity studies include:

- ✓ Provision for auxiliary lanes
- ✓ Prohibition of turning movements
- ✓ Improvements in Intersection control type
- ✓ Changing from two-way to one-way-traffic movement
- ✓ Improvements in traffic-signal timing and phasing
- ✓ Improvements required for site development

The determination of the amount of additional capacity to be obtained from each of the above improvements is indicated in the HCM.

Future Traffic—The traffic capacity of an existing intersection may be compared with the traffic volumes projected for some future date. The comparison will provide information necessary to determine what improvements will be required for the intersection to operate at an acceptable LOS. Capacity analysis of projected traffic volumes may also be used to determine the design standards for improvements.

Project Comparison—Traffic improvement projects may be ranked according to the potential increase in capacity per dollar expended.

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CHAPTER 3—CRASH STUDY

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CHAPTER 3—CRASH STUDY

3.1. OBJECTIVE

Crashes are studied in an attempt to improve roadway safety within the base installation. Information and analysis from a study of crash history is used to prevent future crashes by application of traffic control devices, law enforcement, driver education, and safety-oriented traffic engineering.

Factors contributing to crashes can be listed in three general categories:

Human—including age, judgment, driver error, skill, attention, fatigue, experience and sobriety

Vehicle—including design, manufacture, and maintenance

Roadway/Environment—including geometric alignment, cross-section, traffic control devices, surface friction, grade, signage, weather, and visibility

This type of study should be conducted by properly trained personnel. This chapter describes the general procedures and information necessary for conducting a crash study but is not intended to be a “how to” manual for crash analysis. However, it is critical that installations collect the necessary data (as detailed in this chapter) in a crash report when a crash occurs. This is the basis for conducting a crash study. Refer to SDDCTEA Pamphlet 55-17, Chapter 12, for more information regarding crash analysis. If needed, contact SDDCTEA as crash study conduction is a service they provide.

3.2. INFORMATION NEEDED

The basic data required for a crash study are:

Crash Data—The information from a crash report describes the overall characteristics of the crash and consists of crash location, date and time, crash severity, crash type and basic information about the roadway, environment, vehicles and people involved.

Facility Data—The physical characteristics of the crash site include basic information about the roadway classification, number of lanes, road names, area type, traffic control, and lane configurations.

Traffic Volume Data—Traffic volume information generally required is the ADT for the roadways involved and possibly vehicle miles traveled (VMT) and total entering vehicles of an intersection. Other data may include pedestrian and bicycle counts.

The basic procedures necessary to perform a crash study are:

- ✓ Examine **crash reports** to determine crash attributes, including the contributing circumstances to each crash.
- ✓ Identify and **select location** of intersections and roadway segments with a relatively high number of crashes. Review available collision diagrams to determine crash details.

- ✓ Conduct a **field review** to assess the selected locations. The crash data should always be supplemented by field observations, particularly during the hours when most crashes have been reported.
- ✓ Identify and **analyze** common attributes in these crashes.
  - Human factor examples include driver distraction, alcohol use, speeding, and non-use of safety belts.
  - Infrastructure examples include roadway geometry, design features, and traffic volume.
  - Identify other intersections and roadway segments on the network that have similar roadway features. Examples may include curves, intersections with poor sight distance, and high traffic volume.
- ✓ **Implement improvements**, as appropriate, at identified locations to reduce the potential crashes.
  - Document the change in crash rate (i.e., after-action documentation)

Crash Report—Crash reports should be collected and summarized in an orderly fashion. They are usually filed in the office of the provost marshal, security police, or installation safety office. It is important to note that all crash reports should be properly saved and stored for potential evaluation or inclusion in future crash studies. Accurate reports of crash types should be filed with personally identifiable information (PII) easily detached. Since traffic crashes are relatively rare events when considering the number of potential conflicts that could occur, the crash study should cover at least a 3- to 5-year time period to be statistically significant. A crash report should contain all the pertinent data regarding the crash including:

- ✓ Location of Crash—The location of the crash should be properly identified with the installation name, street names or route designations of roadway(s) involved, and identifying landmarks.
- ✓ Day of the week and time of day—Definite patterns of crash occurrence develop at most installations. The day and time are used to identify these patterns. Differentiating between daylight and darkness is a minimum requirement.
- ✓ Severity of crash—Note whether the crash involves property damage only (PDO), injuries (I), or fatalities (F).
- ✓ Type of vehicle—Describe the vehicles involved; i.e., civilian vehicle, military vehicle, truck, bus, bicycle, or other. Indicate any pedestrian involvement.
- ✓ Description of crash—Describe the action of involved vehicles or persons. It is important to know what each was doing immediately prior to the crash to develop crash patterns (going straight, turning right or left, or stopped). The type of roadway segment (e.g., four-lane highway, two-lane arterial, etc.) and roadway features (e.g., signalized intersection, curve, tangent, etc.), as well as, direction of vehicle(s) travel should be noted. A sketch or "Collision Diagram" of the crash to show movement and vehicle positions is also important. Note type of weather and other unusual circumstances (rain, snow, fog, road construction, alcohol or drug involvement, or other contributing circumstance).

A military crash reporting form can be used to document each crash. The DA 3946 Military Police Traffic Accident Report , as included in Appendix B, can be found at the following web address: http://www.apd.army.mil/pub/eforms/pdf/A3946.pdf

3.3. METHODS

There are various procedures used to identify hazardous locations on installation roadways due to higher frequency of crashes that may warrant more detailed analysis including, crash frequency, crash averaging, trend analysis, crash severity, and hazardous roadway features inventory methods. The method described in this chapter is the crash rate method. The steps and procedures will consist of summarizing data, performing follow-up field checks of the high-crash-frequency locations, and developing potential measures to reduce crash occurrence in the future. These procedures are explained under the analysis portion of this section. Refer to the AASHTO HSM for additional information regarding crash analysis procedures.

As part of all crash studies, SDDCTEA recommends that a Road Safety Assessment (RSA) be performed. An RSA is a formal safety performance examination of an existing or future road or intersection by an independent audit team. It qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety for all road users. RSAs require 5 years of previous crash data to include in the assessment. SDDCTEA staff are available to provide direction and assistance for an RSA or other crash analysis methods.

3.4. ANALYSIS

Identify High-crash Frequency Locations—Crash data collected should be analyzed and reviewed to identify the amount and locations of crashes within the installation. The frequency of crashes, or crash rate, is one of the simplest forms of crash data analysis. It is defined as the number of crashes occurring within a specific corridor, on a roadway segment, or at an intersection. Multiple crashes occurring at the same location over a period of time may be an indication of a safety issue and should be investigated and addressed appropriately.

As a starting point, for determining high-crash frequency locations list all intersections with three or more crashes per year in descending order, placing the locations with the highest number of crashes at the top of the list. Normally, locations with five or more property-damage crashes per year, three of more injury crashes per year, or one or more fatal crashes deserve further study. If the listing indicates that 10 or less locations fall into this category, use 4 or more crashes per year as the standard to designate high-crash-frequency when analyzing for high-crash-frequency intersections.

Crash Rate—The crash rate is the number of crashes that occur at a given site during a certain time period. The crash rate is calculated to determine relative safety of the location being studied compared to other similar roadways, segments, or intersections. Crash rates are used as a tool to identify and prioritize sites in need of modification and for evaluation of the effectiveness of treatments. Typically, those sites with the highest crash rate or with rates higher than certain thresholds are analyzed to reduce potential crashes. The benefit of crash rate analysis is that it provides a more effective comparison of similar locations with safety issues. This allows for prioritization of these locations when considering safety improvements. The crash rate should be listed in terms of crashes per one million vehicle-miles.

Based on FHWA requirements, the equations used to calculate an annual crash rate are as follows:

Intersection Crash Rate:

$$\mathbf{R = \frac{1,000,000 \times C}{365 \times N \times V}}$$

Where

R = Crash rate for the intersection expressed as crashes per million entering vehicles (MEV).
C = Total number of intersection crashes in the study period.
N = Number of years of data.
V = Traffic volumes entering the intersection daily.

If, for example, an intersection were being assessed with the following values:

C = 5 total crashes over the past 5 years.
N = 5 years of data.
V = 1,500 entering vehicles per day.

The resulting intersection crash rate would be:

$$R = \frac{1,000,000 \times 5}{365 \times 5 \times 1,500} = 1.82 \text{ crashes per million entering vehicles}$$

Depending on the details of crash reporting methods and crash history in a particular installation, a value of 1.82 may or may not be cause for additional study. The most appropriate use of this crash rate is to determine the relative safety of an intersection when compared to similar intersections within a specific area.

Road Segment Crash Rate:

$$\mathbf{R = \frac{100,000,000 \times C}{365 \times N \times V \times L}}$$

Where

R = Crash rate for the road segment expressed as crashes per 100 million vehicle-miles of travel (VMT).
C = Total number of crashes in the study period.
N = Number of years of data.
V = Number of vehicles per day (both directions).
L = Length of the roadway segment in miles.

Low-Volume Rural Roads—One limitation of crash rates for low volume roads is the sensitivity of the formula to low traffic volume. The crash rate calculation is not as beneficial at low volumes as it is with higher volume roads, as small changes in the number of vehicles results in a disproportionate change in the crash rate for the segments that in reality operate similarly. Where traffic volume data is unavailable, the length of the roadway segment can be used to factor in the level of exposure on each route. For low-volume rural roads (such as range roads), comparing the number of roadway departure crashes per mile can assist in identifying potential opportunities to improve safety.

The formula to calculate a Roadway Departure crash rate for a rural road segment (*by route length rather than VMT*) expressed as "crashes per mile" is as follows:

$$R = \frac{C}{(N \times L)}$$

Where:

R = Crashes per mile for the road segment expressed as crashes per each 1 mile of roadway per year.
C = Total number of crashes in the study period.
N = Number of years of data.
L = Length of the roadway segment in miles.

For example, two roadways have the same number of crashes but different roadway lengths.

Roadway Departure Crash Rate Calculation by Route Length:

ROADWAY	RD CRASHES (C)	YEARS OF DATA (N)	SEGMENT LENGTH (L)	CRASHES PER MILE (R)
ROUTE A	10	5	17 miles	0.11
ROUTE B	10	5	25 miles	0.08

In this example, Route A has experienced 0.11 crashes per roadway mile. Route B has experienced 0.08 crashes per mile of roadway. In this case, even though both routes have the same number of crashes, Route A may be more susceptible to future crashes. Therefore Route A may be a more promising candidate for safety treatments.

Knowledge of the severity of crashes on an installation can also assist practitioners in determining their safety needs. For example, the frequency of crashes at intersections may be higher than at segment curves, but in many cases the segment curve crashes are more severe. In addition, if two similar locations had the exact same number of crashes, it may be appropriate to select the location with more severe crashes to address first.

Exhibit 3.1: Typical High-Crash Roadway Sections (Sample)

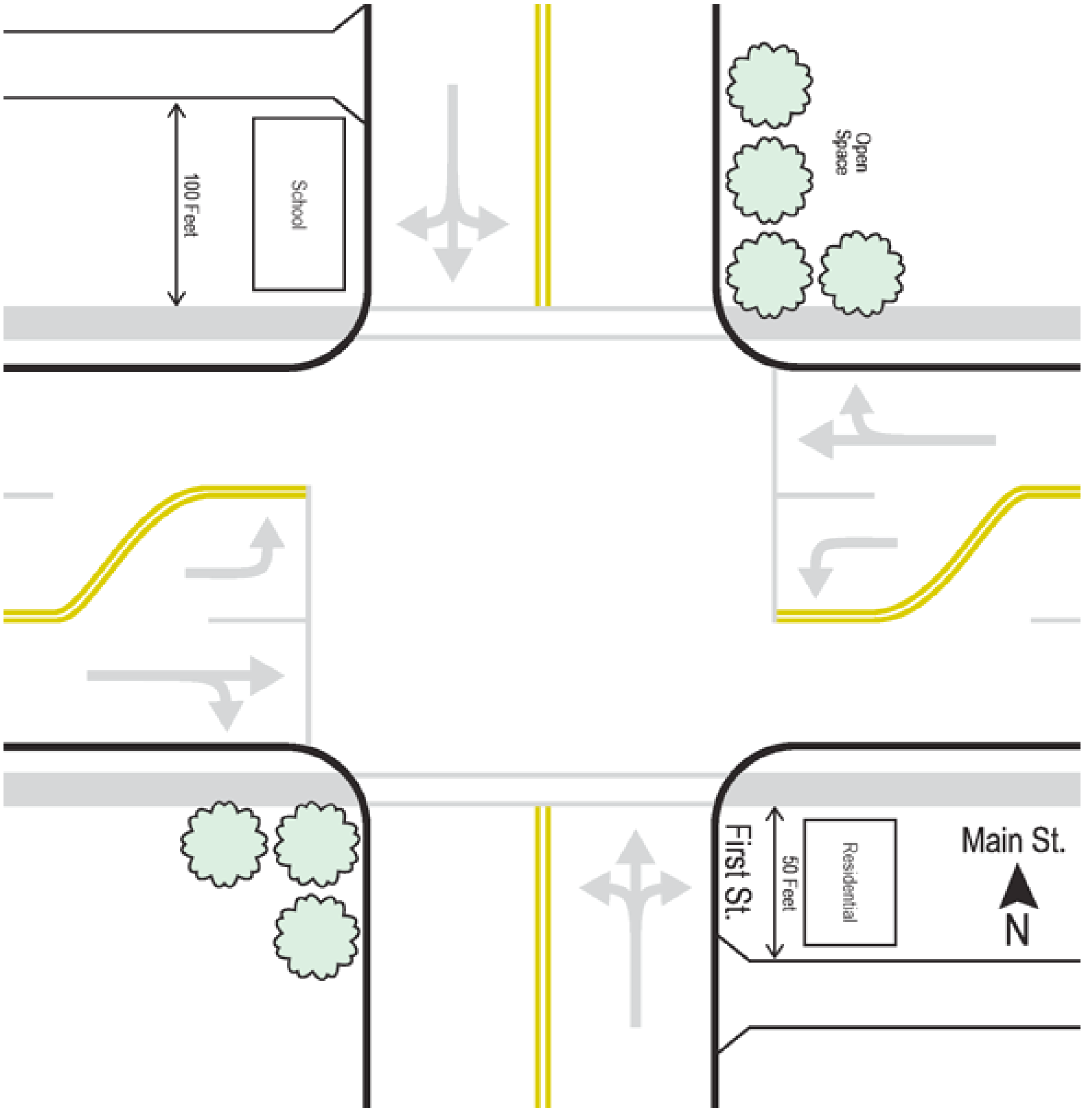
ROADWAY SECTION	LENGTH (MILES)	C (NO. OF CRASHES)				V (VEHICLES PER DAY)	ANNUAL VEHICLE TRAVEL (100 MILLION VEH-MILES)	R (CRASH RATE)
		PDO a/	I b/	F c/	TOTAL	AVERAGE DAILY TRAFFIC		CRASHES PER 100 MILLION VMT
A ST. (1ST TO 5TH)	1.0	20	8	0	28	15,000	0.055	509
A ST. (5TH TO 14TH)	2.2	32	4	1	37	9,000	0.072	513
C ST. (4TH TO 12TH)	2.0	16	6	0	22	5,000	0.036	611
E ST. (12TH TO 19TH)	1.8	4	1	1	6	1,000	0.007	857

a/PDO—Property damage only
b/I—Injury
c/F—Fatality

Assigning crash rates to various intersections or roadway segments within the installation will help identify those crash locations that should receive priority for analysis and possible implementation of safety improvements. The section of roadway for which the rate is calculated should be a section of reasonable length (l/2-mile or longer), which has similar characteristics in terms of traffic volumes, number of lanes, and adjacent development. The traffic volume used is the average for the section if more than one count is available. The Typical High-Crash Roadway Sections Table shown in Exhibit 3.1 indicates a sample format for summarizing the results of these calculations for high-crash-frequency sections of roadways on an installation, or for any high-volume roadways on an installation, in order to identify the sections with high-crash-frequency rates. After high-crash-frequency sections have been determined for further study and improvements have been made, then remaining crash sections with lower rates should be listed in descending order and improvements should be made at all locations, especially at locations where there appears to be a reasonable chance of potential crash reductions.

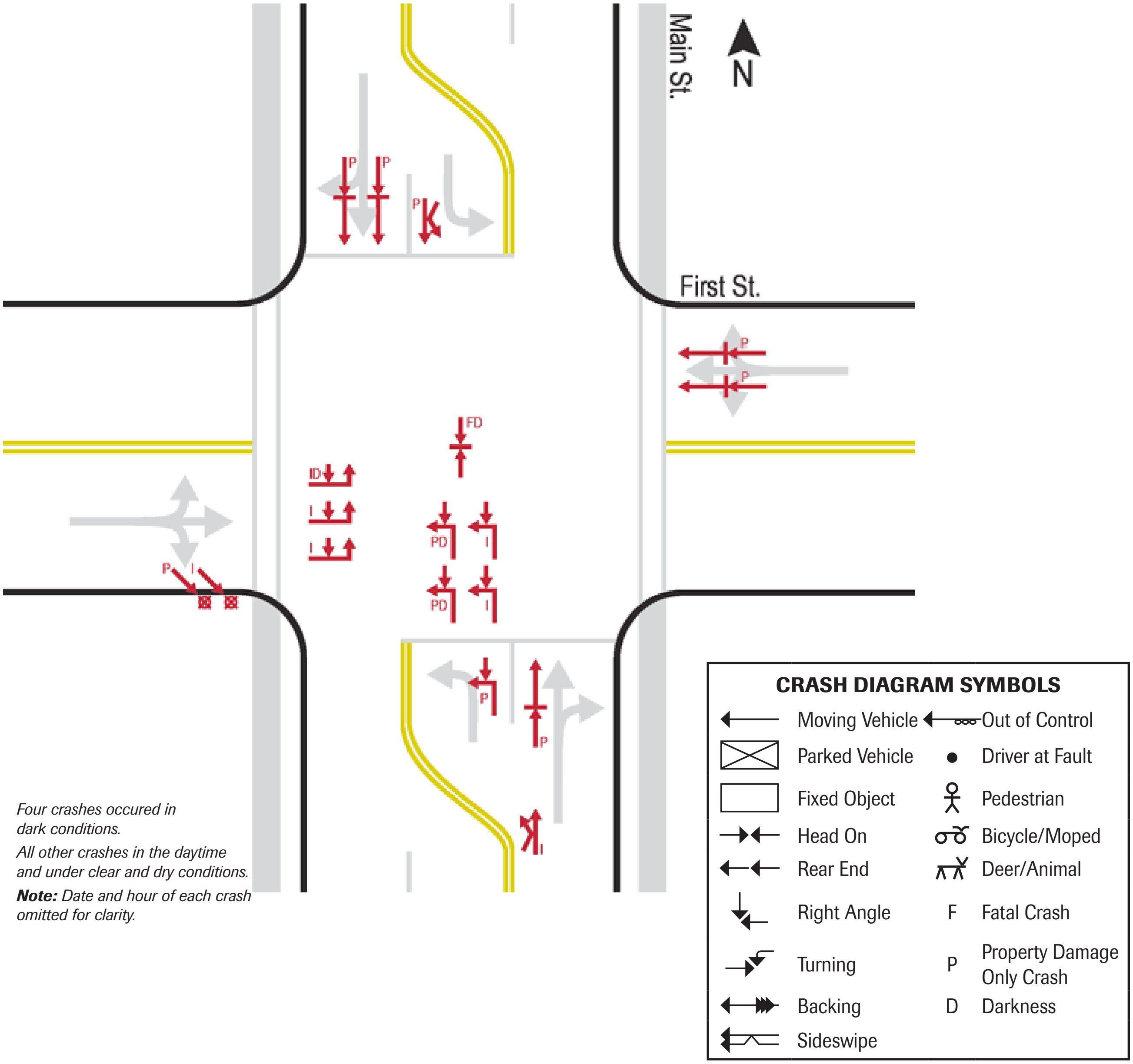
Condition Diagram—In all areas where crashes occur in large numbers or where certain types of crashes occur frequently, a field investigation should be made. A condition diagram shown in Exhibit 3.2 can be constructed to show existing physical conditions. Such a diagram should include roadway grade, curvature, shoulder width, view obstructions, sidewalks and driveways, property lines, type and condition of pavement, signals, signs and pavement markings, bridges, overpasses, culverts, street lighting, sight distance, and types of occupancy of adjacent property. An aerial photograph can serve much of the purpose of the condition diagram, particularly when supplemented with ground-level photographs taken on each approach looking toward the point of interest.

Exhibit 3.2: Condition Diagram



Crash Diagram—Crash diagrams are a technique to graphically illustrate crash data associated with a given site. This summary technique is one of the most valuable tools in analyzing problem intersections or roadway sections. Crash diagrams are developed to illustrate where concentrations (or "clusters") of collisions are located. Each crash is plotted on a schematic of the site at the approximate location where the crash occurred. A sample crash diagram is shown in Exhibit 3.3.

Exhibit 3.3: Crash Diagram (Sample)



Four crashes occured in dark conditions.

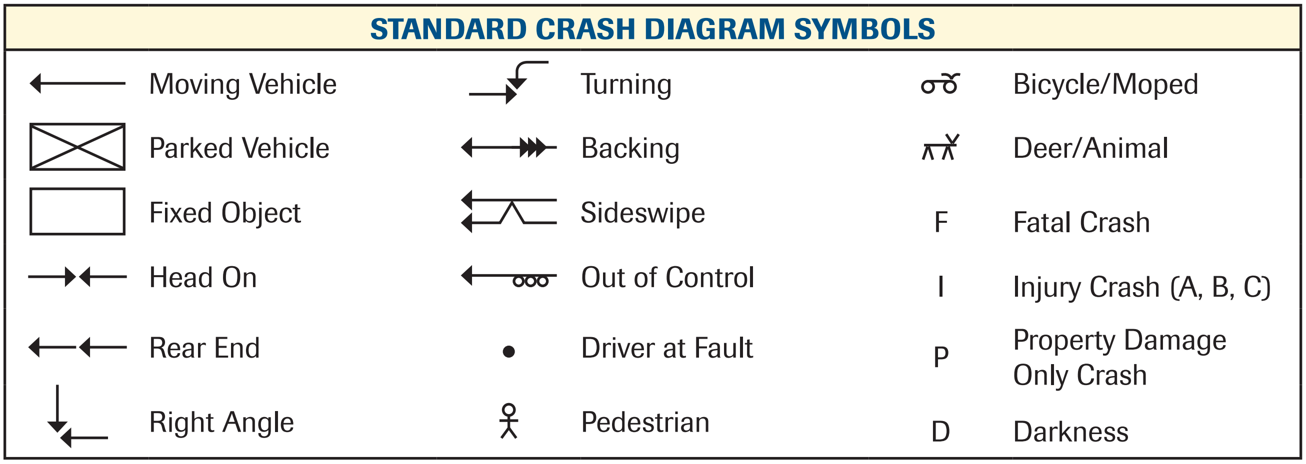
All other crashes in the daytime and under clear and dry conditions.

Note: *Date and hour of each crash omitted for clarity.*

Source: FHWA

Standard crash diagram symbols, as shown in Exhibit 3.4, are used to indicate the movement of each involved vehicle and crash types so that patterns are identifiable.

Exhibit 3.4: Standard Crash Diagram Symbols



STANDARD CRASH DIAGRAM SYMBOLS

	Moving Vehicle		Turning		Bicycle/Moped
	Parked Vehicle		Backing		Deer/Animal
	Fixed Object		Sideswipe	F	Fatal Crash
	Head On		Out of Control	I	Injury Crash (A, B, C)
	Rear End	●	Driver at Fault	P	Property Damage Only Crash
	Right Angle		Pedestrian	D	Darkness

The path of each vehicle should be represented by a solid line, and that of each pedestrian by a dotted line. The date and hour should be written beside each arrow. Unusual weather, road conditions, and pedestrian or driver conditions should also be noted on the diagram.

The location of historical crashes involving vehicles, pedestrians and bicycles, within the installation should be documented on a map of the installation showing all roadways, intersections and parking areas. Typically, this map is maintained by the base security office. A hard copy map denoting crashes by marks or pins can be utilized to plot crashes.

Sometimes additional details can be helpful when placed on the location map. This is done for the purpose of specifying what types of crashes occurred at what place. For example, designation of clusters of left-turn, rear-end, and fixed-object crashes can be helpful in establishing exactly what kind of improvement is needed. Many roadway crash statistics and location maps show clusters of fixed-object crashes at some locations involving horizontal curves.

Traffic volume and travel information are also helpful in reviewing the crash diagram to consider measures to reduce crashes. By preparing crash diagrams after an improvement is constructed (such as a turn prohibition or sight-distance improvement) that covers a period equal to the before period, the effect of the change on crash occurrence may be measured.

Crash diagram computer software programs and web based crash template applications (such as, accidentsketch.com and accidentdiagram.com) are available to record crash data as shown in Exhibit 3.5.

Exhibit 3.5: Crash Data Template

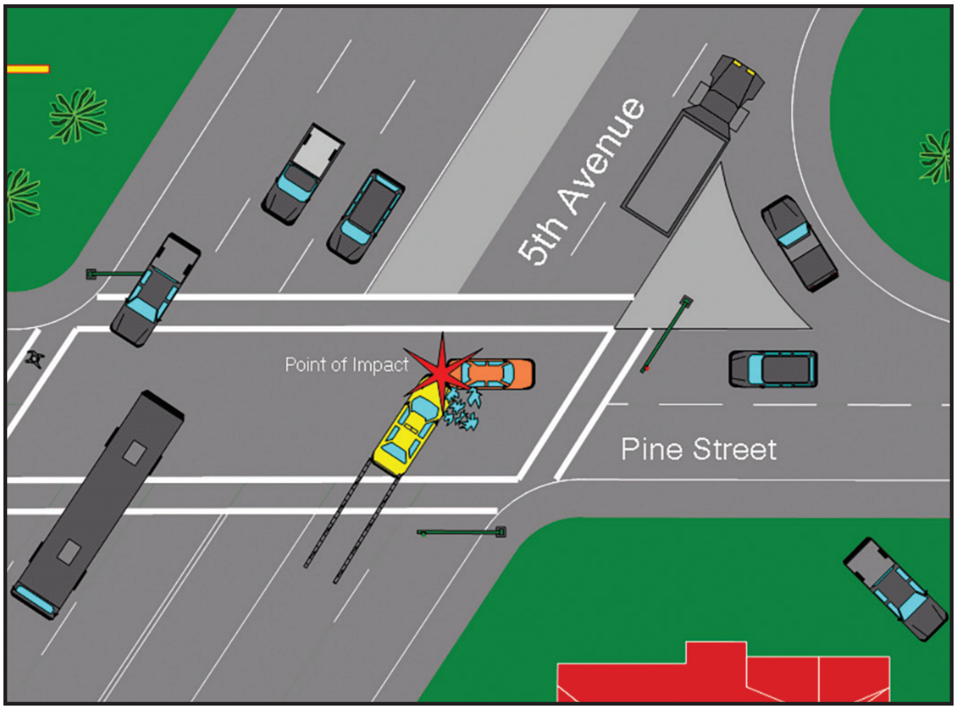
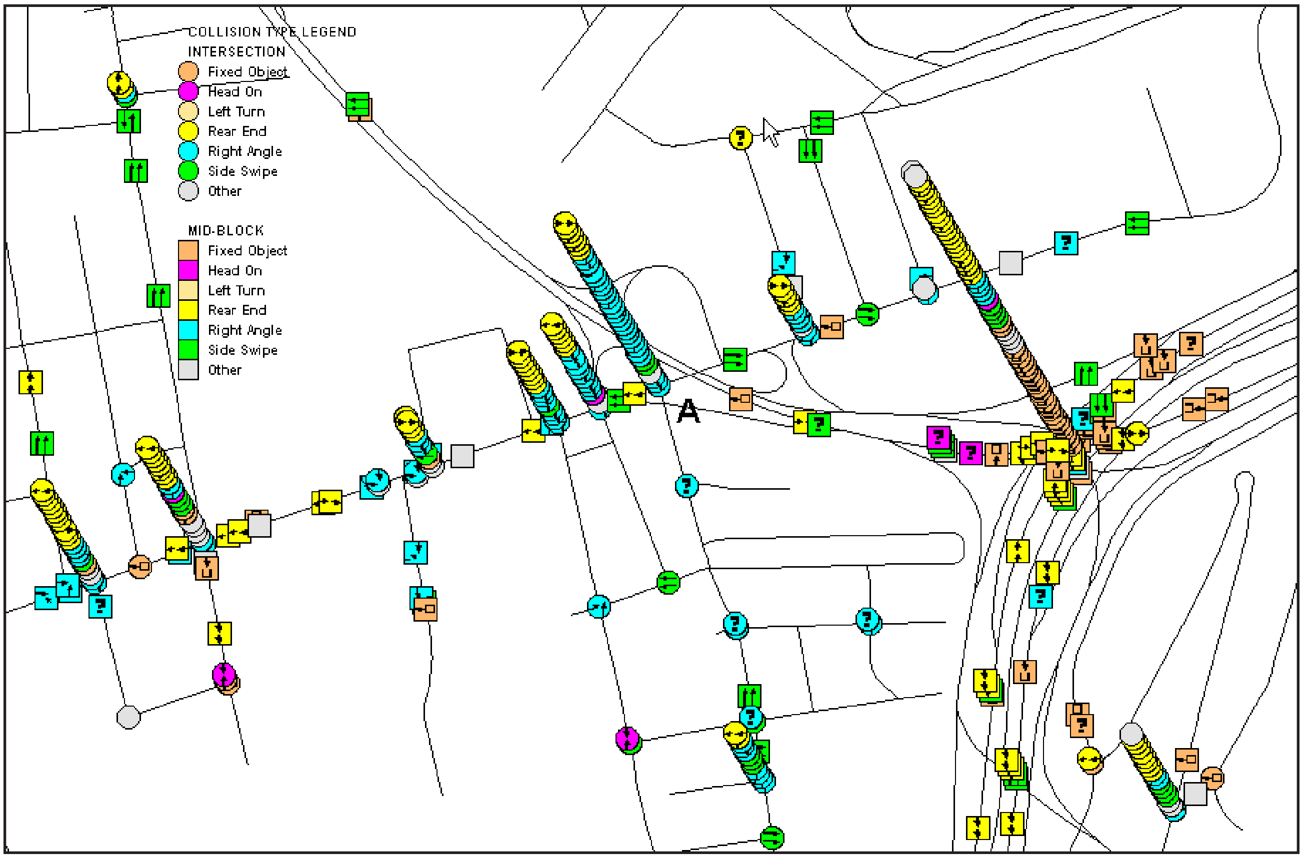


Exhibit 3.6: Sample GIS Crash Map



Geographic Information Systems

Geographic Information Systems (GIS) can be used to help display and analyze crash data as shown in Exhibit 3.6. It is a technology for managing and processing locational and related information. One of the most important benefits of GIS is its ability to graphically represent a large amount of data on a single map. Various crash data including type of crash, number of crashes, injuries and fatalities, crash rate/frequency, location, crash diagrams, roadway geometry, traffic volumes, weather, etc., can be digitized and geocoded in a GIS database and graphically depicted as layers on a map with specific data provided in a drop down box. The maps allow crashes to be represented in multiple ways such that, for example, crash locations with high numbers of crashes can be easily identified. GIS can be used to analyze various types of data in combination with crash data to identify crash patterns, crash clusters, crash causes and severity, roadway obstructions, and road segment and network/corridor safety. This can result in an important method to identify locations that can be correlated with existing roadway geometry and features such as crossroads, curves, and railroad grade crossings that should be given priority for traffic safety improvements. GIS visually displays the results of analyses thus enabling more in-depth analysis and decision making. If the installation does not maintain a crash map, it will be necessary to prepare a crash listing by going through the crash report files.

Road Safety Assessment

A Road Safety Assessment (RSA) is a formal safety performance examination of an existing or future road or intersection by an independent audit team. SDDCTEA recommends conducting an RSA as part of a crash study to identify potential deficiencies that may exist within the crash location regarding roadway geometrics, signing or pavement markings, etc. It is important that a field review of the crash site be conducted in combination with the review of crash data, records and history to fully evaluate opportunities for the implementation of safety improvements. SDDCTEA staff are available to provide direction and assistance for an RSA.

3.5. INTERPRETATION

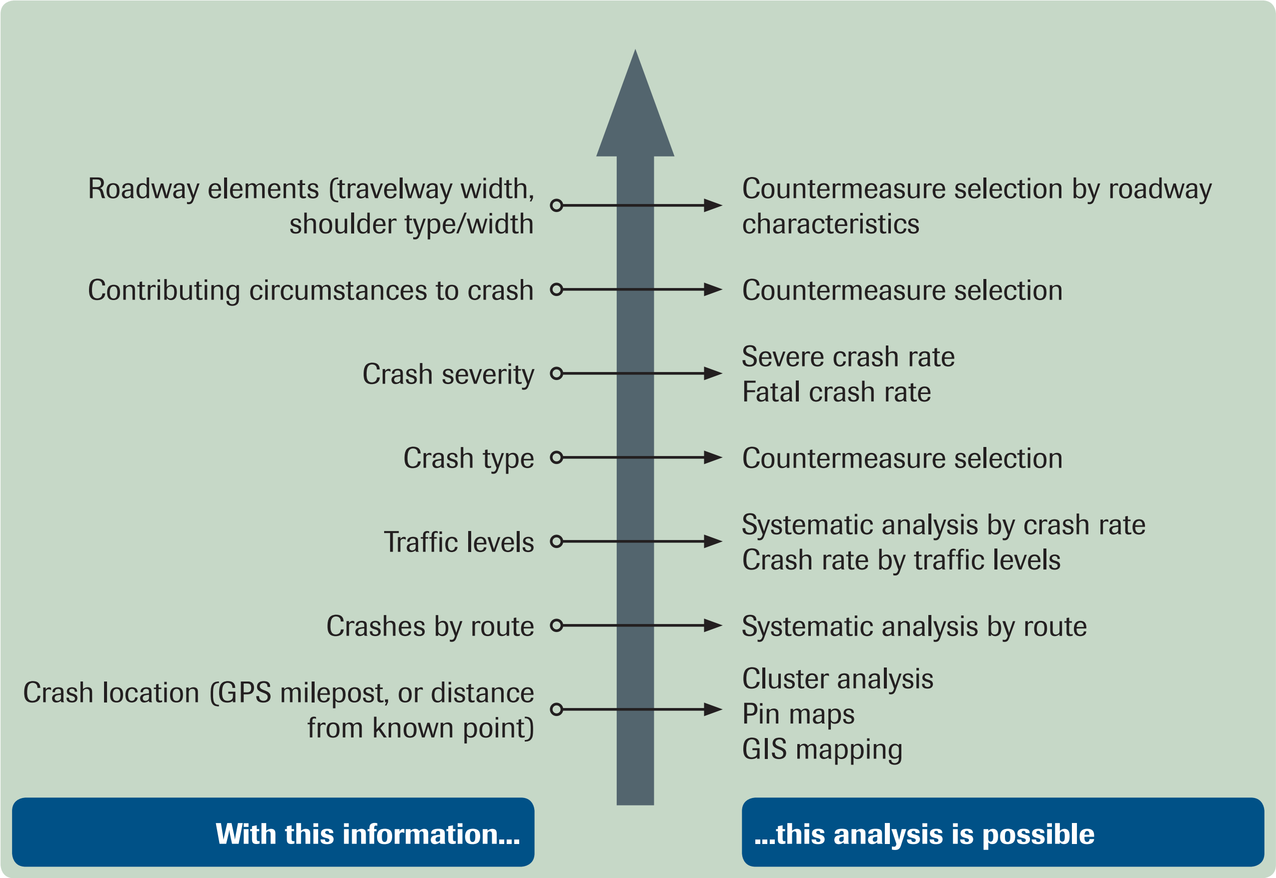
The results of the crash and volume studies, as well as the field investigation, allow the analyst to answer many questions including the following:

- ✓ Are the crashes caused by physical conditions of the road or adjacent development, and if so, can the conditions be eliminated or corrected?
- ✓ Is there a blind corner that could be improved to increase sight distance? If the obstruction cannot be removed, has adequate warning or control (STOP signs, YIELD signs, or traffic signals) been provided for the motorist?
- ✓ Are the existing signs, markings, or signals doing the job for which they were intended? Are there too many signs of too small a size so that their clutter causes confusion and lack of observance? Are traffic signal indications clearly visible without conflicting signs in the background, particularly at night?
- ✓ Is traffic properly channelized and directed through the use of pavement markings and islands to reduce conflicts?
- ✓ Would the potential for crashes be reduced by prohibiting a select turning movement, if a reasonable alternate route is available to serve the prohibited move?
- ✓ Are nighttime crashes far out of proportion to daytime crashes, indicating the need for improved street lighting?
- ✓ Do conditions show that additional enforcement would be helpful in improving driver observance of traffic control devices? Would general public information programs be helpful in informing installation personnel of crash characteristics and problems?
- ✓ Is parking in the vicinity of the problem area contributing to the crashes? If so, would prohibiting parking add to intersection capacity or improve sight distance at corners?

All background facts and field data should be summarized and analyzed to select potential solutions that may be implemented.

Exhibit 3.7 below shows the type of information that can be used to evaluate various crash aspects.

Exhibit 3.7: Evaluation Information for Various Crash Aspects



With this information...	...this analysis is possible
Roadway elements (travelway width, shoulder type/width	Countermeasure selection by roadway characteristics
Contributing circumstances to crash	Countermeasure selection
Crash severity	Severe crash rate Fatal crash rate
Crash type	Countermeasure selection
Traffic levels	Systematic analysis by crash rate Crash rate by traffic levels
Crashes by route	Systematic analysis by route
Crash location (GPS milepost, or distance from known point)	Cluster analysis Pin maps GIS mapping

Many times, crash patterns emerge when evaluating crash data. Refer to SDDCTEA Pamphlet 55-17, Chapter 12, for a listing of common crash types and associated contributing factors, as well as general countermeasures to eliminate the problem causes.

3.6. APPLICATION

The practical application of a study of crash types shown by the crash diagrams and other data will assist in remedial action. Reviews of these patterns may suggest the corresponding remedies as shown:

Right-angle and Rear-end Crashes at Intersections

- ✓ Remove view obstructions
- ✓ Install warning signs on the higher volume (major) approach and STOP signs on the lower volume (minor) legs
- ✓ Install ALL-WAY STOP signs or install traffic signals if traffic volumes warrant
- ✓ Continue operation of traffic signals during certain light traffic periods when signals are normally off
- ✓ Provide proper clearance interval (yellow) for higher speed approaches to signalized intersections
- ✓ Relocate, repair, or provide other means of improving visibility of signs or signals and change 8-inch signal indications to 12 inches for primary indications
- ✓ Improve street lighting if there is a high percentage of nighttime crashes
- ✓ Provide pedestrian crosswalk markings and barriers
- ✓ Reroute through traffic onto specially designated and protected through streets
- ✓ Create one-way streets or make one or more minor legs one way away from the intersection at complex multilegged intersections
- ✓ Install left-turn storage lanes in the center of the roadway to reduce rear-end crashes and improve capacity
- ✓ Provide a traffic signal system timed for progressive movement so that traffic moves in platoons, which will aid side street vehicles to enter or cross, reduce the number of stops for through traffic, and reduce the potential for rear-end crashes

Head-on and Left-turn Crashes at Intersections

- ✓ Provide left-turn storage lanes so that a turning driver has a place to wait without concern about rear-end crashes
- ✓ Prohibit left turns
- ✓ Provide channelizing islands or pavement markings
- ✓ Separate left-turn phases at traffic signal controls for high-volume turns (i.e., over 120 vehicles turning per hour)
- ✓ Install STOP signs (provided no other remedy works)
- ✓ Eliminate or modify view obstructions (i.e., trees, shrubs, signs, or buildings)
- ✓ Create one-way streets to eliminate head-on conflicts
- ✓ Reroute turning traffic via an alternate route
- ✓ Install pavement center and edge lines, but do not install both center and edge lines on pavements narrower than 18 feet when used for two-way traffic
- ✓ Install roundabouts

Pedestrian-vehicular Crashes at Intersections

- ✓ Install pedestrian crosswalk lines and advance warnings
- ✓ Install traffic signals with pedestrian indicators (WALK/DON'T WALK)
- ✓ Install NO TURN ON RED signs where pedestrian volumes are significant
- ✓ Provide pedestrian refuge islands (must be at least 6 feet wide) and sidewalks
- ✓ Prohibit curb parking to improve visibility of pedestrians
- ✓ Provide adequate street lighting for nighttime problems
- ✓ Create one-way streets to simplify movements
- ✓ Reroute through traffic to specially designated and protected through streets when the vehicle/pedestrian problem is area-wide and install malls or diverters to eliminate through traffic in areas where it should not be
- ✓ Provide pedestrian indications at existing traffic signals
- ✓ Provide overhead or below-grade pedestrian crossing when economically justified
- ✓ Establish regulations and guidelines concerning pedestrian outer garments for night wear

Head-on or Sideswipe Crashes

- ✓ Install painted pavement lane lines or raised pavement markers
- ✓ Install center dividing islands
- ✓ Install advance warning signs to warn drivers of the proper lane for certain destinations in order to reduce unsafe lane changing
- ✓ Install centerline rumble strips
- ✓ Establish no-passing zones where passing sight distances are not available
- ✓ Provide acceleration or deceleration lanes at intersections
- ✓ Widen pavement
- ✓ Create one-way streets
- ✓ Eliminate side or width obstructions such as parked cars, narrow bridges, and utility poles

Run-off the Road Crashes

- ✓ Install pavement center and edge lines
- ✓ Install roadside delineators, reflectors, guide posts, or guide rails
- ✓ Install advance warning signs indicating safe speeds
- ✓ Install edge line rumble strips
- ✓ Establish speed zones
- ✓ Install safety lighting at curves and intersections
- ✓ Apply surface treatment and improve shoulder

Crashes with Fixed Objects

- ✓ Apply reflectorized paint and/or reflectors to fixed objects
- ✓ Use pavement markings and/or channelization to guide traffic around obstructions
- ✓ Install edge line rumble strips
- ✓ Improve street lighting
- ✓ Remove fixed objects (if feasible)
- ✓ Install guide rails or impact-absorbing barriers

Crashes with Parked Cars

- ✓ Prohibit parking
- ✓ Change from angle to parallel parking
- ✓ Reroute through traffic to less congested, specially protected through streets
- ✓ Create one-way streets

In addition to the above recommendations, additional measures may be required. For example, improved enforcement of speed or other traffic regulations, assignment of traffic officers or crossing guards to safeguard pedestrian crossings, enforced pedestrian observance of traffic rules, and special driver or pedestrian educational measures.

It must be emphasized that the above is a "shopping list" of potential treatments to reduce crashes. Sometimes none of these will have a beneficial effect; in other cases, one or more may prove effective.

A logical review of the facts and conditions at each problem location will usually identify some remedial treatment that will aid in potential crash reduction. It will be necessary to apply engineering judgment.

CHAPTER 4—SIGN MANAGEMENT STUDY

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CHAPTER 4—SIGN MANAGEMENT STUDY

4.1. OBJECTIVE

Sign management studies (SMS) are performed for two primary purposes: (1) to determine if existing signage complies with the MUTCD regulations, and (2) to determine if there are missing signs. An additional purpose of a SMS is to document the condition of the signs. The MUTCD regulates the application, size, message, placement/installation, and measured retroreflectivity of signage.

FHWA's MUTCD set forth federal requirements that military installations must meet several key traffic control sign compliance requirements between January 2012 and December 2019 for signs on any road open to public travel. On May 14, 2012, the FHWA published final rules to revise the MUTCD provisions on compliance dates. Most compliance dates have been eliminated; however, the requirements still apply. When a sign has reached the end of its useful service life or is replaced as part of other systematic upgrades, it is to be replaced in accordance with these new requirements. Some signs, however, may require higher priority for replacement if they are already beyond their useful service life, and are a critical sign. A brief overview of the MUTCD requirements and any applicable dates are as follows:

- ✓ Conform to new requirements relating to sign size, type, and placement.
- ✓ Implement and continue to use a sign assessment or management method for the purpose of conforming to FHWA's requirement that agencies implement a program by June 13, 2014 (formerly January 2012) for the maintenance of minimum levels of sign retroreflectivity.
- ✓ Ensure compliance with new minimum retroreflectivity requirements, dependent on sign type.

The end product of a SMS is a method to manage and assess the installation's signs in order to comply with the FHWA requirements. A Geographic Information System (GIS)-based SMS is one method to accomplish this.

See SDDCTEA Pamphlet 55-17 for discussion on minimum sign retroreflective requirements.

4.2. INFORMATION NEEDED

Identification of an accurate location for each sign inventoried is necessary in a SMS. This can be based off a survey, road stationing, or similar methods. A more convenient and accurate method for locating signs utilizes Global Positioning System (GPS)-based portable computers which also allows installation aerial imagery to be viewed on the portable computer. Basic GIS information, to include street names and installation property boundaries, are required for this type of system to provide an awareness of location and limits of collection. There are several off-the-shelf sign inventory software programs available to assist with the collection of various sign attributes. Inventory programs can also be developed, however for smaller project this may not be beneficial.

4.3. METHODS

A sign management study requires the physical inventory and inspection of all installation signs to determine their condition, location and compliance with MUTCD requirements. One method involves the manual collection, documentation and recordkeeping of data. The manual recording of field data and retention of hardcopy records may be effective for small installations with few signs. However, it would be extremely labor-intensive for larger installations that have a high number of traffic signs to maintain. The process of capturing, analyzing, and presenting sign inventory information has evolved significantly in the last decade. Computer-based methods are much more efficient and offer the ability for GPS precision when locating signs.

There are several programs that can be employed to replace inefficient or non-compliant signs within the installation including (1) a visual nighttime inspection and measurement of the retroreflectivity of the signs, (2) the replacement of signs based on the age of the sign and expected sign life, (3) the replacement of all the signs based on a previous replacement date, and (4) the replacement of individual signs based on the measured retroreflectivity. Additional information regarding methods of sign management can be found in the SDDCTEA Pamphlet 55-17.

In a systematic manner, all signs are inventoried throughout the installation. This can be very labor-intensive depending on the size of the installation and the number of signs. The inventory typically consists of collecting the following information for all signs:

- ✓ GPS coordinates
- ✓ Sign category (regulatory/warning/guide)
- ✓ Sign message (if unique)
- ✓ MUTCD Sign designation (TEA sign designation, if applicable)
- ✓ Sign size
- ✓ Sign colors
- ✓ Sign mounting height
- ✓ Sign position
- ✓ Sign condition
- ✓ Sign retroreflectivity (as measured using one of the methods in MUTCD Section 2A.08)
- ✓ Sign retroreflectivity condition
- ✓ Sign sheeting type (i.e., grade of retroreflective material)
- ✓ Sign substrate (i.e., the sign backing material; such as aluminum, plywood, fiberglass-reinforced plastic)
- ✓ Sign installation date
- ✓ Sign photo
- ✓ Post type
- ✓ Post breakaway
- ✓ Post condition
- ✓ Post offset from curb or edge of roadway
- ✓ Presence of curb or other barrier
- ✓ Direction of sign (N,S,E,W)
- ✓ Direction with respect to traffic (with, opposed)
- ✓ Side of road (from edge of roadway)
- ✓ Street name
- ✓ Presence of vegetation that is or will block sign

- ✓ Roadway speed limit
- ✓ Number of lanes adjacent to sign
- ✓ Commentary on reason for sign inadequacy
- ✓ Proposed signing where needed
- ✓ Existing signing to be removed

Many of these fields are obtained by direct observation, others are obtained by measurement with a tape measure or wheel.

4.4. ANALYSIS

Upon collection of attributes for all signs, they should be analyzed for adequacy and the need for immediate replacement. If not in need of immediate replacement, the number of years of remaining life should be calculated. A GIS system may be used to identify replacement by identifying priorities, such as those shown in Exhibit 4.1. The priorities are designed to bring all signing into MUTCD compliance based on different requirements, while being conscious of budget under the assumption that replacing all signs at once would exceed available funding.

Exhibit 4.1: Priorities for Sign Replacement

PRIORITY LEVEL	DESCRIPTION
-	All signs obstructed by vegetation (For Information Only)
1	All Signs needing removal
2	Replace Yield with Stop where inappropriate type of intersection control
3	Relocate New Sign to New Location
4	Speed Limit or Keep Right Sign smaller than 18x24 any location
5	Speed Limit or Keep Right Sign smaller than 24x30 (except housing) that is Single Lane (or multi-lane <= 35 mph)
6	Do Not Enter smaller than 30x30
7	YIELD Sign < 36x36 on Single Lane
8	Diamond Warning signs smaller than 36x36 (on multi-lane roads only)
9	Diamond Warning signs smaller than 24x24 (all other roads, i.e. local, housing)
10	W1-8 if smaller than 18x24
11	STOP Sign < 30x30 (non multi-lane)
12	STOP signs <36" (at intersections with multi-lane approaches)
13	Speed Limit or Keep Right < 30x36 (multi-lane road, speed > 35mph)
14	Do Not Enter of 30x30 (on multi-lane roads, road speed > 35 mph)
15	YIELD sign < 48x48 on Multi-Lane roadways
16	W1-6, W1-7 if smaller than 48x24

Exhibit 4.1: Priorities for Sign Replacement (continued)

PRIORITY LEVEL	DESCRIPTION
17	Street Name signs with text <4" in housing areas (not used)
18	Regulatory/Warning/School signs Non-reflective (null)
19	All Type I signs with marginal/poor/null condition
20	Warning/Post-Mounted Guide/School signs, Type I (not permitted) in good condition (EXCLUDES STREET NAME SIGNS)
21	Any sign Type II & marginal/poor/null condition
22	Regulatory/Warning/School—Type III or better but Poor/null Condition
23	All signs not queried above with post type poor/null condition
24	Guide signs more than 4 lines text
25	Regulatory/Warning/School—Type III or better but Marginal Condition
26	Green guide signs Non-reflective (null)—3 lines or less
27	Green guide signs Type II—3 lines or less
28	Green Guide Signs Type III or better but poor/null condition—3 lines or less
29	Blue/Brown Guide Signs marginal/poor/null—3 or less all sheeting types
30	Replace Sign—Reason other than those above. Most likely reason is due to non-standard sign.
31	Overhead guide signs Type II and III (not permitted) & good condition
32	All remaining signs not queried above, having non-breakaway posts where no curb exists (For Information Only)
33	All remaining signs not queried above, mounting height not 7' (+/- 0.5') in ped zone (For Information Only)
N/A	Any remaining signs—No Priority. These signs are relatively new so it is anticipated their replacement will be 7-10 years out.

4.5. APPLICATION

A SMS should be performed to ensure that signs meet required minimum retroreflectivity levels; as well as; to ensure that all signing meets standards for placement, location, and visibility. It also provides a sign inventory (preferably GIS-based) so the engineering office has a copy of required signing. This is important in the event a sign is missing, struck by a vehicle or is vandalized.

CHAPTER 5—PAVEMENT MARKING MANAGEMENT STUDY

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5.1. OBJECTIVE

The MUTCD has developed proposed language regarding minimum standards for pavement marking retroreflectivity. These standards apply for certain types of markings, and to roadways with minimum speed limits. Under the proposed changes in pavement marking requirements in the MUTCD, some markings are required to meet minimum retroreflective levels. Others are required to either be retroreflective with no minimum reflectivity levels or are not required to be retroreflective at all. A pavement marking management study should identify pavement markings throughout the installation, identify which markings are subject to the proposed minimum retroreflective levels, that may become a requirement in the future, and identify recommended changes to pavement markings throughout the installation. The identification of all markings throughout the installation will assist systematic or complete replacement of markings.

See SDDCTEA Pamphlet 55-17 for discussion on proposed pavement marking retroreflectivity requirements, as taken from the FHWA published proposed change to Section 3A.03 of the 2009 MUTCD.

5.2. INFORMATION NEEDED

The first step in a pavement marking management study is a complete inventory of pavement markings. The inventory should be performed either manually or by GPS-enabled computer. If performed manually, a large plotted base map or aerial imagery should be used with sufficient detail to show some level of visibility of the roadways and markings. If performed by GPS-enabled computer, it should be loaded with the aerial imagery and a collection program. The program should be able to capture points for marking start, end, and transition to another marking pattern.

5.3. METHODS

All markings should be collected throughout the installation.

The following attributes should be collected for **longitudinal markings**:

- ✓ Marking type
- ✓ Location (edge/center/lane)
- ✓ Width
- ✓ Color
- ✓ Retroreflectivity level (as measured using handheld contact devices or non-contact devices such as vehicle mounted retroreflectometers currently available on the market)
- ✓ Observed condition
- ✓ Material type
- ✓ Street name
- ✓ Speed limit
- ✓ Number of lanes
- ✓ Commentary on inadequacy
- ✓ Installation date (if known)

An individual longitudinal marking should be considered to be ended at any break, such as at an intersection where a double yellow centerline marking ends for the width of the intersection.

The following attributes should be collected for **transverse markings**:

- ✓ Marking type (stop line/crosswalk/symbols/arrows/text)
- ✓ Location (which travel lane/across all lanes)
- ✓ Length
- ✓ Width
- ✓ Color
- ✓ Retroreflectivity level (handheld contact devices, non-contact devices)
- ✓ Observed condition
- ✓ Material type
- ✓ Street name
- ✓ Speed limit
- ✓ Commentary on inadequacy
- ✓ Installation date (if known)

Each transverse marking should be treated separately. For example, a crosswalk is comprised of at least two lines. The collected data for these lines should be treated as two separate entries.

See SDDCTEA Pamphlet 55-17 for types of pavement markings.

5.4. ANALYSIS

Upon collection of all marking data, analyze for adequacy and the need for immediate replacement. Identify pavement markings that do not meet requirements based on visual or measured retroreflectivity values. Identify markings that need immediate replacement due to poor reflectivity, incorrect marking color, or improper marking type or placement. From this, a pavement marking plan showing marking locations and quantities can be developed and used by a pavement marking contractor.

Proposed pavement marking retroreflectivity level requirements are referenced in the MUTCD Section 3A.03. Proposed rule revision compliance dates for these standards have not been established. When the proposed rulemaking is adopted, a pavement marking management study will fulfill the MUTCD requirement of having a pavement marking assessment method in place.

5.5. APPLICATION

A pavement marking inventory can be used to develop a pavement marking management system, identify markings with insufficient retroreflectivity, develop a pavement marking plan with recommended enhancements to markings, and develop pavement marking replacement quantities.

CHAPTER 6—TRAFFIC SIGNAL MANAGEMENT STUDIES

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6.1. OBJECTIVE

A traffic signal management study has the following objectives:

- ✓ Inventory existing traffic signal equipment
- ✓ Recommend immediate short-term optimization with existing equipment or minor upgrades
- ✓ Recommend long-term optimization, potentially with new equipment

There are two types of studies involved:

Signal Inventory—The comprehensive inventory of traffic signals including visual records and condition evaluation.

Signal Coordination and Timing (SCAT)—A SCAT analysis involves the evaluation of the efficiency of an individual signalized intersection or multiple intersections that are coordinated within a roadway corridor. The overall objective of signal control is to provide for the safe and efficient traffic flow at intersections, along routes and in street networks. A well-timed signal system can reduce fuel consumption, eliminate unnecessary stops and delays, improve safety, and enhance the environment.

6.2. INFORMATION NEEDED

The following information is required for both types of studies:

- ✓ Aerial imagery
- ✓ Traffic signal locations
- ✓ Access to traffic signal controllers

6.3. METHODS

For every traffic signal to be included in a type of traffic signal management study, collect the following information, with commentary on condition.

- ✓ Traffic signal design (mast arm/span wire)
- ✓ Mast arm condition
- ✓ Number of signal heads, and locations
- ✓ Backplates
- ✓ LED indication sizes, colors, and arrows
- ✓ Detection method
- ✓ Detection locations
- ✓ Detection functionality
- ✓ Pedestrian signal location
- ✓ Pedestrian signal type
- ✓ Pedestrian pushbutton location, functionality, type

- ✓ PROWAG (or at a minimum ABA) adequacy relating to curb cut, detectable warning surface, and pushbutton location
- ✓ Wiring location (underground/overhead)
- ✓ Interconnection (if present) method (i.e., spread spectrum/hard wire/fiber/GPS/time-based)
- ✓ Interconnection functionality
- ✓ Junction box location and condition (for underground wiring)
- ✓ Electrical service type
- ✓ Signal controller location
- ✓ Controller equipment and settings as follows:
  - Controller model
  - Controller cabinet mounting type (pole or concrete pad)
  - Conflict monitor presence
  - Battery backup presence
  - Preemption
  - Timing settings (as documented by plans provided by the installation)
    - Cycle length
    - Splits
    - Yellow and red clearance intervals
    - Pedestrian timings
    - Recall phase
    - Recall mode
    - Minimum green times by phase
    - Passage timings
    - Timing plans by time of day
    - Offset (if coordinated)
    - Actuation timings

A traffic signal technician or engineer should perform a signal inventory because obtaining controller settings requires some level of familiarity with traffic signal controllers. GPS-based portable computers can be used to precisely locate the signal and record condition observations, and installation aerial imagery is needed to view on the portable computer. Basic GIS information, to include street names and installation property boundaries, are required to provide an awareness of signal location. In addition to the data collection discussed above, perform an intersection turning movement count, obtain the roadway speed limits, and document the lane use control through the intersection in order to conduct a SCAT study.

6.4. ANALYSIS

Signal Inventory Analysis (traffic signal operations audit)—Analyze the traffic signal equipment to determine its condition, structural integrity, and compliance with current MUTCD and/or state requirements. For example, a mast arm and pole may have surface rust, but still be structurally adequate; however, one struck by a vehicle or with significant rust to the connections must be replaced. Analyze all signal heads for condition and placement. Analyze the condition of other equipment as well. If loop detectors are non-functional, identify them for replacement.

Identify controller settings not normally used, and determine if the settings are needed or if the more common setting is appropriate. For example, most memory settings should be set to minimum recall versus maximum recall, but there may be instances where maximum recall is more appropriate.

Verify that left-turn phases are appropriate or if another left-turn phase type is more appropriate. Verify red and yellow clearance interval timings. Using the counted intersection volumes, use Synchro or another signal timing software to analyze each intersection or network to verify or determine optimum timings. Determine whether the existing equipment is adequate, needs minor upgrades, or is in need of replacement. Provide recommendations for specific upgrades needed or general specifications for equipment replacement.

SCAT Analysis—A SCAT analysis can include a single intersection or several coordinated intersections. Two or more intersections can be evaluated within a section of roadway corridor. Typically, the location and number of intersections at which to perform a SCAT analysis can be determined through observation and knowledge of traffic flow through the installation from a proactive monitoring program. Excessive intersection delay or congestion, or personnel complaints, may also dictate the intersection(s) to analyze. Traffic volume studies, time and delay studies, and turning movement counts will also provide specific data to help determine the existing effectiveness of the intersection controls. The analysis of multiple intersections should be based on groups of intersections logical to control and within similar traffic flow patterns. Sections can also depend on the type and volume of intersecting roads.

SCAT analyses, especially for coordinated intersections, involve the extensive collection of traffic data, development of multiple timing plans for specific sets of traffic conditions, and working knowledge of the existing controller equipment. It is a labor intensive process which can be constrained by available installation personnel and fiscal resources. SCAT analyses should be conducted by technicians and engineers experienced with signal equipment, software, and procedures in performing the study. Additional information regarding traffic signal timing can be found at FHWA website: http://ops.fhwa.dot.gov/arterial_mgmt/tstmanual.htm. SDDCTEA is available to provide direction and assistance in developing a SCAT analysis.

Measure of Effectiveness (MOE)—Changes in vehicle delay and average speed can be used to evaluate before and after signal performance. A travel-time and delay study (see Chapter 7) can be done before and after a SCAT study to determine the reduction in the delay. The results can be used to measure the performance of any improvements made based on the SCAT study.

6.5. APPLICATION

Many military installations have inefficient traffic signal operations, and have equipment in need of repair. Short-term enhancements can have some level of benefit, but many signals require complete replacement.

Unnecessary motorist delay due to poorly timed traffic signals causes unnecessary emissions and delay to roadway users. With additional focus on sustainability and emission reduction, maximizing traffic signal operation is a very beneficial step that is not always considered. Maximizing signal operation can have a large benefit to efficiency, as well as pedestrian and motorist safety.

CHAPTER 7—TRAVEL-TIME AND DELAY STUDIES

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CHAPTER 7—TRAVEL-TIME AND DELAY STUDIES

Travel-time and delay are two of the principal measures of performance of a roadway network. Vehicle speed is directly related to travel-time and delay. A travel-time study provides data on the amount of time it takes to traverse a section of roadway. Travel-time and delay studies are conducted when increases in traffic congestion reduces the average operating speed and traffic flow in a travel corridor.

7.1. OBJECTIVE

The purpose of these studies is to determine typical travel-times and delays experienced by motorists on the roadways serving an installation. The results of a travel-time study will determine the effect that peak-hour-roadway congestion has on average travel speed. The results of a delay study will indicate the location, cause, and duration of traffic slowdowns. These types of studies are sometimes called speed and delay studies. Both the travel-time study and the delay study are used to determine sources of traffic congestion, and to highlight problems that may require additional investigation. Together they indicate the quality of traffic flow on installation roadways.

7.2. INFORMATION NEEDED

Data needs include the travel-time on selected roadways serving the installation. Data may be collected on major installation streets and on public roads that provide access to the installation. Travel-times may be recorded both during off-peak-travel periods and during the morning or evening-peak hours. Also needed is the location of the road encountering any traffic delay, together with the time, length, and cause of the delay. A delay is considered to occur each time traffic is forced to stop or when it must travel much slower than at free-flowing speed.

Common terminology associated with travel-time and delay studies:

- ✓ **Control point** is a node at the beginning or end of a route segment, usually the stop line at a controlled intersection.
- ✓ **Delay** is the elapsed time (seconds) spent driving at a speed less than 5 mph.
- ✓ **Distance** is the length of a segment between nodes or the total length of a run.
- ✓ **Running speed** is the test vehicle's average speed (mph) while the vehicle is in motion.
- ✓ **Running time** is the elapsed time (seconds) excluding delay spent driving a distance.
- ✓ **Travel-time** is the total elapsed time (seconds) spent driving a specified distance.

7.3. METHOD

The most common measure of operational quality is delay, although queue length is often used as a secondary measure. There are a variety of types of delays:

- ✓ **Stopped time delay** is defined as the time a vehicle is stopped in queue while waiting to pass through the intersection or ECF. It begins when the vehicle is fully stopped and ends when the vehicle begins to accelerate. Average stopped-time delay is the average for all vehicles during a specified time period.
- ✓ **Approach delay** includes stopped-time delay but adds the time loss due to deceleration from the approach speed to a stop and the time loss due to re-acceleration back to the desired speed.

- ✓ **Travel-time delay** is the difference between the driver's expected travel-time through the intersection (or any roadway segment) and the actual time taken. To find the desired travel-time to traverse an intersection is very difficult. So this delay concept is rarely used except in some planning studies.
- ✓ **Time-in-queue delay** is the total time from a vehicle joining an intersection queue to its discharge across the STOP line on departure. Time-in-queue delay cannot be effectively shown using one vehicle, as it involves joining and departing a queue of several vehicles.
- ✓ **Control delay** is the delay caused by a control device, either a traffic signal or a STOP sign. It is approximately equal to time-in-queue delay plus the acceleration-deceleration delay component. Delay measures can be stated for a single vehicle, as an average for all vehicles over a specified time period, or as an aggregate total value for all vehicles over a specified time period. Aggregate delay is measured in total vehicle-seconds, vehicle-minutes, or vehicle-hours for all vehicles in the specified time interval. Average individual delay is generally stated in terms of seconds per vehicle for a specified time interval.

Stopped time delay is typically the simplest measure to adequately determine delay at intersections, roadway segments or ECFs on an installation. There are several methods for conducting travel-time and delay studies. The method selected here, referred to as the test vehicle or floating-car technique, is thought to be the most appropriate for military installations. This test vehicle method requires the analyst to use a vehicle to make runs on the roadway corridor or corridor segment that is of interest. A typical study involves a driver and an observer driving from one end of the corridor to the other while recording times at predetermined points of interest. This test vehicle method allows the analyst to determine the:

- ✓ Travel-time
- ✓ Running time
- ✓ Type, location, duration and cause of traffic delays
- ✓ Distance traveled

Equipment—The test vehicle method requires a test vehicle and the means to record time and distance. A standard unmarked car, a driver and an observer, street maps, timing devices, and a clipboard with data sheets will be needed.

Procedure—The driver and observer travel along the study route within the installation and record their observations on a travel-time and delay study field sheet as shown in Exhibit 7.1 by use of the symbols shown at the bottom. Two timing devices are required. One is run continuously and is used to indicate elapsed time; the other is started when a delay occurs, stopped when traffic moves again, and the duration of the delay time is then recorded. The cause of delay is noted on the form. Space is provided for several possible delays between major intersections, and more can be inserted if necessary. Prior to the test run, a starting point, end point, and control point locations along the route are identified. On arterial surface streets, these locations are usually at major intersections or other easily identifiable control points. A run along a particular street is begun at some landmark (typically the stop line at a controlled intersection) just prior to the first major cross street. The elapsed time is then recorded when the stop line of each intersection is crossed. The driver should use the floating car technique, proceeding along the route and passing as many vehicles as pass the test car. The idea is to emulate an average driver for each section of roadway and float with the traffic at a speed considered to be that of an average vehicle (rather than at the posted speed limit). The observer should be sensitive to changes in the traffic or environmental conditions.

Exhibit 7.1: Travel-Time and Delay Study Field Sheet (Sample)

Location Elm Street Weather Fair [✓ Peak] Off Peak

Date June 18, 2015 Time Period 0715 to 0719 Observer J. W. Jones

Control Point	Major Cross Street	Run 1			Run			Run		
		Direction NB			Direction			Direction		
		Elapsed Time	Delay Time	Delay Cause	Elapsed Time	Delay Time	Delay Cause	Elapsed Time	Delay Time	Delay Cause
Ⓐ	Pine Street	0.00								
		0.30	0.30	PV						
Ⓑ	Oak Street	1.00								
		1.30	0.53	SS						
Ⓒ	Birch Street	1.83								
		2.35	0.55	MP, RT						
Ⓓ	Maple Street	2.90								
		3.15	0.40	RR						
		3.68	0.21	TS						
Ⓔ	Spruce Street	3.89								

Delay Cause Symbols:
SS—Stop Sign
PV—Parking Vehicle
T—General
TS—Traffic Signal
RR—Railroad
PD—Pedestrian
IO—Insufficient Capacity
BS—Backup Signal
PL—Passenger Loading
RT—Right Turning Vehicle
MP—Police Control
OT—Other Cause
LT—Left Turning Vehicle

Preparation—Prior to the actual road travel-time measurements, it will be necessary to prepare a map sketch showing the major streets that will be included in the study. The intersection of two major streets is typically used as a control point. All control points on the sketch should be numbered sequentially, as are all segments of roadway. Segment distances should be recorded alongside numbered control points. Distances between control points can be measured from a variety of tools including: plans, maps, online mapping services, vehicle-mounted distance measuring instrument (DMI), GPS receiver, or from the vehicle odometer. Odometer readings may be less accurate than other methods.

Data Collection:

- ✓ **Manual Data Collection**—Test vehicle runs should be made during clear weather and when traffic conditions are fairly typical. A series of runs should be made during off-peak-travel periods to obtain normal travel-times. These data are compared with the results of other runs made during the morning-and the evening-peak hours. Peak-hour runs are made in the direction of the maximum traffic flow. It is necessary to make several runs and average the results. For practical purposes three to five runs are usually sufficient. Several teams in other test cars can aid in collecting travel-time data by departing at 5-minute intervals. It may be necessary to conduct separate travel-time and delay studies for different portions of the peak period and average the results. Signal progression can introduce variability during data collection. Signal timing should be understood before starting the study so the analysis can account for changes in progression over the study period.
- ✓ **Automatic Data Collection**—Automatic data collection equipment is available to aid with data collection. Globalpositioning System (GPS) units can be used to measure the test vehicle's position and speed along the route. A variety of software programs for use with GPS units or laptop handheld computers are available to perform travel-time and delay studies. These products can capture features including speed, distance, delay, and number of stops. A laptop computer software program with a time-stamp procedure can also be used to record the same information with predefined keystrokes that represent locations or delays.

  Bluetooth technology can also be utilized for travel-time and delay study data collection. Bluetooth is an open, wireless communication platform used to connect many electronic devices. Many computers, car radios and dashboard systems, PDAs, cell phones, headsets, or other personal equipment are, or can be, Bluetooth-enabled to streamline the flow of information between devices. Bluetooth devices can be placed along a roadway to collect travel-time and speed data.

  Generally, manual data collection is considered adequate for collecting travel-time data for travel delay analysis on installation roadways. Automatic data collection equipment (i.e., GPS units, Bluetooth products, antennas and software packages) can be expensive for the occasional use and additional data process procedures are required.

7.4. ANALYSIS

Analysis will consist of computing the average travel-time for each segment and then calculating the travel speed aided by the Travel-Time Work Sheet in Exhibit 7.2. A table, such as Exhibit 7.3, should be prepared summarizing travel-time and delay results for road segments with significant delays. Note that the delay codes used correspond to those on the suggested travel-time and delay field data sheet in Exhibit 7.1. A map can be prepared that summarizes the travel-times and emphasizes road segments with significant delays as in the Speed and Delay Map in Exhibit 7.4. A written commentary should accompany the map, and should describe field observations concerning specific causes of delay.

Exhibit 7.2: Travel-Time Work Sheet (Sample)

Location Elm Street Weather Clear, Dry [✓ Peak] / Off Peak

Date June 18, 2015 Start Time 0715 Start Time 0719

Control Point	Major Cross Street	Distance (ft)	Seg. #	Elapsed Time (Min:Sec)	Elapsed Time (Min:Dec)	Travel-time (Min.Dec)	Travel Speed (mph) = Distance (ft) / Travel-time x 88
A	Pine Street			0:00	0.00		
		1320	1			0.50	30.0
B	Oak Street			0:30	0.50		
		3550	2			1.00	40.3
C	Birch Street			1:30	1.5		
		4200	3			1.00	44.2
D	Maple Street			2:35	2.58		
		4820	4			1.55	35.3
E	Spruce Street			4:08	4.13		
		720	5			0.35	23.4
F	Orange Street			4:29	4.48		

Exhibit 7.3: Summary Sheet for Roadway Segments with Significant Delays (Sample)

Roadway	Mileage	Terminal Points	Segment No [a]	Time Period [b]	Posted Speed (mph)	Overall Speed (mph)	Delay Cause Symbols [c]	Overall Time (min)	Delay Time (min)
Elm Street	0.4 mile	Pine Street to Oak Street	①	Morning Peak	30	16	TS	1.54	0.64
				Off peak	30	27		0.9	
				Evening Peak	30	18	RR	1.33	0.43
Elm Street	0.35 miles	Oak Street to Ash Street	②	Morning Peak	30	22		0.97	0.22
				Off peak	30	28		0.75	
				Evening Peak	30	16	PD, LT	1.32	0.57
Birch Street	0.25 miles	Ash Street to Holly Street	③	Morning Peak	25	9	MP, PK	1.60	0.90
				Off peak	25	21		0.70	
				Evening Peak	25	10	MP, PD	1.55	0.85
Birch Street	0.20 miles	Holly Street to Spruce Street	④	Morning Peak	25	11	RT, TS	1.08	0.58
				Off peak	25	24		0.50	
				Evening Peak	25	18	PL	0.67	0.17
		to		Morning Peak					
				Off peak					
				Evening Peak					
		to		Morning Peak					
				Off peak					
				Evening Peak					
		to		Morning Peak					
				Off peak					
				Evening Peak					

[a] Numbers used to identify route segments

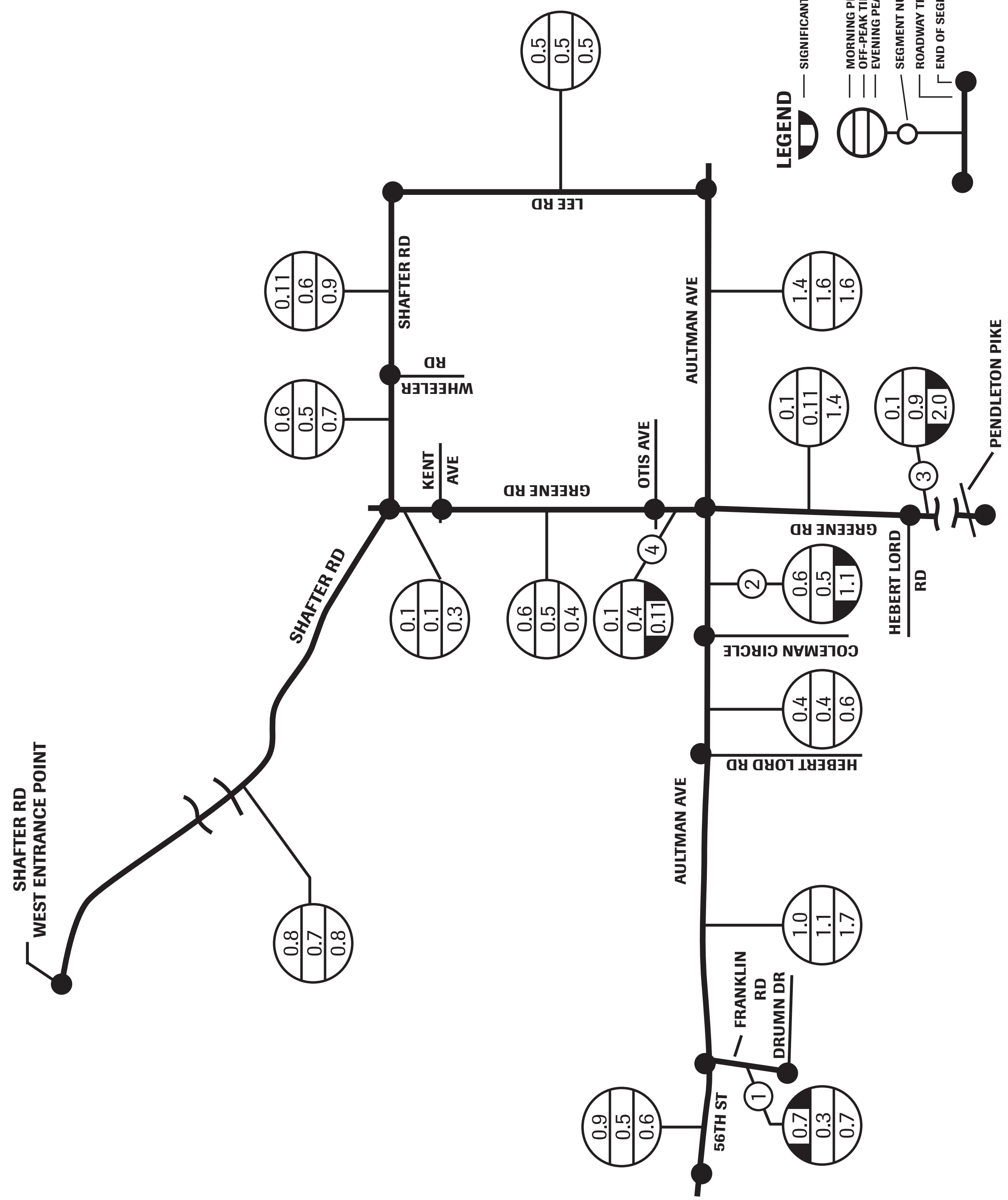
[b] Morning- and evening-peak speed and delay runs were made in the direction of the maximum traffic flow

[c] **Delay Cause Symbols:**

TS—Traffic Signal
SS—Stop Sign
PD—Pedestrian
BS—Backup at Signal
RR—Railroad Train
RT—Right Turning Vehicle
MP—Police Control
PL—Passenger Loading (car or bus)
LT—Left Turning Vehicle
PK—Parking Vehicle
OT—Other Cause
IO—Insufficient Capacity

[d] Minus sign indicates that travel time was greater for the off-peak run than for the peak-hour

Exhibit 7.4: Speed and Delay Map



The following formulas are applicable to travel-time and delay studies:

- ✓ Distance = Length of road segment (feet)
- ✓ Travel-time (min) = Elapsed time (end run) - Elapsed time (start time)
- ✓ Total delay time (min) = Sum of delay times
- ✓ Running time (min) = Travel-time - Total delay time
- ✓ Overall travel speed (mph) = $\dfrac{\text{Distance (ft)}}{\text{Travel-time (min)} \times 88}$
- ✓ Running speed (mph) = $\dfrac{\text{Distance (ft)}}{\text{Running time (min)} \times 88}$

These formulas can be used to analyze the collected data and compare peak and normal travel-times of the installation routes to identify points of delay issues and determine the appropriate corrective measures.

7.5. INTERPRETATION

For every automobile trip, there exists a desirable travel-time including a minimum number of delays defined as:

Travel-time—A comparison should be made between both the peak and off-peak travel periods for the same roadways. On most installation roads, as traffic volumes increase, average speeds decrease and travel-times increase. A significant increase in segment travel-time is considered to have occurred if the peak-period-travel-time is more than twice the off-peak travel-time. On very short segments, such as one or two blocks, a delay of 0.5 minute is considered to be significant.

Delays—The number (frequency) of delays along a route indicate the frustration a driver experiences during his trip. Delays cost the driver both time and money in terms of additional fuel costs. In addition, slow or idling vehicles increase the release of carbon fuel emissions into the environment. It is thus desirable to minimize delays.

Delays along corridors on a military installation will generally be caused by controlled intersections (signalized or stop condition at stop signs or ECFs). The capacity of an intersection is determined by the volume of vehicles effectively moving through it, i.e.:

- ✓ An intersection with insufficient capacity will constrain traffic causing excessive delay.
- ✓ Inefficient signal timing at signalized intersections may cause lengthy queues.
- ✓ The traffic volume of a primary street at a stop sign controlled intersection may cause excessive delay warranting a traffic signal.
- ✓ The spacing of intersections in the corridor can also impact the traffic flow and exacerbate delay.

When significant delays have been encountered during the travel-time and delay study, it will be necessary to revisit the scene of the delay and to study the causes in detail in order to arrive at appropriate improvement measures. Before and after study of delay time can provide a performance measure to evaluate the effectiveness of the roadway or intersection improvements.

7.6. APPLICATION

If the data from the study show that resultant delays are few, and that peak-hour-travel-times are approximately the same as off-peak times, then no further action is necessary.

Travel-time Standards—Standards for travel-time and running speed have been established through federal studies. The suggested standards shown in Exhibit 7.5 Suggested Minimum Desirable Overall Travel Speeds, allow for a comparison of the data results from travel and delay studies completed within the installation. Special speed restrictions, such as for schools, should be considered in the overall evaluation. The **collector** and **local** road classifications are the predominant installation roadway functional classifications.

Exhibit 7.5: Suggested Minimum Desirable Overall Travel Speeds (MPH)

ROAD CLASS	OFF PEAK	PEAK HOUR
ARTERIAL	25-35	25
COLLECTOR	20-25	20
LOCAL	10-20	10

Delays—When excessive delays exist and the causes have been determined, the following actions should be considered.

Traffic Signals

- ✓ Recalculate the signal timing. Check the warrants for traffic signals contained in the MUTCD http://mutcd.fhwa.dot.gov/.
- ✓ Perhaps the signal is not warranted and should be removed.
- ✓ Consider the addition of a signal controller with settings for morning, evening, and off-peak-travel periods.
- ✓ Consider the use of traffic-actuated-signal controllers.
- ✓ Where there are several signals in short succession, consider synchronizing the system so that traffic may progress from one to another on a green band.
- ✓ Consider adaptive signalization methods utilizing real-time traffic information to reduce congestion at single or multiple intersection locations based on actual traffic demand.

Stop Signs

- ✓ When traffic is delayed by a STOP sign, several items must be considered. Recheck the warrants for a traffic signal.
- ✓ Perhaps the STOP sign should be replaced. Determine if the sight distance along the cross-street is sufficient or whether sight is blocked by parked cars, buildings, unnecessary signs, or shrubbery; then, remove the sight restriction.
- ✓ Check to see if the STOP sign is on the correct approach and is not stopping a major flow for the benefit of a smaller group.

Turning Movements

- ✓ When delay is caused by left-or right-turning vehicles, consider prohibiting such turns.
- ✓ Consideration should also be given to adding separate turn lanes or separate traffic signal-turning phases.
- ✓ Determine if the curb radius is adequate to facilitate right turns, particularly where there are numerous trucks and buses.
- ✓ When right turns into driveways are a problem, determine if the curb radius and curb-cut openings are sufficient, or if any other obstructions exist.

Parking

- ✓ When parking, unparking, or double-parking vehicles are obstructing traffic, parking prohibitions (NO PARKING signs) should be considered and they should be backed up by enforcement and tow-away zones.
- ✓ Off-street parking lots should be established whenever curb parking impacts travel time.

Passenger Loading

- ✓ When traffic is delayed by cars stopping to load or unload passengers, consideration should be given to providing an off-road turnout lane. This can be supplemented by using NO PARKING signs along the road. This is also applicable for problems involving school, troop, or commercial buses during peak hours.

Pedestrians

- ✓ Pedestrian mid-block crosswalks should be avoided when possible.
- ✓ Pedestrian crossing signals should be installed only when warranted by the MUTCD and installed in accordance with SDDCTEA guidelines for mid-block crossings as detailed in SDDCTEA Pamphlet 55-17. Following which, pedestrian signals then should be synchronized with signals at nearby intersections.
- ✓ When large volumes of pedestrian crossings obstruct traffic, consideration should be given to providing pedestrian overpasses or underpasses. Pedestrian separations should be provided where pedestrian volume, traffic volume, intersections capacity, and other conditions favor their use, although their specific location and design require individual study. They may be warranted where there are heavy peak pedestrian movements in combination with high volume vehicular traffic resulting in an unusual risk to pedestrian safety. Pedestrian grade separated facilities must be ABA/PROWAG compliant. Refer to AASHTO Guide for the Planning, Design and Operation of Pedestrian Facilities for additional information. Contact SDDCTEA staff for additional guidance and assistance.
- ✓ Troop movements can be rescheduled so they will not occur during peak hours, and off-road troop-movement trails can be created.

Police Control

- ✓ When the police officer is performing efficiently, he/she should be instructed always to favor the major flow and not to interrupt arterial traffic just to let one or two cars out of a side street or to make a left turn. The police officer should wait for several pedestrians to collect on the curb before stopping traffic for them.

Railroad

- ✓ Railroad crossings at high-volume roads should be identified by flashing red lights and automatic cross-arms.
- ✓ Where traffic and train volumes are significant, grade separation should be considered. The decision to grade separate a highway-rail crossing is primarily a matter of economics. Investment in a grade separation structure is long-term and impacts many users. Such decisions should be based on long-term, fully allocated life-cycle costs, including both highway and railroad user costs, rather than on initial construction costs. Contact SDDCTEA staff for guidance and assistance in establishing the need for grade separated facilities.
- ✓ When spotting and siding operations block roadways during peak hours, these operations should be rescheduled to other times.
- ✓ Coordination with the railroad activity may be necessary.

Roadway Geometrics

- ✓ All of the above problems limit roadway capacity. In addition, geometric and design features of the road itself may be responsible for delays.
- ✓ Delay can be caused by inadequate pavement width (not enough lanes), lateral obstructions (phone poles, no shoulders, parking availability, narrow bridges), sharp curves without superelevation, steep grades (slow trucks), rough or broken pavement.

Before/After Studies

- ✓ Measuring the performance of the transportation network is an important component of effective traffic management within the installation.
- ✓ In addition to aiding the development of potential transportation needs and priorities on an installation, performing travel-time and delay studies after roadway and intersection improvements have been completed can also help identify how and to what degree the improvements may have positively impacted the preexisting capacity issue.
- ✓ The results of roadway and intersection improvements can be demonstrated by comparing travel-time and delay runs that have been performed before and after the revision.

Entry Control Facility

Entry Control Facilities (ECFs) on military installations can present congestion issues. Maintaining a secure access to the base facility is critical to the safe operation of the installation. Congestion issues at ECFs are a function of both the volume of vehicles entering the facility and the need to provide effective security controls upon entry. The amount of throughput at an ECF is largely a combination of sufficient personnel required to effectively process the vehicle occupants, and the capacity (i.e., the number of lanes available for vehicles to enter the installation) of the ECF. Congestion issues typically occur during peak entry periods when a large percentage of both military and civilian personnel are arriving for duty. Lengthy traffic queues at ECFs waste time, effect air quality, frustrate the vehicle drivers, and can negatively impact the security of the ECF. Depending on the proximity of the installation ECF to public roadways, capacity issues may extend to roadways outside the base. Travel-time and delay studies, along with other roadway capacity analysis studies, provide additional data to help better understand the existing conditions with respect to traffic flow through the ECF, and help determine the appropriate facility size and number of lanes the ECF needs to accommodate the volume of vehicles entering the facility. See Chapter 13 of this pamphlet for more information on ECF Studies.

CHAPTER 8—SPOT SPEED STUDIES

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CHAPTER 8—SPOT SPEED STUDIES

8.1. OBJECTIVE

Speed is a basic measure of traffic performance. Spot speed studies determine typical traffic speeds at a given point on a roadway. The instantaneous speeds at a specific check point are called the spot speeds. Spot speed studies serve to estimate the speed distribution of the traffic stream during the observation period. The data collected may sometimes be presented as a plotted distribution curve of speeds for the sample. Speed information may be used:

- ✓ For provision of posted speed limits.
- ✓ To determine driver compliance with existing speed limits.
- ✓ To determine the need for new traffic-control devices for regulation or warning.
- ✓ To determine the relationship of speed at high crash locations.
- ✓ To determine the effect of a road change by a before and after study.

Speed data are usually necessary when accident information indicates safety problems that may be caused by high speeds or unusual speed distributions. Spot speed studies may also be conducted upon completion of a Roadside Safety Assessment (RSA) if field observations indicate a possible vehicle speed problem. A RSA is a formal safety performance examination of an existing or future road or intersection by an independent audit team.

8.2. INFORMATION NEEDED

The data collected is the instantaneous speed (miles per hour) of each free-flowing vehicle that passes the checkpoint. Average-speed data may be categorized by the type of vehicle (cars, buses, or trucks) or by the ownership (civilian or military). The accuracy of the speed data will improve with the number of samples performed. A sample size of 100 is desirable, but never should the sample size be less than 50. In addition to the collection and analysis of speed data, other physical characteristics should be evaluated and considered when determining safe vehicle speeds on roadways within the installation. These can include determining roadway classification, width and number of lanes; volume and type of traffic; sight distance; severity of curves; design speed; number of crashes, and other roadway features that might present special safety concerns not be readily apparent to drivers.

8.3. METHOD

The method used for a spot speed study will vary with the installation depending on availability of equipment. The study's objective and scope will dictate the location, time and conditions of the study. For example, to determine the free flowing speed at a particular location the study should be conducted in the off-peak period. A crash analysis, as discussed in Chapter 3, may require the study be conducted during the time (day/night) and in the conditions (dry/wet) that warrant investigation. Determining the traffic issues and selecting the proper location, day and time are the first steps to conducting a spot speed study.

Traffic-speed data may be collected at any location where a speed problem is thought to exist. It is generally desirable, where locations are conducive, that the observer and his equipment be concealed from the driver to ensure the accuracy of the measurement. Usually data will be collected:

- ✓ At open areas on all major thoroughfares
- ✓ At mid-block street locations at least 200 feet from the nearest intersection
- ✓ At points several hundred feet prior to congested areas such as intersections, shopping areas, schools, hospitals, or entrance gates
- ✓ At points prior to dangerous situations such as curves, hills, or bridges

A simple manual system is sometimes useful for occasional spot speed studies. It usually involves recording the time for the subject vehicle to travel between two marks on the pavement. It is recommended to mark the beginning and end locations between two trees, signs or other existing objects to avoid using traffic cones or other markers that would be obvious to motorists. The observer should be positioned in the center of the two marked locations, ensuring that the vehicle can be seen as it passes each point to decrease the margin of error. The time is clocked manually using a digital timer, and the reading is recorded to the nearest one-tenth of a second. An approximate 100-foot study length is sufficient.

The speed, S (mph), for the subject vehicle is given by:

$$S = \frac{D}{1.47 \text{ x } T}$$

Where

D = study distance (in feet)
T = time (in seconds) to travel the study distance

A sample field-data sheet is shown in Exhibit 8.1, Speed Study Field Data Sheet for Measured Distances. If a speed gun (using radar, lidar, or similar technology) is used to conduct a spot speed study, a field data sheet suitable for use with a speed gun (using radar, lidar, or similar technology) is presented in Exhibit 8.2, Speed Study Field Data Sheet using Speed Gun. Subsequent calculations for the 85th percentile speed are made easier if exactly 100 vehicle speed samples are made. In Exhibit 8.2, the 85th observed cumulative vehicle-speed represents the 85th percentile speed.

Exhibit 8.1: Speed Study Field Data Sheet Using Measured Distances (Sample)

Date 8/5/2015 Weather Clear Road Surface Dry Direction East

Location Oak Street Time Period 0900 to 0930 Posted Speed Limit 35 (mph)

Distance 88 (ft) Observer B. Jones

Time (sec)	**Speed (mph)** $S = \frac{Distance}{1.47xT}$	**Vehicle Count**	**No. of Vehicles**	**% of Total**	**Cum. %**	**Notes**
4.2	16.2	|	1	0.5%	0.5%	
4.1	16.6		0	0.0%	0.5%	
4	17.0	|	1	0.5%	1.0%	
3.9	17.4	||	2	1.0%	1.9%	
3.8	17.9		0	0.0%	1.9%	
3.7	18.4		0	0.0%	1.9%	
3.6	18.9	||||	4	1.9%	3.8%	
3.5	19.4	|	1	0.5%	4.3%	
3.4	20.0	𝍸 |	6	2.9%	7.2%	
3.3	20.6	|||	3	1.4%	8.7%	
3.2	21.3	𝍸	5	2.4%	11.1%	
3.1	21.9	𝍸 𝍸	10	4.8%	15.9%	
3	22.7	𝍸 |	6	2.9%	18.8%	10 mph Pace Range Begin
2.9	23.5	𝍸 𝍸 𝍸 𝍸	20	9.6%	28.4%	
2.8	24.3	𝍸 𝍸 𝍸	15	7.2%	35.6%	
2.7	25.2	𝍸 𝍸 𝍸 𝍸 |	21	10.1%	45.7%	Average Speed
2.6	26.2	𝍸 𝍸 𝍸 𝍸	20	9.6%	55.3%	Average Speed
2.5	27.2	𝍸 𝍸 𝍸 ||||	19	9.1%	64.4%	
2.4	28.3	𝍸 𝍸 𝍸 𝍸 ||||	24	11.5%	76.0%	
2.3	29.6	𝍸 𝍸 𝍸	15	7.2%	83.2%	85th Percentile
2.2	30.9	𝍸 𝍸 ||	12	5.8%	88.9%	85th Percentile
2.1	32.4	𝍸 𝍸 |	11	5.3%	94.2%	10 mph Pace Range Begin
2	34.0	𝍸	5	2.4%	96.6%	
1.9	35.8	|||	3	1.4%	98.1%	
1.8	37.8	|||	3	1.4%	99.5%	
1.7	40.0	|	1	0.5%	100.0%	
	Total	208				
10 MPH Pace	22 **To** 32	**85th Percentile Speed**	30			
		Average Speed	26.4			

Exhibit 8.2: Speed Study Field Data Sheet Using Speed Gun (Sample)

Date 8/5/2015 Weather Fair Road Surface Dry Direction East/West
Location Oak Street Time Period 1015 to 1115 Posted Speed Limit 25 (mph)
Distance 88 (ft) Observer J.B. Brown

<table>
<tr><th>Speed (mph)</th><th colspan="2">Vehicle Count</th><th>No. of Vehicles</th><th>% of Total</th><th>Cum. %</th></tr>
<tr><td>21</td><td colspan="2">𝍷</td><td>1</td><td>1.0</td><td>1.0</td></tr>
<tr><td>22</td><td colspan="2">𝍷𝍷</td><td>2</td><td>2.0</td><td>3.0</td></tr>
<tr><td>23</td><td colspan="2">𝍷𝍷</td><td>2</td><td>2.0</td><td>5.0</td></tr>
<tr><td>24</td><td colspan="2">𝍸𝍷</td><td>6</td><td>6.0</td><td>11.0</td></tr>
<tr><td>25</td><td colspan="2">𝍷𝍷𝍷𝍷</td><td>4</td><td>4.0</td><td>15.0</td></tr>
<tr><td>26</td><td colspan="2">𝍷𝍷𝍷𝍷</td><td>4</td><td>4.0</td><td>19.0</td></tr>
<tr><td>27</td><td colspan="2">𝍸𝍷𝍷𝍷</td><td>8</td><td>8.0</td><td>27.0</td></tr>
<tr><td>28</td><td colspan="2">𝍸 𝍸𝍷𝍷𝍷</td><td>13</td><td>13.0</td><td>40.0</td></tr>
<tr><td>29</td><td colspan="2">𝍷𝍷𝍷</td><td>3</td><td>3.0</td><td>43.0</td></tr>
<tr><td>30</td><td colspan="2">𝍸 𝍸 𝍸𝍷</td><td>16</td><td>16.0</td><td>59.0</td></tr>
<tr><td>31</td><td colspan="2">𝍸𝍷𝍷𝍷</td><td>8</td><td>8.0</td><td>67.0</td></tr>
<tr><td>32</td><td colspan="2">𝍸𝍷𝍷𝍷𝍷</td><td>9</td><td>9.0</td><td>76.0</td></tr>
<tr><td>33</td><td colspan="2">𝍸𝍷𝍷𝍷</td><td>8</td><td>8.0</td><td>84.0</td></tr>
<tr><td>34</td><td colspan="2">𝍷𝍷</td><td>2</td><td>2.0</td><td>86.0</td></tr>
<tr><td>35</td><td colspan="2">𝍸𝍷𝍷</td><td>7</td><td>7.0</td><td>93.0</td></tr>
<tr><td>36</td><td colspan="2">𝍷𝍷𝍷</td><td>3</td><td>3.0</td><td>96.0</td></tr>
<tr><td>37</td><td colspan="2">𝍷</td><td>1</td><td>1.0</td><td>97.0</td></tr>
<tr><td>38</td><td colspan="2"></td><td>0</td><td>0.0</td><td>97.0</td></tr>
<tr><td>39</td><td colspan="2">𝍷𝍷</td><td>2</td><td>2.0</td><td>99.0</td></tr>
<tr><td>40</td><td colspan="2">𝍷</td><td>1</td><td>1.0</td><td>100.0</td></tr>
<tr><td colspan="3">Total</td><td>100</td><td></td><td></td></tr>
<tr><td rowspan="2">10 MPH Pace</td><td rowspan="2">26 To 35</td><td>85th Percentile Speed</td><td>33.5</td><td></td><td></td></tr>
<tr><td>Average Speed</td><td>29.8</td><td></td><td></td></tr>
</table>

With the availability and variety of inexpensive speed meters on the market, the radar or laser speed detector has become the most commonly used device to measure individual vehicle speed. A typical radar device may be vehicle-mounted, tripod-mounted, or hand-held and operates at microwave frequency by determining the Doppler shift of the signal reflected from the vehicle. The observer must be careful to collect accurate data. A radar speed device may lock on either the fastest vehicle in a stream or on the largest vehicle in a stream and give undesired readings. A radar detector is easily operated by one person depending on the volume of traffic at the study location. Care should be taken to conceal the radar device and user from vehicle drivers to avoid influencing the speeds and assure an accurate reading. Many devices have built-in data storage. Operators can manually write down the digital readings displayed on the device and transfer them later to a computer for analysis (see Exhibit 8.2).

Automatic traffic counters (as discussed in chapter 1) can also be used to collect speed data, however, vehicle platooning (i.e., a platoon of vehicles following a slow vehicle) will cause artificially lower vehicle speeds. If there is a platoon of traffic, only the speed of the first vehicle in the platoon is to be recorded. Data collected manually or automatically during vehicle platooning should be discarded from the analysis. As traffic volume increases, the average speed decreases until eventually all vehicles are moving at the same speed in one long platoon. A vehicle is considered to be free flowing if the driver is free to choose his own travel speed, unhindered by other traffic. To obtain a free flowing spot speed, a speed measurement should be performed for a randomly selected lone vehicle moving along a roadway during an off-peak travel period, as free-flowing traffic is seldom observed during peak-travel periods. Sufficient time should be allowed to collect the desired sample size of 100, but not less than 50 measurements. Observations for free flowing spot speed measurements should be taken on straight sections of roadway during ideal weather, road, and traffic conditions.

Samples must always be both random and representative. The largest sample size possible is often dictated by the volume at the location and/or the time period being studied. If the volume is very light or the time period very short, large sample sizes may not be possible. In these cases, a minimum sample size of 30 vehicles should be collected. For ordinary conditions this will provide an estimate of the average and the mean or 85th percentile speed.

8.4. ANALYSIS

Though the nationally recognized method for establishing safe and reasonable speed zones is based upon the 85th Percentile Speed, the analysis will usually consist of determining the average speed; the 85th percentile speed (critical speed); the 10 mph pace speed; and the standard deviation, if statistical measures are to be applied. A speed-distribution curve also may be plotted. These terms are defined as:

Average Speed—The mean, or average, speed is calculated by summing the individual speed observations, S, and dividing by the total number of observations, N.

$$S_{avg} = \Sigma S / N$$

Such an average is called the time-mean speed and refers to the basic arithmetic mean of speed collected at a spot location. However, the average of those readings taken by the time-distance method is called the space-mean speed. Time-mean speed should not be directly compared with space-mean speed, since the two represent different quantities. However, for most practical purposes of spot speed studies, the difference is insignificant. The average speed is useful for making comparisons between several sets of data, such as before/after studies; for example, "The average speed observed on Maple Street north of 1st Street increased from 31 mph to 37 mph over a 10-year period."

85th Percentile Speed—The 85th percentile speed is the speed that 85 percent of the free-flowing vehicles are traveling at or below. Restated, only 15 percent of the drivers travel faster than the 85th percentile speed. Studies have shown that the typical driver is a relatively good judge of what constitutes a safe operating speed. Accordingly, the 85th percentile speed is often used by many states and cities for establishing the basis for a regulatory speed zone. The 85th percentile speed most closely conforms to a speed limit which is considered safe and reasonable. The MUTCD indicates that the speed limit should be within 5 mph of the 85th percentile speed; however, this is before any adjustment due to crash history, safety concerns such as poor sight distance, high pedestrian volume, etc. To determine the 85th percentile speed, list the vehicle speed observations in order of increasing speed. Calculate the vehicle speeds from the corresponding field recorded vehicle times as shown in the sample field sheet in Exhibit 8.1. If 100 vehicles are used in the study, the 85th cumulative vehicle speed observed is the 85th percentile speed. If more than 100 vehicles are used in the study, calculate the percent of total vehicles recorded and the cumulative percent of vehicles recorded. The 85th cumulative percent represents the corresponding 85th percentile speed. In the example field sheet, Exhibit 8.1, the 85th percentile speed is 30 mph.

10 mph Pace Speed—The 10 mph pace speed is the 10 mile-per-hour range that contains the highest number of vehicles observed. The percentage of vehicles within the pace is a measure of the spread of the speed data. The higher this percentage is, the more uniform the speeds are. For example, speed data having 80 percent of the observations falling within the pace have less spread than data having only 40 percent in the pace. A normal speed distribution contains approximately 70% of the vehicles within the pace, with approximately 15% of the vehicles below and 15% above the limits of the pace speed. In most cases, the upper limit of the 10 mph pace speed is approximately the 85th percentile speed. However, depending on the distribution curve of the vehicle speeds, the upper limit of the pace speed may vary from the 85th percentile speed.

Standard Deviation—This is a statistical parameter and is a measure of the spread (variation) of the sample data. A higher standard deviation indicates a larger spread of data about the sample mean. The calculation of the standard deviation is not usually part of a speed zoning study, but may be used in before/after comparisons.

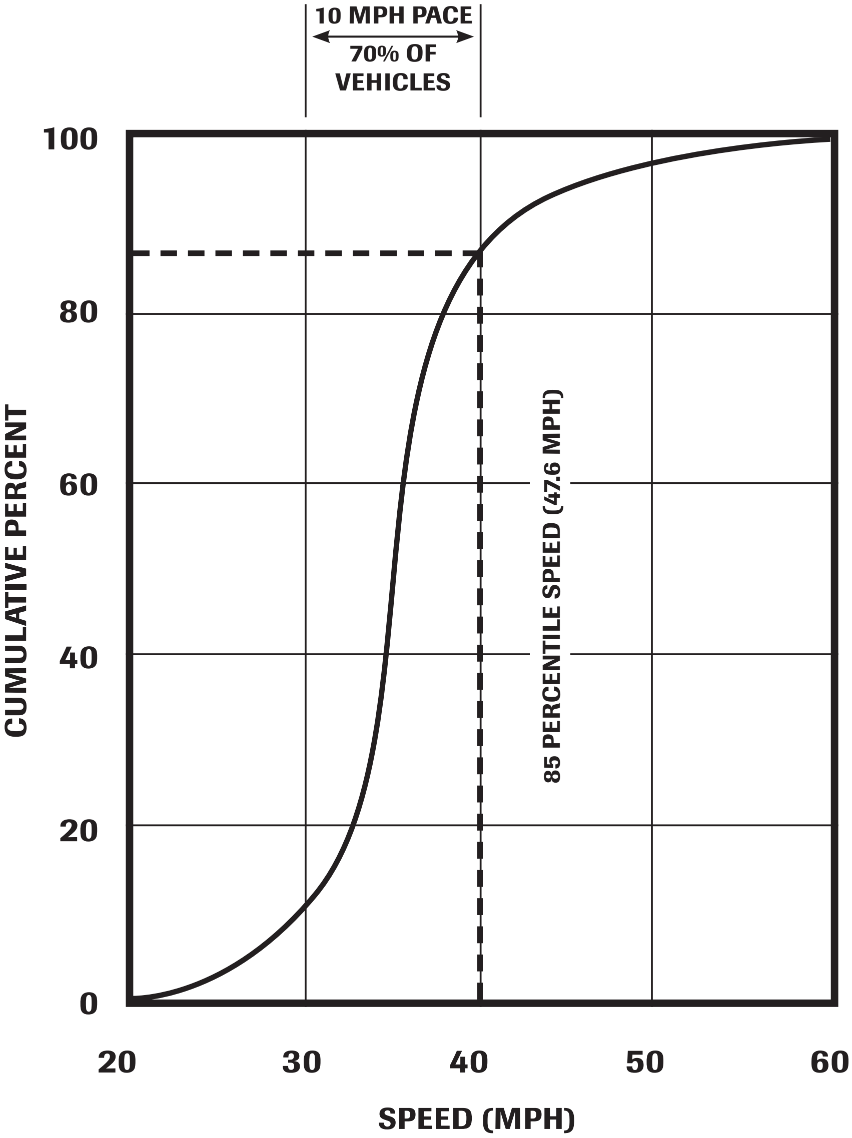
8.5. INTERPRETATION

The spot speed data should be totaled and the numerical average speed computed as previously discussed. If statistical comparisons of speed data are to be made, the standard deviation should be calculated.

A speed-accumulation curve, also known as a cumulative frequency diagram, may be plotted by starting at the lowest speed grouping and consecutively adding each higher speed group (one after another) to produce a cumulative count. The percentage for each number is then calculated by dividing by the number of observations, N. These values are then plotted, and a smooth curve is drawn through the points as shown in Exhibit 8.3, Speed Accumulation Curve. The 10 mph pace speed is indicated at 30 to 40 mph.

Statistical techniques show that a normal probability distribution will occur when a random sample of traffic is measured. The cumulative frequency diagram suggests a certain percentage of drivers drive too fast for the existing conditions and a certain percentage of drivers travel at an unreasonably slow speed compared to the trend of traffic.

Exhibit 8.3: Speed Accumulation Curve



Most speed-accumulation curves “break” at approximately 85 percent of the total number of observations as seen in Exhibit 8.3. Consequently, the motorists speeds observed above the 85th percentile value are assumed to be exceeding a safe and reasonable speed. Therefore, for purposes of speed zoning, the maximum posted speed should be as near as possible to the 85th percentile value.

Several indications may be found on the speed-accumulation curve. Some curves are fairly vertical in appearance, while others appear to be more horizontal. The more vertical curve usually shows better driving conditions than the gently sloping curve and indicates that most traffic is traveling at nearly the same speed. A reduction in the spread of speed data is one of the primary goals of speed zoning. Effective speed zoning will automatically make roadways safer, since it is speed differential and not speed alone that is a principal cause of traffic crashes.

Proper speed zoning will reduce the speed of the faster vehicles, increase the speed of the slower vehicles, and thereby increase speed uniformity between the vehicles. The first step in setting the proper speed posting is to determine the 85th percentile speed. It is important to fully evaluate the 85th percentile speed, including:

- ✓ The volume and type of vehicles traveling the roadway
- ✓ The crash history data involving vehicles and pedestrians
- ✓ Geometry of the roadway
    - Horizontal and vertical profile of the roadway
    - Number of intersections,
    - Stopping sight distance
- ✓ Pedestrian activity
- ✓ Number of crosswalks
- ✓ The amount of roadside development
- ✓ The number of access points
- ✓ Vehicle speeds on adjacent roadway

All of these conditions should be considered prior to setting a limit for a speed zone. It is important that the proposed speed limit not be set below the 67th percentile speed of free flowing vehicles as indicated in the ITE Speed Zoning Guidelines. Speed zone setting should also comply with all state statutes.

Potential corrective actions to enforce a safe speed zone may include:

- ✓ Adjust the posted speed limit (Increments of 5 mph should be used on speed limit signs)
- ✓ Increase speeding enforcement
- ✓ Initiate traffic calming measures
- ✓ Conduct public awareness efforts
- ✓ Roadway or pedestrian safety improvements

Ball-Bank Indicator—The ball-bank indicator, as shown in Exhibit 8.4, is a device used as a method to determine the advisory speed for horizontal curves. The ball-bank indicator measures the driver discomfort while negotiating a horizontal curve and consists of a curved glass tube which is filled with a liquid. A weighted ball floats in the glass tube. The ball-bank indicator is mounted in a vehicle, and as the vehicle travels around a curve the ball floats outward in the glass curved tube. The movement of the ball is measured in degrees of deflection and this reading is indicative of the combined effect of superelevation, lateral (centripetal) acceleration, and vehicle body roll. It has been determined that speeds on curves that avoid driver discomfort are indicated by ball-bank readings of:

- ✓ 16 degrees of ball-bank for speeds of 20 mph or less
- ✓ 14 degrees of ball-bank for speeds of 25 to 30 mph
- ✓ 12 degrees of ball-bank for speeds of 35 mph and higher

Source: 2009 MUTCD, Section 2C.08

Exhibit 8.4: Ball-Bank Indicator

Model 1023W1 Ball-Bank Indicator, Courtesy of Rieker, Inc., ©2002-2006 Rieker® All Rights Reserved.

Curve Speed—The ball-bank indicator method can be used in a curve speed analysis. This method is based on a set of field driving tests to record ball-bank indicator readings using a ball-bank indicator and a speedometer. The vehicle speedometer should be checked by using a calibrated radar detector or other method. Two people will be required to conduct the study, one person to drive and the other to record the ball-bank readings, especially if advisory speeds are being determined for a series of curves. The ball-bank indicator must be mounted in the vehicle so that it displays a 0-degree reading when the vehicle is stopped on a level surface.

The positioning of the ball-bank indicator is checked before starting any test. This can be done by stopping the car so that its wheels straddle the centerline of a two-lane highway on a tangent alignment. In this position, the vehicle is essentially level, and the ball-bank indicator should give a reading of 0-degree. Starting with a relatively low speed, the vehicle is driven through the curve at a constant speed following the curve alignment as closely as possible, and the reading on the ball-bank indicator is noted. On each test run, the driver must reach the test speed at a distance of at least ¼ mile in advance of the beginning of the curve, and maintain the same speed throughout the length of the curve.

The path of the vehicle must be maintained as nearly as possible in the center of the lane. For two or more lanes in the same direction, locate the vehicle in the center of the innermost lane (the lane closest to the inside edge of the curve) in the direction of travel. If there is more than one lane in the direction of travel, and these lanes have differing superelevation rates, the lane with the lowest amount of superelevation should be used.

Because it is often difficult to drive the exact radius of the curve and keep the vehicle at a constant speed, it is suggested that at least three test runs in each direction be made to more accurately determine the ball-bank reading for any given speed. On each test run, the recorder carefully observes the position of the ball throughout the length of the curve and records the deflection reading that occurs when the vehicle is (as nearly as possible) being driven the exact radius of the curve. It is desirable for the reading to be taken nearest to the center of the curve where full superelevation has been achieved. If the readings on the ball-bank indicator for a series of test runs does not exceed the MUTCD criteria previously stated, then the speed of the vehicle is increased by 5 mph and the test is repeated. The vehicle speed is repeatedly increased in 5 mph increments until the ball-bank indicator reading exceeds the acceptable maximum. On sharp radii curves with no superelevation, as typically seen on installations, test runs should be conducted in both directions as each direction may result in a different speed posting. The curve advisory speed is set at the highest test speed that does not result in a ball-bank indicator reading greater than an acceptable level. Other factors may also need to be observed to evaluate the appropriateness of the advisory speed determined from the test runs.

The field evaluation of curve conditions should include consideration of the following roadway features:

- ✓ Approach sight distance at the beginning of the curve
- ✓ Visibility around the curve
- ✓ Unexpected geometric features within the curve, such as:
  - intersection or driveway
  - sharp crest vertical curve
  - sharp curves
- ✓ Position of the most critical curve in a sequence of closely spaced curves

In addition, refer to SDDCTEA Pamphlet 55-17 and the 2009 MUTCD criteria for appropriate warning signs and advisory speed plaques in advance of and/or at curves.

Information regarding traffic and speed statutes and laws for each state can be found from the following website link from the Massachusetts Institute of Technology, http://www.mit.edu/~jfc/laws.html. This informational site is provided to access links to state’s statute codes for speed limits and should not be considered all-inclusive and/or current. Appropriate state statutes should be reviewed and adhered to when conducting a spot speed study. Another source available on the internet that can be used to obtain the number of the actual state statute is the document entitled *Summary of State Speed Laws* by National Highway Traffic Safety Administration (NHTSA).

8.6. APPLICATION

Vehicle spot speed study data are used for many purposes including:

Establishing Speed Zones—Each speed-zoning problem should be considered separately. For example, speeds higher than the posted limit may indicate the need for greater enforcement if they occur in a congested area. However, on an open boulevard, an 85-percentile speed more than 5 mph higher than the posted limit may indicate an unrealistically low posted speed limit.

Signs (letter height and placement)—An informational or warning sign must be legible to the driver. Typical vehicle speeds may be used to design effective signs by allowing choice of the proper size letters for the sign, and by permitting placement of the sign far enough in advance so that the driver can take action. In general, with higher speeds, larger signs are required and should be mounted at greater advance distances. See SDDCTEA Pamphlet 55-17 for information on signing requirements.

Setting Signal Clearance Intervals—The average, free-flow road speed is used to determine the proper clearance interval (yellow plus all red) for signalized intersections. Speed is also a factor in determining the warrants for a new traffic signal.

Congestion Management—Data from spot speed studies can be used in a roadway level of service analysis to determine the level of traffic congestion within a particular roadway segment or corridor.

Crash Analysis—Spot speed studies may contribute to a recognition of the causes of vehicle crashes within the installation and help identify remedial improvements to eliminate or reduce the severity of crashes. Speed studies are also useful for crash investigations, identifying the need for increased enforcement within speed zones, evaluating alignment and general roadway features, and designing safety appurtenances.

Environmental Impacts—Spot speed studies can help address traffic congestion issues which can directly affect air and noise quality when introduced into regional air quality models.

Performance Measures—The before/after spot speed study is used to determine what effects (if any) recent changes to the road environment may have had on typical speeds. For example, a before/after spot speed study may be used to show the results of road improvements such as widening a dangerous road. The study may indicate whether newly placed Hazard Warning signs are having any effect on driver behavior, or show the effect of a newly revised speed zone.

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CHAPTER 9—ORIGIN-DESTINATION STUDY

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CHAPTER 9—ORIGIN-DESTINATION STUDY

9.1. OBJECTIVE

Origin-destination (OD) studies are often used in transportation planning to determine the travel patterns of traffic on an installation during a typical day. Origin-destination studies can be helpful in determining the travel patterns of the population in and around the military installation and in assisting long-range traffic planning where changes are anticipated in the installation mission or strength. Every trip is considered to have a point of origin and a destination. The results of an origin-destination study may be grouped to determine travel patterns according to trip purpose and preferred transportation mode. Trips can be identified as:

- ✓ Internal—From one point on the installation to another point on the installation.
- ✓ External—From on-installation to off-installation or off-installation to on-installation
- ✓ Through—From off-installation to off-installation, by going through the installation

Understanding where traffic is coming from and going to can be useful to:

- ✓ Assist in making installation planning decisions based on regional origin of personnel
- ✓ Aid in the analysis of traffic congestion within the installation
- ✓ Determine the optimum location for new routes and/or internal/external installation access points
- ✓ Determine the size of ECFs
- ✓ Determine the location and size of parking lots
- ✓ Design or improve transit services and other multi-modal transportation modes throughout the installation

9.2. INFORMATION NEEDED

Required data can vary with the OD method used. All OD studies require the trip origin, the trip destination, and the travel mode (vehicle type). Some study methods may also require the trip purpose (work or shopping, etc.), the number of persons in each vehicle, the route chosen, the time of trip, and the parking facility used. Some questionnaires may require the person to supply certain socioeconomic data such as the number of vehicles owned, employment status (civilian, military, or retired), wage or service grade, and residence type (bachelor housing, installation housing, or private dwelling). It may be necessary to use several types of OD methods to gather complete travel information.

9.3. METHODS

There are several methods for conducting an OD study. The methods to collect survey information range from personal interviews and handout forms, to more technological methods including; internet use, GPS location, cell phone tracing, video imaging and loop detectors. The methods most applicable to military installations will be discussed in this chapter and are as follows:

- ✓ Web-based personnel questionnaire
- ✓ Bluetooth Tracking

The number of personnel needed to conduct the study will depend on the method of study used. If a survey is justified, the proper type of method must be selected. This decision should be based on the way in which the data will be used. For example, when it is necessary to predict the effects of closing an entrance gate, a personnel questionnaire will likely suffice.

The OD survey should begin by establishing and numbering traffic analysis zones on and around the installation. The purpose of the zones is to summarize travel patterns into suitable small local areas. It is assumed that all trips having an origin or destination (trip end) within the boundaries of a particular zone occur from the centroid of that zone. Several pointers for establishing zones are:

- ✓ Design the zones small enough to discern travel patterns. For example, if 4,000 trips are destined for a training area, it may be desirable to split the area into several zones. The more densely an area is populated, the more zones will be needed.
- ✓ Do not establish too many zones; they increase the complexity of the data reduction without providing any new knowledge. If less than 5 percent of the total trips are bound for numerous zones, then too many have been made.
- ✓ Establish zone boundaries along natural or recognizable barriers such as railroad tracks or rivers.
- ✓ Establish boundaries so as to group similar land use or functional activities. Be logical. For example, perhaps a suitable boundary can be found to include all housing in one zone.
- ✓ Establish separate zones for heavy traffic generators. For example, one zone could be used to hold both the exchange and the commissary, and another zone used for the medical facility.
- ✓ Use established zones. For example, the surrounding community may be zoned by using ZIP codes or township lines, or the installation could be zoned using building numbers, block numbers, or zones established by a previous traffic engineering study.
- ✓ Develop external zones to include the major portion of the off-installation working population. This can usually be accomplished by zoning an area within a 25-mile radius of the installation. Zones outside the radius should have infinite boundaries. For example, let one zone include all other areas to the north and establish similar zones for other directions.

9.3.1. Method 1: Web-based Personnel Questionnaire

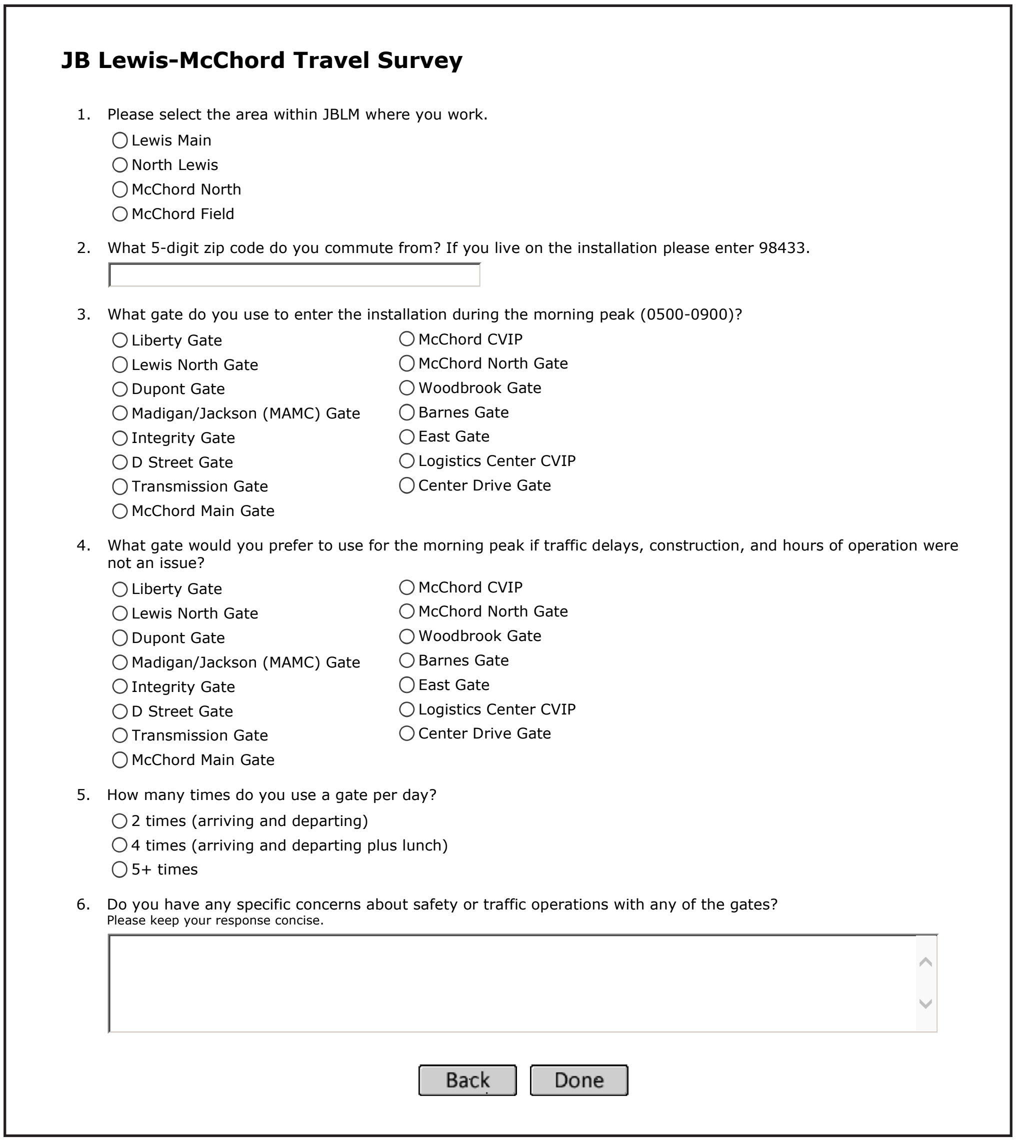
A web-based questionnaire is one of the most convenient and widely utilized methods of conducting an OD study. This is an electronic method of collecting and analyzing specific data for many applications and is distributed to each person (military, civilian, and contractor) having a duty station on the installation. Web-based surveys are relatively economical to develop and can easily reach a large number of respondents. It can be developed to collect general travel origin and destination information along with other data such as residence location, demographics, place of work, duty hours, mode of travel, etc. from all personnel accessing the installation. There are numerous websites available as well as companies specializing in web surveys to help develop the survey template, content, implement the survey, and provide a summary of the resulting survey data.

The first step in the process to conduct a web-based survey is to request and receive approval from the installation command to post the questionnaire on the installation website. Electronic notification (email) can be made to all military, civilian and contractor personnel to inform them of the survey availability and purpose, and request their online response to the survey questions.

Exhibit 9.1 shows a sample of a generic web-based questionnaire. Web surveys can also be accessed via smart phone applications. Survey questions can address internal installation travel patterns or external points of origin to determine the distribution of installation personnel arriving from various regions surrounding the installation. It can also include the type of travel to determine the distribution of travel mode by type. The survey questions should be focused on gaining insight on travel patterns on a typical work week with all organizations operating near strength. This would exclude periods containing a holiday, a training-school vacation, special maneuvers, or periods when the fleet is at sea. Midweek days (i.e., Tuesday, Wednesday and Thursday) typically are the best periods for conducting a survey.

Information and analysis derived from a web survey can be summarized in multiple formats (bar charts, graphs, tables, etc.) and posted on the installation website for respondents to view.

Exhibit 9.1: Sample of a Web-based Questionnaire

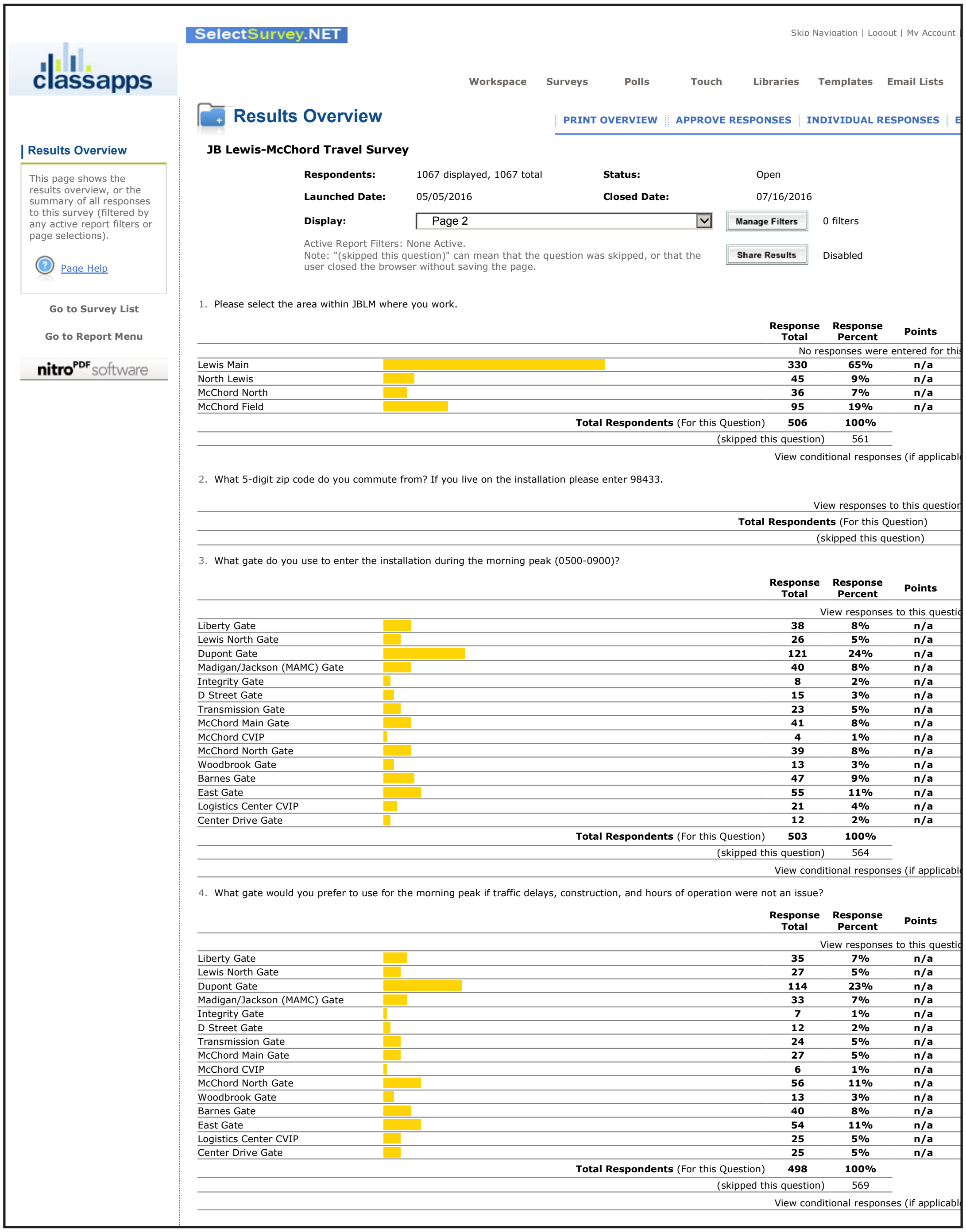


JB Lewis-McChord Travel Survey

1. Please select the area within JBLM where you work.
   - ○ Lewis Main
   - ○ North Lewis
   - ○ McChord North
   - ○ McChord Field
2. What 5-digit zip code do you commute from? If you live on the installation please enter 98433.
3. What gate do you use to enter the installation during the morning peak (0500-0900)?
   - ○ Liberty Gate
   - ○ Lewis North Gate
   - ○ Dupont Gate
   - ○ Madigan/Jackson (MAMC) Gate
   - ○ Integrity Gate
   - ○ D Street Gate
   - ○ Transmission Gate
   - ○ McChord Main Gate
   - ○ McChord CVIP
   - ○ McChord North Gate
   - ○ Woodbrook Gate
   - ○ Barnes Gate
   - ○ East Gate
   - ○ Logistics Center CVIP
   - ○ Center Drive Gate
4. What gate would you prefer to use for the morning peak if traffic delays, construction, and hours of operation were not an issue?
   - ○ Liberty Gate
   - ○ Lewis North Gate
   - ○ Dupont Gate
   - ○ Madigan/Jackson (MAMC) Gate
   - ○ Integrity Gate
   - ○ D Street Gate
   - ○ Transmission Gate
   - ○ McChord Main Gate
   - ○ McChord CVIP
   - ○ McChord North Gate
   - ○ Woodbrook Gate
   - ○ Barnes Gate
   - ○ East Gate
   - ○ Logistics Center CVIP
   - ○ Center Drive Gate
5. How many times do you use a gate per day?
   - ○ 2 times (arriving and departing)
   - ○ 4 times (arriving and departing plus lunch)
   - ○ 5+ times
6. Do you have any specific concerns about safety or traffic operations with any of the gates?
   Please keep your response concise.

Exhibit 9.2 shows results from a separate sample web-based survey. Generally, an adequate response rate for a web-based survey is 20 to 25 percent.

Exhibit 9.2: Sample Web-based Survey Results



Results Overview

This page shows the results overview, or the summary of all responses to this survey (filtered by any active report filters or page selections).

Results Overview

JB Lewis-McChord Travel Survey

Respondents: 1067 displayed, 1067 total

Status: Open

Launched Date: 05/05/2016

Closed Date: 07/16/2016

Display: Page 2

0 filters

Active Report Filters: None Active.
Note: "(skipped this question)" can mean that the question was skipped, or that the user closed the browser without saving the page.

Disabled

1. Please select the area within JBLM where you work.

	Response Total	Response Percent	Points
		No responses were entered for thi	
Lewis Main	330	65%	n/a
North Lewis	45	9%	n/a
McChord North	36	7%	n/a
McChord Field	95	19%	n/a
Total Respondents (For this Question)	506	100%	
(skipped this question)		561	

View conditional responses (if applicabl

2. What 5-digit zip code do you commute from? If you live on the installation please enter 98433.

View responses to this questior

Total Respondents (For this Question)

(skipped this question)

3. What gate do you use to enter the installation during the morning peak (0500-0900)?

	Response Total	Response Percent	Points
		View responses to this questi	
Liberty Gate	38	8%	n/a
Lewis North Gate	26	5%	n/a
Dupont Gate	121	24%	n/a
Madigan/Jackson (MAMC) Gate	40	8%	n/a
Integrity Gate	8	2%	n/a
D Street Gate	15	3%	n/a
Transmission Gate	23	5%	n/a
McChord Main Gate	41	8%	n/a
McChord CVIP	4	1%	n/a
McChord North Gate	39	8%	n/a
Woodbrook Gate	13	3%	n/a
Barnes Gate	47	9%	n/a
East Gate	55	11%	n/a
Logistics Center CVIP	21	4%	n/a
Center Drive Gate	12	2%	n/a
Total Respondents (For this Question)	503	100%	
(skipped this question)		564	

View conditional responses (if applicabl

4. What gate would you prefer to use for the morning peak if traffic delays, construction, and hours of operation were not an issue?

	Response Total	Response Percent	Points
		View responses to this questi	
Liberty Gate	35	7%	n/a
Lewis North Gate	27	5%	n/a
Dupont Gate	114	23%	n/a
Madigan/Jackson (MAMC) Gate	33	7%	n/a
Integrity Gate	7	1%	n/a
D Street Gate	12	2%	n/a
Transmission Gate	24	5%	n/a
McChord Main Gate	27	5%	n/a
McChord CVIP	6	1%	n/a
McChord North Gate	56	11%	n/a
Woodbrook Gate	13	3%	n/a
Barnes Gate	40	8%	n/a
East Gate	54	11%	n/a
Logistics Center CVIP	25	5%	n/a
Center Drive Gate	25	5%	n/a
Total Respondents (For this Question)	498	100%	
(skipped this question)		569	

View conditional responses (if applicabl

9.3.2. Method 2: Bluetooth Tracking

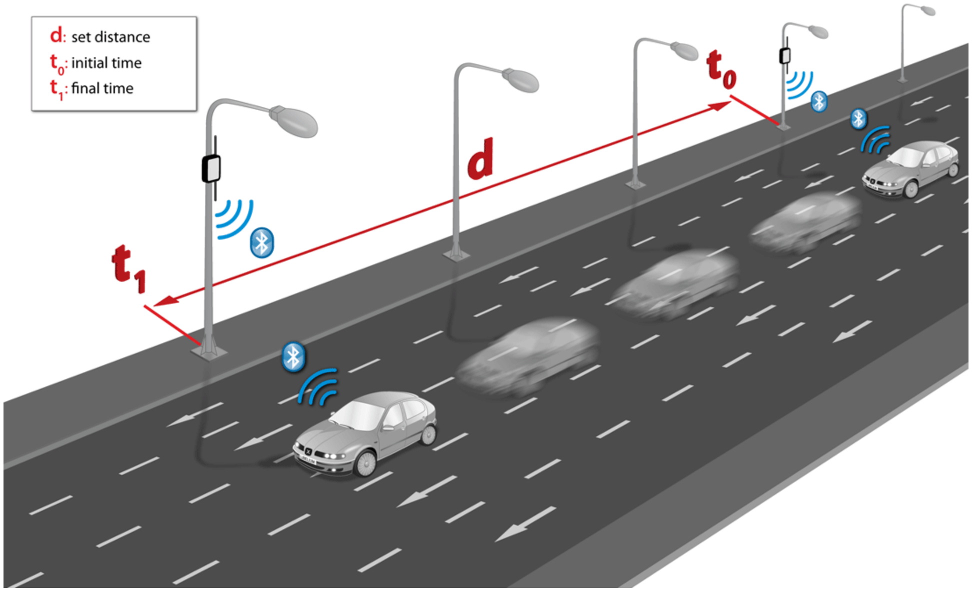
Bluetooth technology can be utilized for travel time and delay study, and OD data collection. Bluetooth is an open, wireless communication platform used to connect many electronic devices. Many computers, car radios and dashboard systems, cell phones, headsets, or other personal equipment are, or can be, Bluetooth-enabled to streamline the flow of information between devices. Bluetooth detector devices can be placed along a roadway segment or between an origin zone and destination zone along a corridor to collect travel time and speed data to help develop origin and destination travel patterns, as shown in Exhibit 9.3.

A basic Bluetooth sensor system for traffic monitoring consists of a Bluetooth probe device (s) that scans for other Bluetooth-enabled device (s) within its radio proximity, then stores the data for future analysis and use. The scanned devices are typically either within the vehicle electronics or carried by the driver/passengers.

Bluetooth detects anonymous Media Access Control (MAC) addresses which are wireless identifications used to connect Bluetooth technologies on mobile devices in vehicles. The system calculates travel time through analysis of detections between multiple detectors. The unique address of each signal is logged, along with the time to the nearest second. A similar process occurs at every detector point, and once the data is processed through software, it builds up an OD pattern of the traffic movements. However, since the exact origin and destination of the vehicle is unknown when passing a Bluetooth detector, only estimations of vehicle travel patterns can be derived.

Companies that provide Bluetooth products, software and services for use in developing OD information are available on the market.

Exhibit 9.3: Bluetooth Tracking



9.3.3. Other Methods

In addition to the web-based personnel questionnaire and bluetooth tracking methods, there are several older methods that can be utilized when conducting an OD study and include:

- ✓ Roadside interviews
- ✓ Postcard/mail-back survey
- ✓ License-plate survey
- ✓ Tag-on-vehicle method

Though these methods are available, they are not recommended due to associated safety concerns. It is unsafe for survey personnel to stand in traffic and the survey process itself may cause congestion. The combination of the presence of the survey personnel and the congested traffic conditions, further create unsafe conditions for both the drivers and the observers. In addition to the safety concerns, errors are more easily introduced in several processes during data collection. Considering that technology is readily available and low cost, these out dated methods are not described in detail in this pamphlet. For further information about these methods, contact SDDCTEA.

9.4. ANALYSIS

Analysis will consist of preparing numerical tables of raw data and then creating visual aids to help interpret the results. The visual aids will consist of simple tables, graphs, travel desire-line drawings, and bar charts. Examples of these are found in Exhibits 9.4–9.8. Exhibit 9.4 illustrates a typical mode table generated from responses to an OD questionnaire. On a bar chart, as in Exhibit 9.5, the height of the bar represents the number of persons desiring to travel in a certain direction. The travel desire-lines may be drawn from the origin zone to the destination zone as in Exhibit 9.6; or, as in Exhibit 9.7, drawn along existing roadways if the travel route is known. Exhibit 9.8 represents an example of the entrance gate-to-work zone travel desires. The line intensity represents the number of vehicles traveling between origin and destination zones.

Exhibit 9.4: Transportation Mode of Base Working Population by Work Zone

WORK ZONE	MODE							TOTAL
	DROVE	PASSENGER	COMMERCIAL BUS	MILITARY BUS	BICYCLE	MOTORCYCLE	WALKED	
1	1038	119	7	0	3	9	42	1218
2	97	17	0	0	0	1	9	124
3	173	20	1	2	3	0	24	223
4	45	5	0	2	0	2	1	55
5	1852	290	20	2	20	5	45	2234
6	987	166	8	10	13	4	2	1190
7	678	73	2	0	11	6	27	797
8	559	45	7	4	18	5	16	654
9	1239	119	0	4	13	25	46	1446
TOTAL	6668	854	45	24	81	57	212	7941

Exhibit 9.5: Typical OD Bar Chart

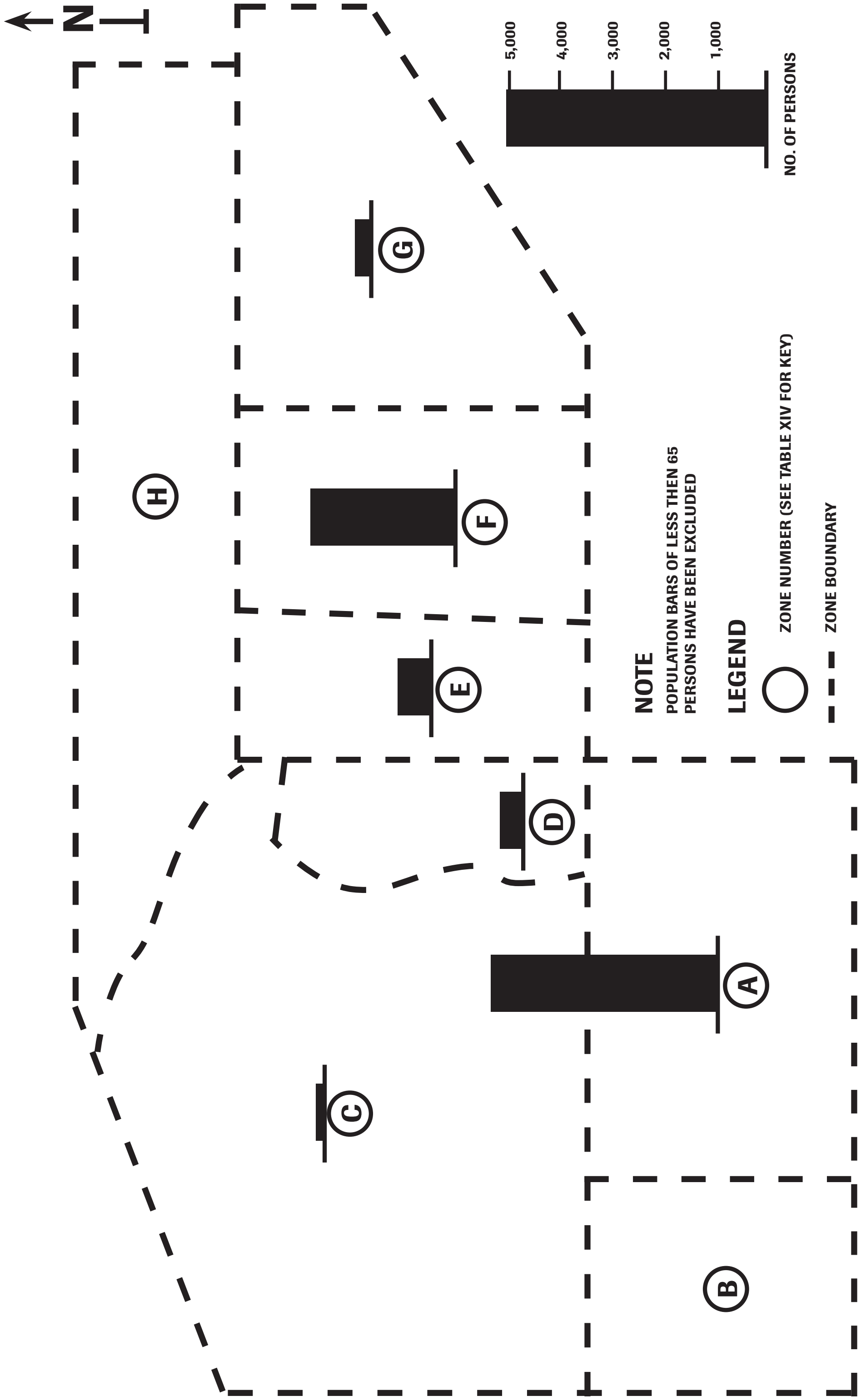


Exhibit 9.6: Typical OD Map

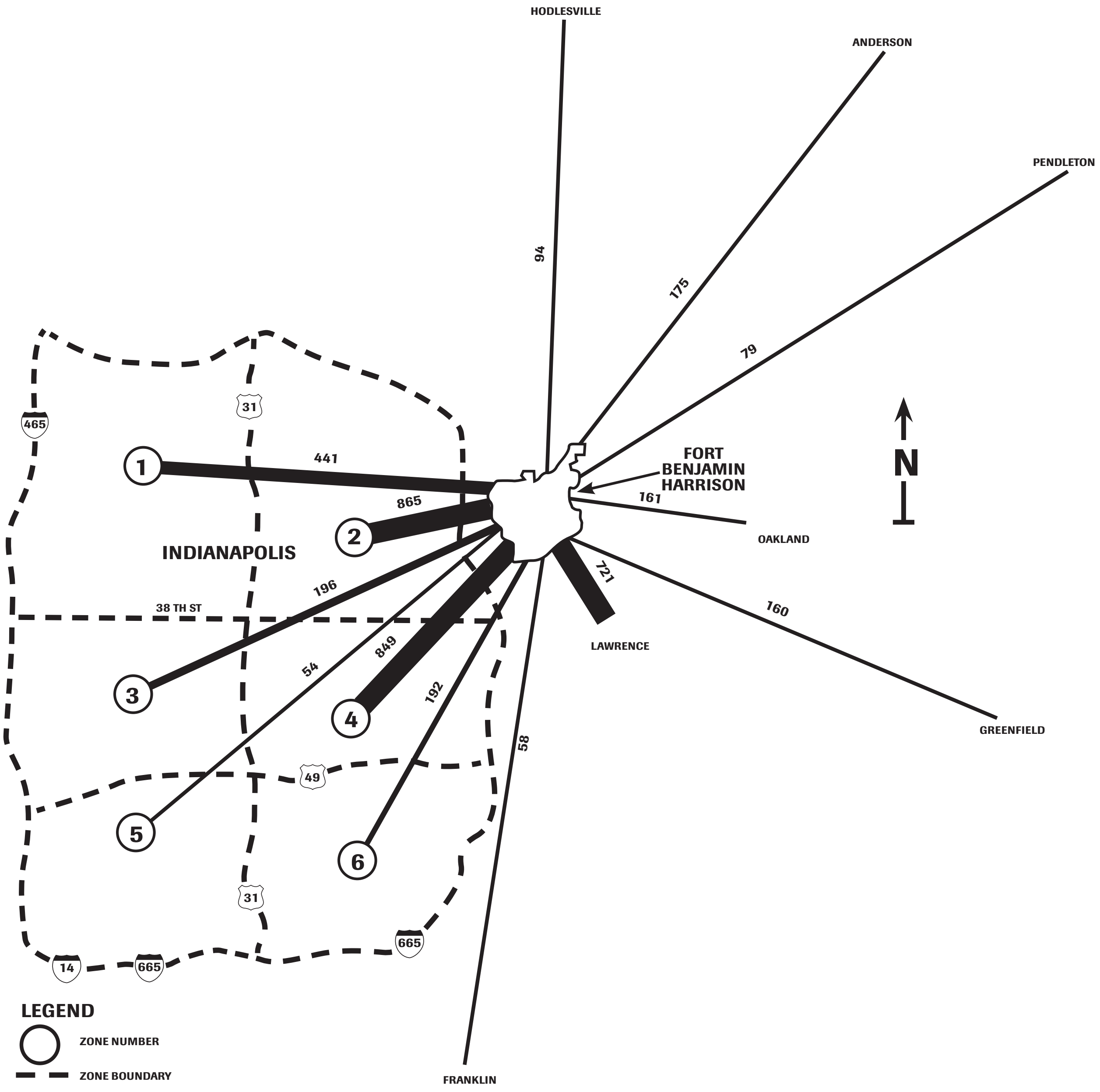


Exhibit 9.7: Typical Approach Road-to-Entrance Gate Map

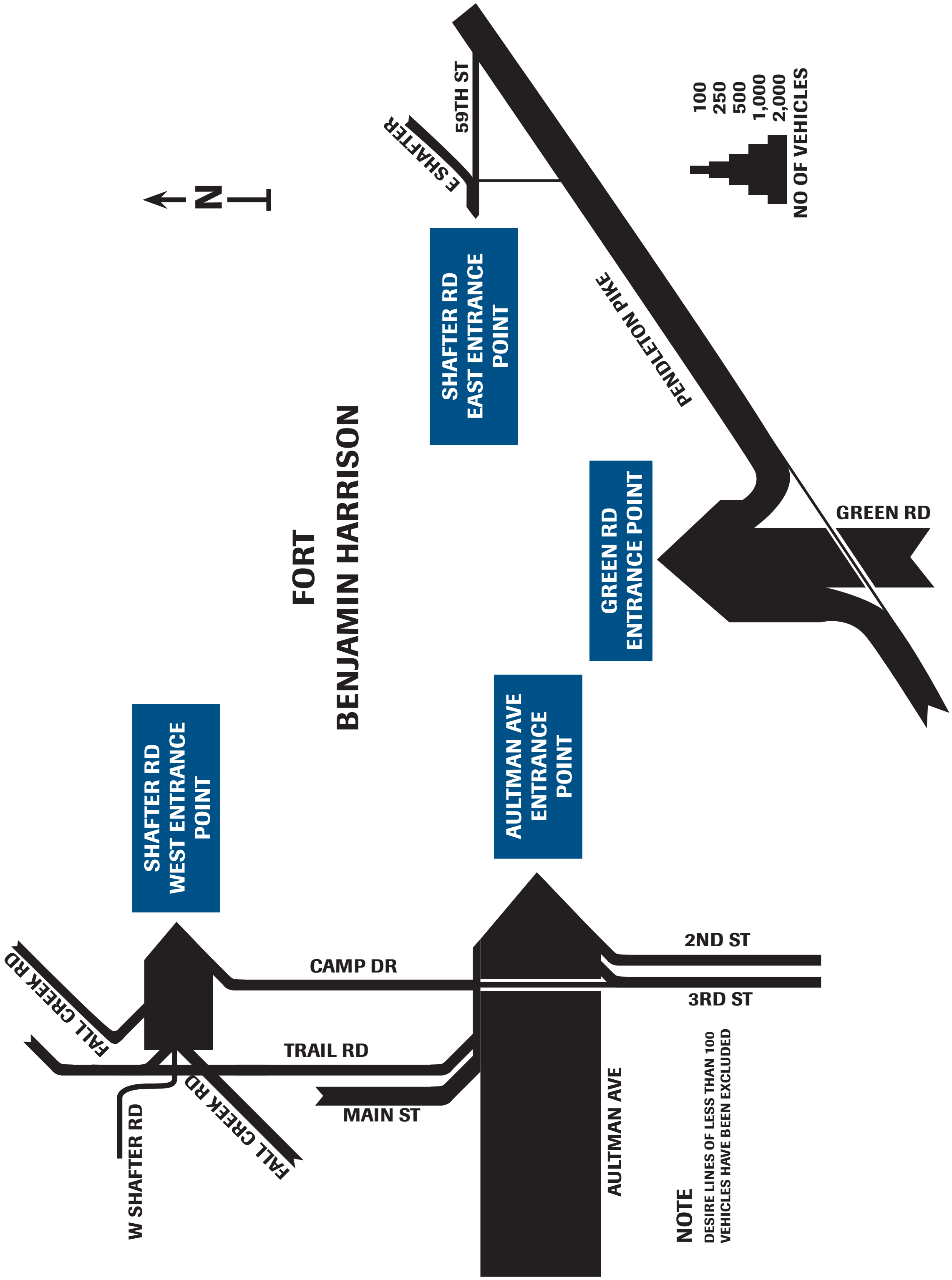
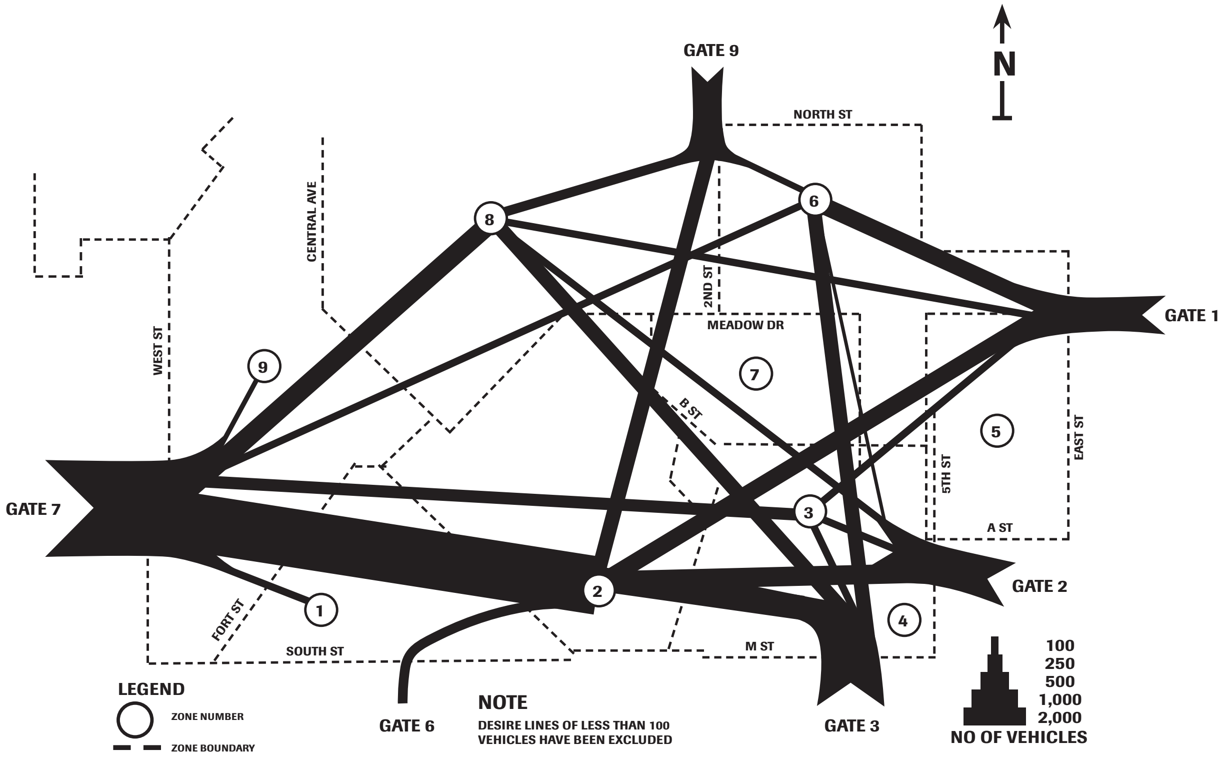


Exhibit 9.8: Typical Entrance Gate-to-Work Zone Map



When analyzing raw data, care must be taken to reject illogical or impossible conclusions. For example, if a particular statement on the OD questionnaire was misunderstood by the readers, many wrong answers could result. A system of cross checks should be devised to prevent possible errors. For example, if only 300 cars were actually counted at Gate 6, but 750 drivers responded that they entered via Gate 6, there is a discrepancy with your questionnaire or its instructions.

9.5. INTERPRETATION

This will depend on the subject matter of the table, graph, or desire-line drawing. It will also depend on the original purpose for undertaking the OD study. The interpretation will usually place much greater emphasis on the larger numerical answers. Then, some statement should be made about the conclusion you reach. It is also appropriate to make comparisons between data. For example, for Exhibit 9.4 typical mode table from OD study questionnaire, one might state: “It is seen that 6,668 persons drove to work, while only 45 persons used the commercial bus service.” Also, for example, from Exhibit 9.6 Typical OD Map, one might conclude that: “It is seen that the town of Lawrence generates almost as many trips as some of the more populated zones of Indianapolis.”

9.6. APPLICATIONS

The purpose of an OD study is to determine an travel patterns of the base population entering, exiting, and within a military installation. Once the travel desires are known, many applications in terms of practical transportation decisions can be made.

Building Location—The results of an OD study may be applied to help determine the optimum location for new or expanded buildings within the installation. For example, if the survey reveals that most of the customers of the commissary are traveling from off the installation, consider locating a new commissary within an area of the installation that provides more convenient access to reduce both the number of trips, and the average trip length.

Route Location—If an OD study indicates a wide desire line (a higher concentration of traffic volume along a corridor) from one location to another within the installation, consideration should be given to potential methods for maintaining a smooth traffic flow along the desire line. In addition to potential capacity improvements such as roadway widening or additional lane configurations, consideration of traffic signal upgrades, new or additional bicycle lanes and pedestrian pathways, and additional transit stop(s) along the desire line will promote an inexpensive, environmentally sensitive and healthy choice of alternative transportation modes for the installation personnel that will help to reduce vehicular traffic volume along the route.

Transit Routes—When planning or improving routes for mass transit, OD studies can identify higher travel patterns within the installation where transit stops will serve the most populated areas. It is also desirable to have the route pass through major population concentrations as indicated by the population bar chart as seen in Exhibit 9.5.

Entrance Gates—OD studies can provide useful information regarding the travel patterns of personnel entering the installation. Location, size and number of ECFs needed to serve the installation can be determined from OD analysis. The need for expansion, relocation or elimination of the ECFs serving the installation can also be identified. For example, if only 5 percent of the post working population use Gate 7, it might be feasible to close it completely. Using the travel desire lines, it would then be possible to predict the amount of increased traffic at the other gates.

Through Traffic—Once the amount of through traffic has been determined from the survey results, it may be desirable to alter existing traffic routing. For example, a large amount of traffic following routes through housing areas would be an indication that existing arterial routes are inadequate or improperly defined. In such a case, it may be desirable to either upgrade the arteries or to establish THRU TRAFFIC ROUTES by means of proper signs.

Parking—Parking-space adequacy may be obtained by comparing the supply with the demand indicated by parking-zone replies. In general, it is desirable to locate parking lots within or near zones having a large working population.

Duty Hours/Car Pools—The results of an OD survey may indicate that too many employees have the same duty hours. Excessive concentrations can cause traffic congestion and delays. The results may also indicate the number of employees carpooling. Comparison of duty hours with organizational working strengths will identify potential work force scheduling improvements such as staggered work hours, telecommuting, flextime, etc.

Other Jurisdictions—It is of mutual benefit for military installations to exchange OD results with local transportation planning agencies and public officials.

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CHAPTER 10—PUBLIC TRANSPORTATION STUDY

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CHAPTER 10—PUBLIC TRANSPORTATION STUDY

10.1. OBJECTIVE

Public transportation studies provide information needed to assess the effectiveness and quality of the public transit services provided on a military installation, and develop supporting data that may indicate a need to improve operational characteristics. The studies provide the foundation for:

- ✓ Planning future routing
- ✓ Improving service reliability and safety
- ✓ Identifying passenger demand at various stops
- ✓ Assessing passenger satisfaction
- ✓ Determining the amount and location of access points
- ✓ Coordinating transit service schedules to effectively correlate with personnel work schedules.

Ultimately, the studies are intended to help determine how best to serve the public transportation needs of the military installation personnel.

When the transit service is provided by a private or government agency transit service provider, perceived transit service problems or concerns within the military installation should be brought to the attention of the service provider so that coordinated efforts to study, analyze problems and determine appropriate remedial action can be made. The transit service provider may provide the data collection and analysis information and/or conduct any necessary studies.

10.2. INFORMATION NEEDED

Transit service can be evaluated based on a single stop, a route segment with multiple stops, or a system of multiple routes. Generally, installation personnel utilizing a fixed route bus transit system will be concerned mainly with the number and location of transit stops on the installation, the transit pick up and drop off schedule, and the reliability of service. The evaluation of the single stop or possibly a route segment with multiple stops would apply most for the study objectives of the transit operation on a military installation.

Basic information required for a transit study includes:

- ✓ A map showing all transit routes
- ✓ The location of all stops
- ✓ A transit schedule for the installation

The time and length of the study will be determined by the study objective. It can be conducted during peak hour traffic conditions or during a complete day by taking a sample of each major period to allow expansion to the full day using the scheduled number of vehicles in each period.

The first step in conducting a transit study is to identify the problem to be solved and performance characteristics to be evaluated. Transit studies may provide information on the overall performance of operational aspects within the installation or address a particular stop, route or multiple routes where potential operational or safety improvements can be made. Transit needs can be ascertained through:

- ✓ Observation
- ✓ Informal passenger comments
- ✓ Formal user surveys within the installation

10.3. METHOD

The three main manual data collection methods most applicable to military installations include:

- ✓ Driver Study
- ✓ Point Checks
- ✓ Ride Check

Data obtained by one of these methods would allow evaluation of an individual transit stop, a transit route or a route segment.

Two additional data collection methods for a public transportation study are the automatic data collection method and the customer survey. Automatic data collection devices may be available through a transit authority and provide information on overall system performance. Information on customer satisfaction can be obtained through conducting customer surveys by hand-in and mail-in survey forms or utilizing available web-based and smart phone applications.

Transit system information can also be obtained by direct observation. Making observations at transit stops can help determine various conditions that may warrant improvement including ease of loading and unloading passengers, proper access for persons with disabilities, and transit stop amenities (i.e., shelters, benches and lighting).

Transit data to conduct a public transportation study can also be collected by automatic data collection methods that may be available through a transit authority. Information on customer satisfaction can be obtained by conducting a customer survey or utilizing available web based and smart phone applications.

10.3.1. Driver Study

Certain transit information can be collected by the driver throughout the route. Having drivers count boarding and alighting passengers is an accurate and efficient manual method to determine the number of passengers per trip at a single stop, and on a route or route segment. Exhibit 10.1, Boarding Count Field Sheet, shows an example field sheet where the driver can write the total count or the count per fare category. Information from a driver study can be used to help determine the most effective points of access based on passenger demand between fare types.

General method procedures:

1. Choose the transit stop(s), route or route segment to be studied.
2. Provide the driver with the appropriate field-data sheets or electronic counters.
3. Driver records information based on the number of routes and/or stops.

Exhibit 10.1: Boarding Count Field Sheet (Sample)

Route E

Block Number None

Day Wednesday

Date 5-8-15

Weather Clear

Observer B. Jones

Route Segment		Boarding Passengers					
From	**To**	**Full Fare**	**Reduced Fare**	**Transfer**	**Full + Transfer**	**Reduce + Transfer**	**All Passes**
15th St	Green St	5					
Green St	Market St	10	3				
Market St	7th St	6					
7th St	8th St	3	2				
8th St	10th St	0					
10th St	Transit Center				12	2	
Total		24	5		12	2	

10.3.2. Point Checks

Another method that would provide useful information for a military installation application is point checks. In this method, checkers conduct point checks while standing along a route, usually at a stop, watching boarding, alighting and on-vehicle activity. The checkers can count the number of buses and the number of passengers on each at selected stops. The number of passengers in each bus is either counted or estimated at selected bus arrival and departure stops or when it passes a given location such as an installation entry gate. The bus number, time of arrival, and time of departure are noted. The bus number can be used to ascertain the seating capacity from the operating agency. Point checks primarily provide load counts and schedule adherence. Point checks typically are conducted at the peak load point, i.e., the point where the maximum number of passengers is expected. Transfer points, points where routes overlap, and points where buses may turn around may be additional locations of interest to conduct point checks. The Point Check Field Sheet shown in Exhibit 10.2, can be used to record the point check data. Other information that can be attained through the point check method includes:

- ✓ Boarding and alighting counts at the particular stop
- ✓ Deceleration time at stops
- ✓ Stop and acceleration times at stops
- ✓ Data on passenger behavior (i.e., arrival times, wait times, direction and mode of travel before or after the transit trip)

In addition, checkers can ascertain information at each stop including passenger amenities such as:

- ✓ Bus shelters
- ✓ Appropriate signing and pavement markings
- ✓ Access for persons with disabilities
- ✓ Safety and security issues
- ✓ Bike access
- ✓ Parking availability

General method procedure:

1. Choose the transit stop(s), route or route segment to be studied.
2. One checker is assigned to each stop as identified by the transit route map.
3. Each checker is provided field-data sheets and a timing device.
4. The checker records the appropriate data based on the number of routes and/or stops.

Exhibit 10.2: Point Check Field Sheet (Sample)

Route(s) C, D, E, F

Bus Stop Number Transfer Center

Day Wednesday

Date 5-8-15

Weather Clear

Observer B. Jones

Departing Load ☐

Arriving Load ☑

Route Number	Direction	Block Number	Vehicle Capacity	Arriving Time		Passengers
				Scheduled	Actual	
C	East	Transfer Center	38	0815	0820	32
D	East	Transfer Center	38	0825	0825	12
E	East	Transfer Center	38	0810	0812	32
F	West	Transfer Center	38	0830	0835	23

10.3.3. Ride Checks

A ride check is conducted by a checker riding in a particular bus of interest and recording data as it covers its route. In addition to collecting similar information to that of a point check, a ride check can provide additional information that may be useful including: deceleration and acceleration times, duration time and causes of delay, and number of standing passengers. Ride checks are generally more accurate than point checks and can be comparable in accuracy to automatic data collection under most loading conditions. Ride checks are usually more expensive than a driver study or point checks because the checker can only collect data on one trip at a time. Multiple checkers can be utilized to reduce the amount of time for each bus route run. Exhibit 10.3 Ride Check Field Sheet, shows a form suitable for recording the data for the ride check method.

General method procedure:

1. Choose the transit stop(s), route or route segments to be studied.
2. Each ride checker is provided with appropriate field-data sheets and a timing device.
3. One or more ride checkers are assigned to each vehicle depending upon the passenger volume and the number of doors in the vehicle. An observer may be required at the curbside to record counts at stops where volume is exceptionally heavy.
4. Each ride checker records information during the vehicle's journey between stops. Enough trips must be made to provide a complete picture of passenger volumes during peak and off-peak periods.

On-time performance is a criticle element to provide an assessment of a customer's perception of whether a transit operator is providing a reliable service. A ride check provides a snapshot of the current level of activity and delivery performance of the transit system.

Exhibit 10.3: Ride Check Field Sheet (Sample)

Route(s) E
Bus Stop Number 82
Day Wednesday
Date 5-8-15
Weather Clear
Observer B. Jones
Direction of Trip East
Schedule Start Time 0750

From	To	Passengers			Time Check	Remarks
		On	Off	Load		
1st St	Green St	5	2	14	0755	
Green St	Market St	10	0	24	0808	
Market St	7th St	6	6	24	0816	
7th St	8th St	4	13	15	0821	
8th St	10th St	1	4	14	0825	
10th St	Transit Center		12	2	0831	
Total		26	32	219		

10.3.4. Automatic Data Collection

Advances in data collection technology, computer software programs and smart phone applications has increased the amount of information available to both the transit provider and the system user. The use of these technologies is becoming more common among many transit agencies. The data collected from these technologies can provide continuous performance monitoring of the transit system, as well as providing their customers with a real time knowledge of transit schedules, location of vehicles, and estimated stop arrival times.

Installations themselves will likely not employ automation for data collection, however, it is possible that if a local transit authority operates the transit service on the installation, they may utilize automatic data collection technology.

Much of the data from the transit studies described can be automatically collected and analyzed on a more frequent basis to increase the efficiency of the transit system. Automated Passenger Counters (APC) and Automated Vehicle Location (AVL) systems are the two main technologies available. APC automatically counts passenger boarding and alighting volumes. AVL uses on-board GPS technology to record position and speed data on transit vehicles. The main advantage of APC systems is that data are available in a permanent form allowing the transit agency to track performance on a continuous basis. AVL systems can automatically collect a significant amount of data including travel times, schedule adherence and delays. AVL systems can benefit customers through the use of real-time transit data by distributing timely information to customers through electronic display boards, websites, and cellular phone applications.

An investigation should be made to determine if a transit operator for the installation has this technology. The transit operator may provide the necessary data to evaluate and improve the transit service within the installation.

10.3.5. Customer Surveys

Customer surveys are an important resource to:

- ✓ Engage passenger satisfaction of the transit services
- ✓ Identify system problems
- ✓ Provide information to help improve customer interaction

Surveys can provide data on passenger demographics, traits, origin and destination, travel desires, attitudes and other characteristics not able to be collected by the data collection methods described. Two types of surveys typically used are:

- ✓ Hand-in survey
- ✓ Mail-in survey

Both types of surveys include brief questions for customers to answer and are distributed by hand to boarding riders. The hand-in survey is collected as the riders alight from each trip. Mail-in surveys can be completed elsewhere and returned via a pre-posted envelope or post card. These surveys can be relatively expensive to develop and conduct, and may be less detailed or accurate.

Web-based and cellular text messaging based surveys have become widely used for transit surveys. These types of customer surveys can generally contain more detailed questions while being faster and easier for the customer to fill out. Web-based surveys can be advertised on host websites, through cellular phone text messaging, as well as other traditional publications. Customers can complete the survey while they are aboard the transit vehicle via web access through laptops or cellular phone applications, or the customer can complete the survey after the trip at their convenience. A survey done via text messaging uses cell phone technology to “vote” on a specific transit survey question. A number of web survey companies are available for developing web-based customer surveys that can satisfy specific objectives for various price options.

10.4. ANALYSIS

Data collected from the various types of transit studies can provide a number of useful data plots and statistics to aid in determining potential transit system improvements. Data can be analyzed by comparing seated passengers, standing passengers, and seats available by time of day. Exhibit 10.4 Transit Load Check Graph shows a sample vehicle load check graph. This graph represents the volume of riders during the length of the route and indicates peak loading periods during the day. Also, the amount of seats available and occupied is identified. Exhibit 10.5 Bus Loading Profile, shows a bus load profile that may be constructed with the horizontal axis corresponding to stops along the route and the vertical axis representing the total number of passengers at various stops on the route. This profile can be made for each trip or for the average of individual trips during selected periods. Exhibit 10.6 Boarding and Alighting Graph, indicates a typical boarding and alighting summary graph to show the total number of passengers entering or exiting the vehicle over a given time period. By preparing these types of data plots and customer surveys, and reviewing the information for various stops and/or routes, specific observations of inefficiencies, safety concerns, or user issues can be interpreted. The results of the analysis should be shared and discussed with the local transit operator to determine and prioritize potential improvements to the transit network and establish funding sources that can be programmed to implement the improvements.

Exhibit 10.4: Transit Load Check Graph

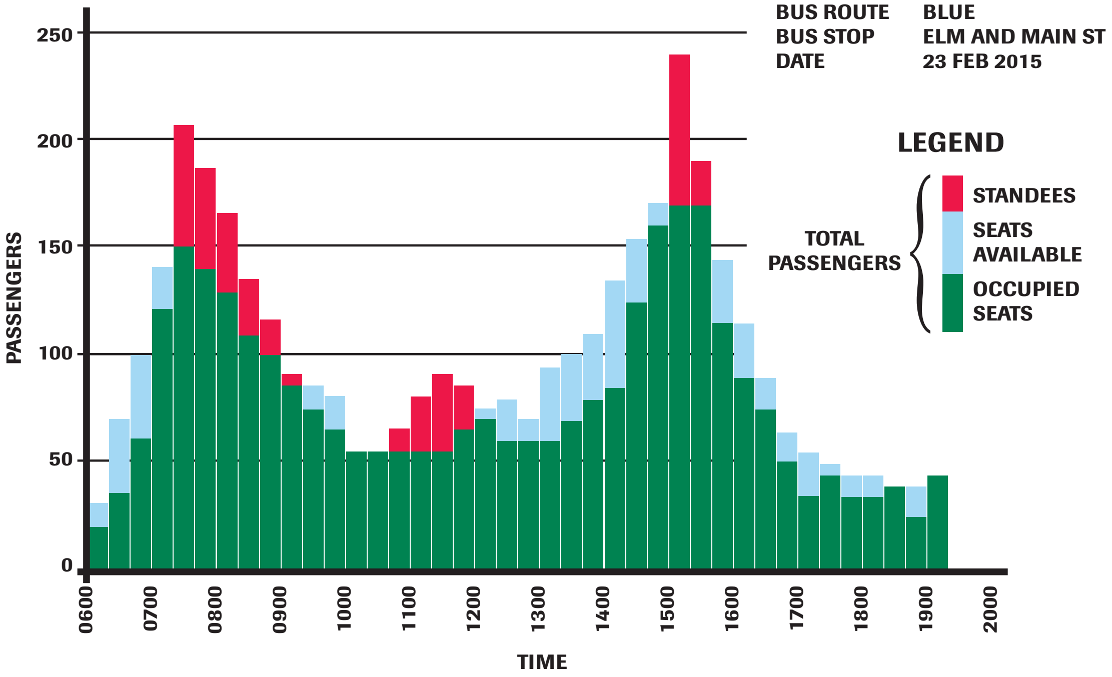


Exhibit 10.5: Bus Loading Profile

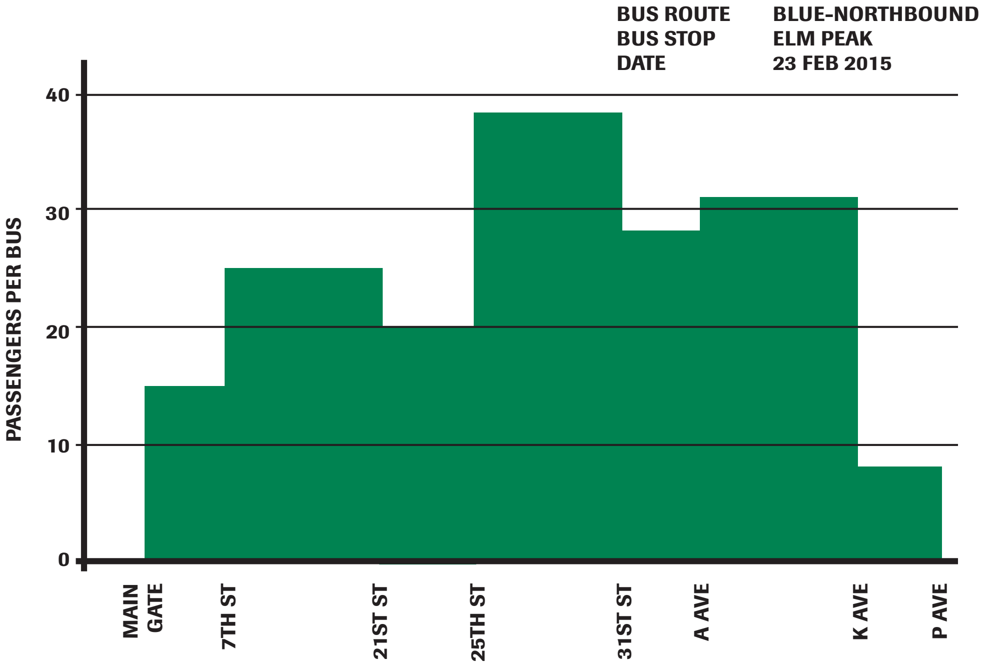
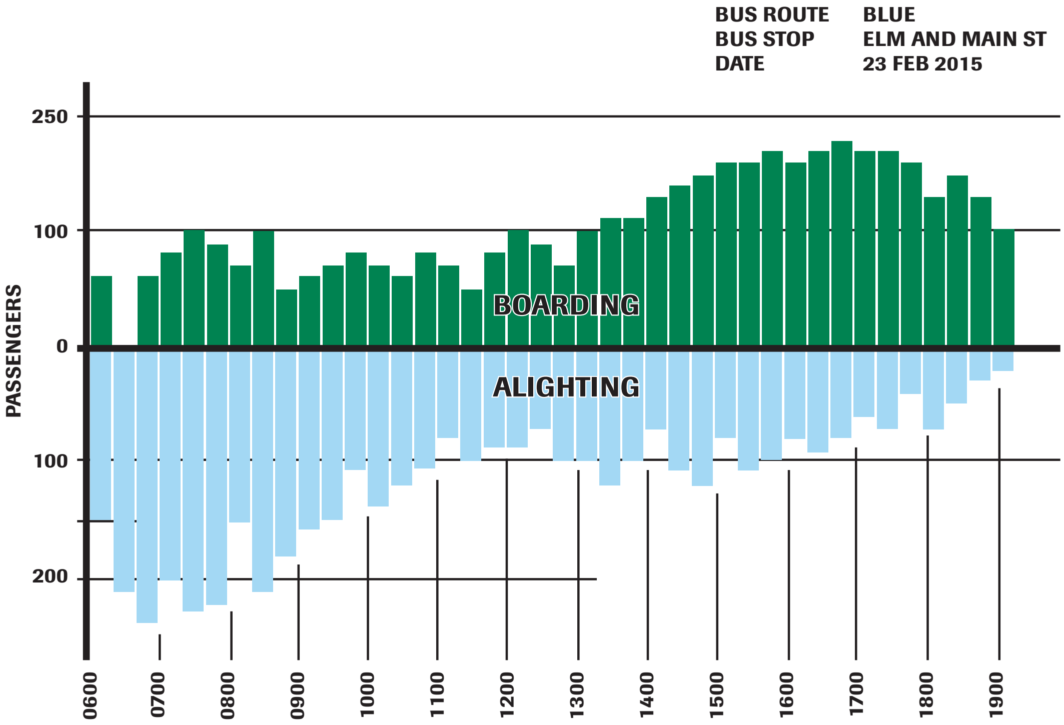


Exhibit 10.6: Boarding and Alighting Graph



10.5. INTERPRETATION

An efficient transit service that is safe, reliable and includes appropriate stops to meet passenger demand is an important objective in providing a multi-modal transportation system within the installation. Information obtained from the various transit data collection methods can be a valuable tool for identifying necessary improvements to a transit stop, route or route segment. For example, point check data can provide information regarding the highest volume of passengers boarding and alighting a bus on a particular stop within a route. Comparing user count volumes from multiple stops can help to determine the current route efficiency. It may be desirable to combine two lower volume stops that are relatively close in proximity to each other, to reduce the overall route run time. The driver, point checks or ride checks can help determine:

- ✓ The possible consolidation or rerouting of transit lines
- ✓ The elimination or addition of route stops
- ✓ Daily passenger volumes
- ✓ Boarding and alighting counts
- ✓ Arrival times
- ✓ Causes of delay
- ✓ Stop times
- ✓ Overall travel time

- ✓ Safety and security issues
  - ✓ Amenity improvements at stops

These studies can also determine requirements for additional transit service and aid with future planning scenarios.

10.6. APPLICATION

The methods of conducting public transportation studies described above can be applied to a variety of issues that may be of concern to the installation staff regarding the efficient and safe operation of the public transit network. The metrics needed to evaluate a transit network or a component of a network will depend on the specific performance features at issue. There is a range of performance measures that can describe and quantify transit operations. Exhibit 10.7 Transit Performance Measures, defines the types of transit service performance measures that could be evaluated for potential efficiency improvement of a fixed route bus service. Generally, the three areas of transit performance that an installation is typically concerned with are:

- ✓ **Transit Stops**: measures addressing transit availability, comfort and convenience at a single location within the installation.
- ✓ **Route Segment**: measures that address availability, comfort and convenience along a portion of a transit route within the installation.
- ✓ **System**: measures of availability, comfort and convenience for more than one transit route operating within the installation.

The installation staff will need to assess and prioritize those issues involving the transit network that may need to be addressed. Installation staff may be made aware of transit issues by being contacted by the local transit operator, by receiving a complaint, by observation, or by conducting a user survey. Once the key problems to be analyzed are determined, the type of data collection method(s) can be selected. Exhibit 10.8 Transit Data Items and Study Methods, identifies some performance measures that relate to applicable data collection methods that may be considered for analysis.

Exhibit 10.7: Transit Performance Measures

PERFORMANCE MEASURES*		LEVEL OF ANALYSIS		
		TRANSIT STOP	ROUTE SEGMENT	SYSTEM
Availability	Service Measures	Frequency	Hours of Service	Service Coverage
	Other Measures	Pedestrian Crossing Difficulty		
		Pedestrian Access		
		Bicycle Access		
		Park & Ride Access		
		Access for Disabilities		
		Passenger Loading Ease		
Comfort and Convenience	Service Measures	Passenger Load	% Reliability on-time	Transit-Auto Travel Time Diff.
	Other Measures		Reliability Headway adherence	
		Reliability	Missed Trips	Transit-Auto Travel Time Diff.
		Boarding & Alighting	Freq. Mechanical Breakdowns	Speed, Travel Time and Delay
		Transit Stop Amenities	Speed, Travel Time and Delay	Safety a & Security Performance
		Customer Satisfaction	Wait Assessment	Passenger Miles
		Security		Passenger OD Patterns

*Measures adopted from *Transit Capacity and Quality of Service Manual, TRB, 2003*

Exhibit 10.8: Transit Data Items and Study Methods

TRANSIT DATA ITEMS SERVICE MEASURES	STUDY METHOD				
	DRIVER STUDY	POINT CHECK	RIDE CHECK	CUSTOMER SURVEY	OBSERVATIONS
Service Frequency		X			
Hours of Service		X	X		
Area, Coverage					
Passenger Load	X	X	X		
Reliability		X	X		
Travel Time Difference		X	X		
OTHER MEASURES					
Customer Satisfaction				X	
Safety and Security Performance				X	X
Missed Trips		X	X		
Freq. of Mechanical Breakdowns			X		
Travel Speed			X		
Travel Time and Delay			X		
Wait Assessment		X			
Transit Travel Time		X	X		
Transit-Auto Travel Time Ratio		X	X		
Boarding and Alighting	X	X	X		
Passenger Miles		X	X		
Passenger Origin & Destination					
Pedestrian Crossing Difficulty					X
Pedestrian Access					X
Bicycle Access					X
Park & Ride Access					X
Access for Persons with Disabilities					X
Passenger Loading Ease					X
Transit Stop Amenities					X

CHAPTER 11—PARKING STUDY

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11.1. OBJECTIVE

Most parking studies within a military installation are performed to determine the need to expand existing parking or adjust management techniques by comparing parking demands to existing parking space availability. The information obtained from a parking study can also be utilized to make projections of the future requirements for parking space if there is to be expansion of installation facilities.

Lack of adequate parking presents a significant problem at many installations. The problem usually is localized in only a portion of the base; often at commissaries, exchanges, barracks areas, and major employment concentrations.

The objective of parking studies is to develop an improvement program to place the proper number of stalls, with properly designed layout and traffic circulation patterns, in convenient locations to serve the many different portions of an installation. Usually when a parking study is desired, a problem area already has been identified and solutions are needed. In other cases, the parking study will be used to identify problem areas through an overall installation check and then will be followed with more detailed study in the problem areas. Normally, parking areas used only for military vehicles (motor and equipment pools) are omitted from the study, since their special problems are more easily identified and solved. This chapter will cover the procedures to be used in either case.

Refer to SDDCTEA Pamphlet 55-17 Chapter 17 for additional information concerning parking analysis, as well as, parking stall dimensions and other various design criteria.

Another type of parking analysis focuses on the calculation of the amount of anticipated parking that will be generated based on the land use. This type of study should be used for future parking lots, such as when a facility is being planned, but can also be used to calculate the amount of parking that should theoretically be generated by an existing facility. This theoretical approach is discussed at the end of the 'Analysis' section.

11.2. INFORMATION NEEDED

For studies of existing parking, the necessary information will generally include an inventory of the existing parking, a classification of the types of spaces (open, reserved, or visitor), an identification of which installation facilities are served by the parking spaces, and a measurement of parking space usage.

Common types of parking studies include:

✓ Parking inventory
✓ Parking usage

Parking Inventory—A parking inventory on a military installation assembles information about the location, number and other pertinent characteristics of existing parking spaces at the curb and in off-street areas. Information needed includes:

✓ Number of parking spaces
✓ Time limits and hours of operation (if any)
✓ Type of spaces (open, reserved, visitor, handicap accessible)
✓ Type of facility (curb, lot, garage)

- ✓ Type of facility served
- ✓ Parking space characteristics (space markings, dimensions, isles, entrance/exits, circulation pattern)
- ✓ Parking sketch and description

Parking Usage—To determine how existing parking spaces are used, the data collected should include:

- ✓ Number of cars parked at the peak time of the day
- ✓ Length of time vehicles are parked (parking duration)
- ✓ Average number of cars parked in each parking space (i.e., parking duration and turnover) during the study period
- ✓ Vehicle types
- ✓ Incorrect parking practice
- ✓ Violations should also be noted during the study

11.3. METHODS

The field work consists of identifying the study area, conducting a parking-space inventory, determining parking usage characteristics, and parking-duration and turnover. These steps involve the following procedures:

Determine Study Area—The purpose of the parking study must be defined prior to defining the area where it will occur. If it is the entire installation, the objective will be to identify where parking shortages exist. If the study is to cover a limited portion of the base, it will normally be associated with an identified land use (hospital, work area, commissary, or exchange). This is the more common case.

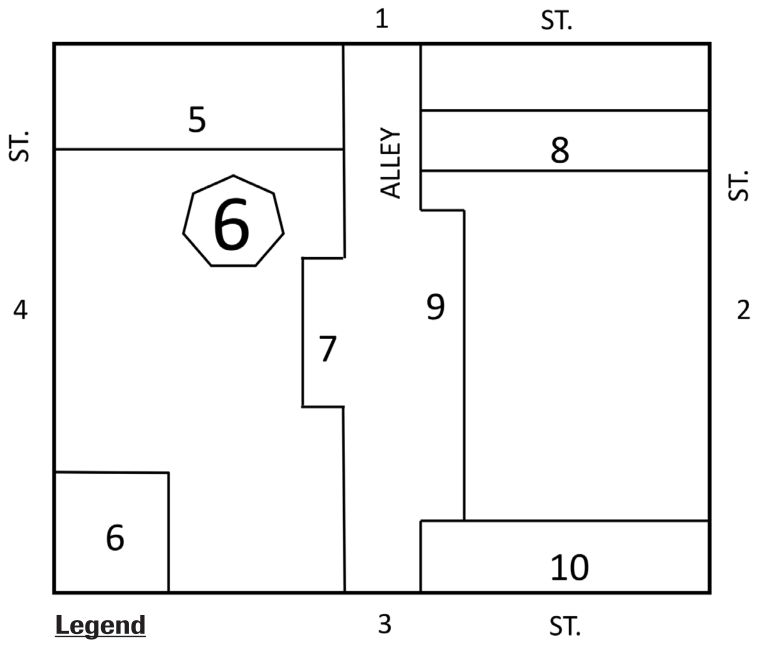
To identify the study area, a field check of the area during a period of heavy parking demand is required. Parking demand refers to the number of cars (normally the maximum) present in a given area. Parking demands normally are related to an individual land use or groups of uses in an area. The field check will result in drawing a boundary line on a map around the principal study site to include all locations where people park who are destined for that site both on street and off street. This boundary line then defines the study area. If the entire base is to be studied, it will normally be divided into sectors that logically split the different functional areas of the base. Personnel conducting the study will need to make an assumption on the expected walking distance (i.e., the distanced measured along the shortest normal walking path between a parking space and the nearest pedestrian entrance at the parker's trip destination). The expected walking distance will help determine which parking lots people will generally use. Studies shown in the *Parking Manual by Weant & Levinson*, report that 84% of people will typically walk 1500 feet or less.

Parking Inventory—Parking supply is determined by a parking inventory. Obtain a map of reasonable scale that covers the study area. The same map can be used to determine the study area referenced above. A vertical aerial photograph can be of significant use. The study area should be divided into zones. Each parking area within the zones, both on street and off street, should be identified on the map by a letter or number.

The use of web-based mapping tools, such as IRRIS/TGIS, installation aerial imagery, or other commonly available imagery, can be useful to indicate the orientation, quantity, and overall capacity of parking spaces. Aerial photography, as such, can be used to help determine location of exposed curb and off-street parking area and number of parking spaces by viewing the satellite images of the area of interest. However, exact counts can be limited to the satellite image resolution and viewing obstructions such as buildings, topography, foliage, shadows, etc.

Therefore, the actual inventory is made by field observers who enter the proper information on field sheets. One sheet is the parking zone map as in Exhibit 11.1 Parking Facility Numbering System. The second sheet is the inventory form. A sample form for parking space inventory is shown in Exhibit 11.2 Installation Parking Inventory Sheet. Each sheet is identified by the proper code number from the zone map. If the parking spaces are defined by painted stall markings, the actual number of parking spaces is counted; if not, measurements should be made and the number estimated. The number of on-street spaces is estimated by measuring the length between driveways and calculating the number of stalls that can fit in that length. The number of stalls possible in an unmarked off-street lot may be estimated by dividing the area of the lot in square feet by 300 (the average square foot area for each car, including aisles, in a normal lot). For example, a lot 125 feet by 400 feet contains 50,000 square feet and could accommodate approximately 166 cars in self-parking stalls. If there are any restrictions on use of the stalls in any facility, the number of stalls in each category should be tallied separately under three categories: Reserved for individuals, Restricted by a time limit, unlimited usage. Any restrictions on use, permit systems, and the message on the face of any restrictive signs should be indicated on the back of the inventory form.

Exhibit 11.1: Parking Facility Numbering System



Legend

⬡6 Block Number
1 to 4 Curb Face Numbers
5 to 10 Off-Street Ffacility Numbers

Parking Usage—Parking usage determines the number of vehicles parked within the study area. If the entire installation is to be covered, by zone, two observers riding in a vehicle can accomplish this task; the driver counts vehicles parked on the left side of the street or aisle and the other observer counts those on the right side. For smaller areas, a single observer can obtain the data on foot. The checks should be made on the heaviest day of a normal week; a complete count should be made at 1000, 1215, and 1430 (military time), since normally the peak number of parked vehicles occurs during one of these periods. The route followed should be set so that it can be covered in approximately 30 minutes, starting 15 minutes before the time indicated and finishing approximately 15 minutes after. Depending on the installation size, multiple days may be necessary to finish the task. If necessary, the remainder of the counts should be done on days with similar parking demand characteristics. All on-street and off-street facilities in one area should be covered on the same day. The route should be laid out on a map (or aerial photograph) in advance to ensure complete coverage. The data can be recorded on the map using different colors for each of the three observation periods. Show the number of cars parked along each block face and in each off-street facility. Illegally parked vehicles and those parking in unauthorized areas are shown separately in parentheses. The objective of the study is to determine the highest number of vehicles parked in each sector and/or facility so that it may be compared with the available parking supply to identify areas and amounts of parking shortage. Some areas may require checks at times other than those noted above if their heaviest parking demands occur during different hours.

Parking Duration and Turnover—This procedure is conducted during normal hours to obtain a picture of typical parking usage. When the spaces serve special-purpose facilities such as the exchange, commissary, and theaters, the study should be conducted during the period of maximum use. In determining the typical usage, the following must be identified:

- ✓ The number of cars that use the spaces in a given time period (called turnover)
- ✓ Whether or not the time limits (if any) are proper and are being observed
- ✓ The number of cars present at the time of peak accumulation
- ✓ The average length of time parked

Exhibit 11.2: Installation Parking Inventory Summary Sheet (Sample)

Installation Ft Butler
Date 07/25/15
Location of Parking Inventory[1] Zone 4

Total Parking Spaces 791 **Reserved** 20 **Open** 771
On-Street (Curb) Spaces 28 **Reserved** 4 **Open** 24
Off-Street (Lot) Spaces 763 **Reserved** 16 **Open** 747

On-Street					**Off-Street**				
Location[2]	**Number of Spaces**				**Lot / Area**	**Number of Spaces**			
	Reserved	**Open**	**Parallel**	**Angle[3]**		**Reserved**	**Open**	**Angle[3]**	**Paved[4]**
1st St between A and B	0	8	No	60°	Bank	2	8	90°	✓
Main Street between B and Elm Ave	2	3	Yes		PX	2	213	60°	✓
Maple St between Elm Ave and Apple Ave	2	13	No	60°	Commissary	2	300	60°	✓
					Post Office	1	20	90°	✓
					Bowling Alley	0	100	90°	✓
					Credit Union	4	25	90°	✓
					Service Club	5	81	90°	✓

1. Location, lot, or area by name keyed to a coded map on a site plan.
2. Extent of parking (name of street; i.e., John Street between A Street and B Street, north side.
3. Relates to stall or parking angle (i.e., 90 degrees; 60 degrees; 45 degrees).
4. Use check mark (√) if yes; (x) if no.

Each observer is assigned an area to cover that will allow monitoring of each parking space once during every 15-minute period or less. This period may be extended when the parking area obviously is utilized by long-time parkers (30-minute or 1-hour intervals). As a rule, one observer can cover from about 60 to 80 spaces in a 15-minute period. The observer walks a predetermined route and records the right-hand four numbers or letters of the license plate or installation decal numbers on the field-data sheet as shown in Exhibit 11.3, Parking Utilization Field Sheet. Parking time limits for each space should be recorded on the field-data sheet the first time the route is covered. The same route is followed on subsequent trips so that each parking space corresponds to a horizontal row of spaces on the field sheet. All parking spaces must be accounted for on the field sheet. An empty parking space can be recorded by leaving the appropriate space blank on the field sheet. When the same vehicle is observed in the same parking space during subsequent trips, the observer records it as a check mark rather than repeating the license plate. This makes it easier to pick out long-term parkers. Parking spaces that are reserved for either permanent personnel or visitors should be so identified on the field sheet. The method described above for studying the space utilization can be used for on-street or off-street parking. Normally, a 30-minute round trip is adequate for off-street parking.

Exhibit 11.3: Parking Utilization Field Sheet (Sample)

Date 07/25/15 Location Post Office

Weather Sunny/Dry Start Time 1000 End Time 1035

Observer T. White

	Time						
License Plate Number of Vehicles	1000	1010	1015	1020	1025	1030	1035
	CB65	✓	✓		8927	✓	B765
		XL04	3201	✓		B750	C800
	1786	9302		7878	✓	G755	✓
	BL56		7333	0059			7652
	7575	DC75		1903	1654	1876	
	9053		2765	✓	2022		7803
		9737	0042	1014		0505	6230
	1900	6378		ML82	A555	1678	4303
	C759	✓	8201		3075	✓	7007
	GB07	2982	1472	1688		✓	9123
	0090	✓	✓	1505	7386		0065
	7676	0976	✓		8090	1784	
	WL89		1698	✓	5555	✓	7803
		0988	0907		7679		0665
	NL78	✓	4202	1997		1491	
	TB40	8007	B766		T468	1878	
	6636	1050	D888	✓	✓	6565	✓
	0402		1842		9606	7575	0796
	0901	1565	✓	1789	✓	✓	7876
		1804	✓	✓	✓	2011	
	5707	0304		7015		✓	✓

✓ = Repeated License Plate

In many cases, the facility that is served by a particular group of parking spaces, whether on street of off street, can be identified by field observation. However, when several possibilities exist, the use of the spaces can be determined by questionnaire, direct interviews, or tracing of license plate numbers. These techniques are costly and should only be used if there is a special problem that can be analyzed only through their use.

Direct interviews or use of returnable questionnaires require adequate advance publicity in order to carry out the study with a minimum of explanation to parkers. The data are collected either by on-the-spot interviews when the driver returns to the vehicle, or by inserting a questionnaire under the windshield wiper to be filled in by the driver upon returning to the vehicle. In either case, the questions should be simple but should yield enough information to accomplish their purpose. The following is an example of some information that might be requested:

- ✓ Time of arrival at parking space (in the case of direct interviews, the observer records this when the parker arrives, as well as the license number).
- ✓ Time of departure from parking space.
- ✓ Reason for visiting destination (work or shopping).
- ✓ Frequency of parking in the area.

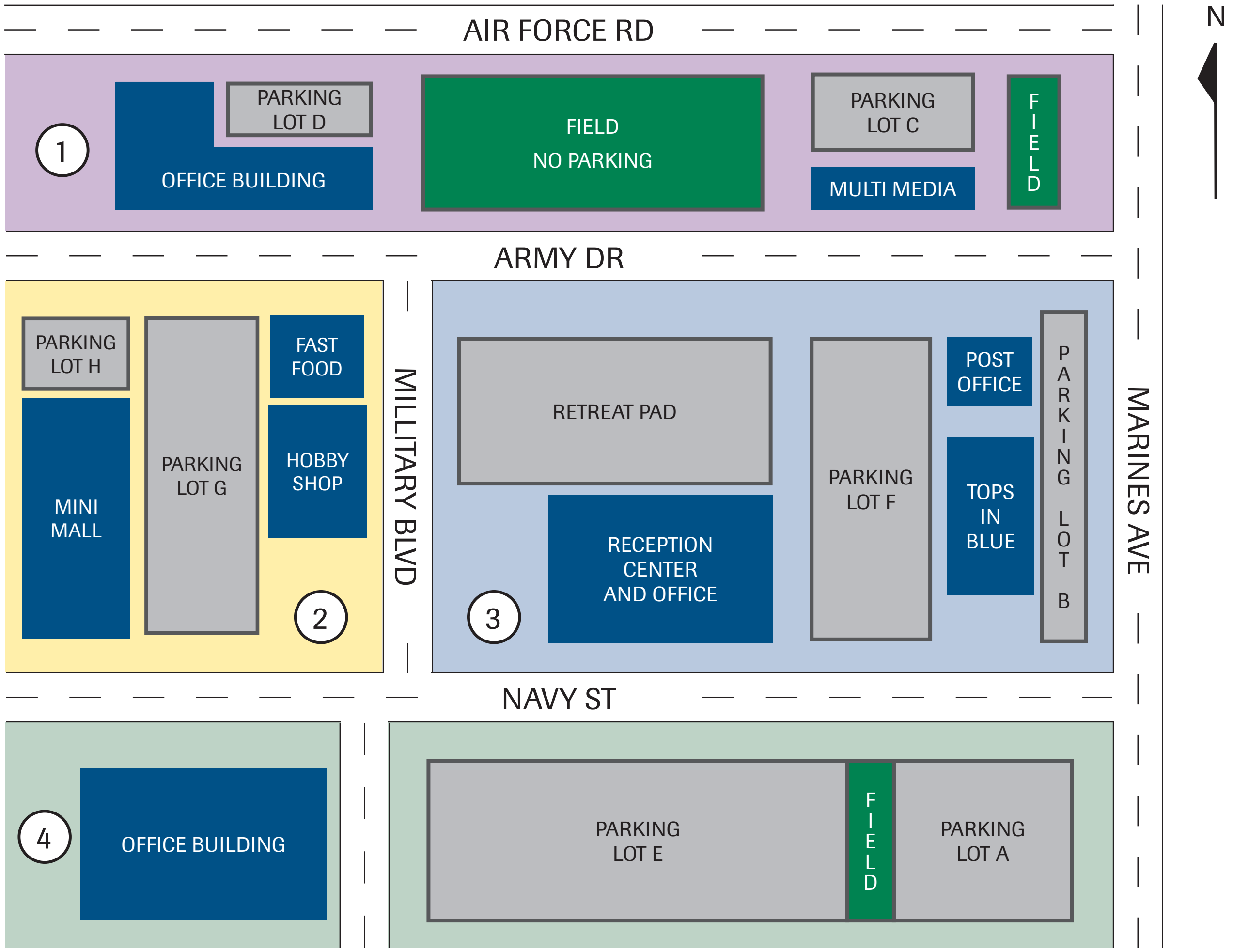
Other items might include the number of persons in each vehicle, home location, next destination after unparking, and any special items involved in solution of the problem being studied. Questionnaires also should include instructions for returning it through the desired channels, and some method of identifying the location of the parking space (probably entered by the person distributing the questionnaires).

Online survey questionnaires targeted to personnel in buildings adjacent to the parking study area or other likely sources of parked vehicles may be used exclusively or in combination with direct interviews to yield the appropriate information.

11.4. ANALYSIS

The supply of available parking spaces may be summarized according to area or sector of the installation. These areas may be located on a map by the zone and facility numbers, and the parking capacity of each area can be noted directly on the map. Exhibit 11.4 Vehicle Parking Zone Map, shows a comparison of the peak number of cars parked to the number of employees working in the zone with available parking stalls by zone; similarly, parked cars could be compared with available parking stalls by zone. A tabular summary should be prepared to indicate usage of the available parking supply by parking category similar to that shown in Exhibit 11.5 Parking Inventory and Usage Table (by parking category). The calculation of the percentage of parking spaces filled is valuable in identifying areas of high usage which may indicate areas of parking shortages.

Exhibit 11.4: Vehicle Parking Zone Map



ZONE	1	2	3	4	TOTAL
NO. OF PARKING SPACES	85	152	240	430	907
NO. OF VEHICLES PARKED	59	145	230	153	587
NO. OF EMPLOYEES	75	32	110	185	402

LEGEND

① ZONE

▨ ZONE BOUNDARY

Exhibit 11.5: Parking Inventory and Usage Table (by parking category) (Sample)

	OFF STREET				ON STREET				TOTAL PARKING SPACES						
	GENERAL		RESERVED		GENERAL		RESERVED		TOTAL	BY USE		% FILLED	BY CATEGORY		% RESERVED
ZONE	EMPTY	FILLED	EMPTY	FILLED	EMPTY	FILLED	EMPTY	FILLED		EMPTY	FILLED		GENERAL	RESERVED	
1	170	22	7	11	0	0	0	0	210	177	33	15.7	192	18	8.6
2	215	126	15	24	23	37	0	0	440	253	187	42.3	401	39	8.9
3	53	132	43	113	7	50	2	6	406	105	301	74.1	242	164	40.3
4	143	344	145	144	1	27	0	0	804	289	415	59.8	415	289	41.1
5	15	276	126	379	3	35	2	12	848	146	702	62.8	329	519	61.2
6	135	412	10	2	0	0	0	0	559	145	414	74.1	547	12	2.1
7	660	370	36	44	0	0	0	0	1110	696	414	37.1	1,030	80	7.2
8	377	581	264	643	0	32	0	0	1897	641	12,56	66.2	990	907	47.8
TOTAL	1,768	2,263	646	1,360	34	181	4	18	6,274	2,452	3,722	60.4	4,146	2,028	32.9

*Data collected during the morning hours (0900-1200)

Parking space usage data can be analyzed by entering it on a summary sheet similar to that shown in Exhibit 11.7 Parking utilization Summary Sheet. The duration of parking is determined by the number of consecutive times the same vehicle was observed in the same parking space and by the time period required for each round trip on the route. For example, if the time period for each round trip averages 15 minutes, then a vehicle that is observed only once would have a parking duration of 1 to 29 minutes or a mean of 15 minutes; if it were observed twice, then the duration would be 15 to 44 minutes or a mean of 30 minutes, and so forth. Other values in the summary are computed as follows:

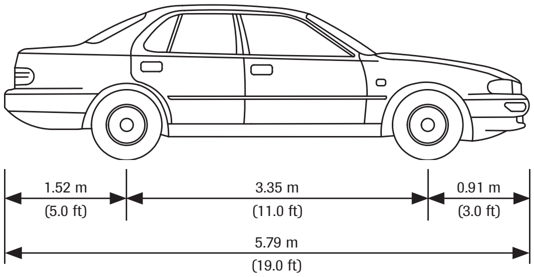
- ✓ **Vehicle-hours Parked** = Parking duration (hours) x Number of vehicles parked for that length of time. *(This is a cumulative total.)*
- ✓ **Average Duration** = Total vehicle-hours parked or Total vehicles parked
- ✓ **Space-hours of Parking Available** = Number of spaces available for parking x Number of hours covered in study *(100 spaces available during an 8-hour-study period represents 800 space-hours)*.
- ✓ **Utilization Ratio (efficiency)** = $\frac{\text{Total vehicle-hours parked}}{\text{space-hours available}}$
- ✓ **Percent Overtime** = Sum of figures in vehicle percent column for all durations longer than legal limits; the number of overtime parkers as a percentage of total parkers.

When conducting a parking study, consideration should be given to the following:

Delivery Loading and Unloading—Delivery and service trucks require access to loading docks and service entrances which may need to accommodate the necessary special maneuvering into and out of the dock or service entrance. Service access to a building that is required through a parking area should have a direct entrance and exit that is independent from the normal parking circulation for the facility to avoid conflicts. Parking areas must be separated from truck docks and other activity areas. Site security must be enforced by separating the storage facility from the remainder of the activity and further isolating parking from receiving and shipping functions.

Design Vehicle–The size of the vehicle that will define the parking space dimensions should be based on vehicles that will typically be used for personal transportation and that are likely to be parked within the installation (i.e., cars and light trucks, including SUV's, pickup trucks, and minivans). Parking facilities should be designed to accommodate the general use of the type of service, or mixed service, the parking facility will used for (e.g., offices, retail, commercial, medical, etc.), and the amount of vehicle turnover. Generally, standard design vehicle sizes should be used for determination of parking space dimensions for parking designs. The AASHTO standard passenger car (P) design vehicle, as shown in Exhibit 11.6, is the standard basis.

Exhibit 11.6: Standard Passenger Car (P) Design Vehicle Dimensions



Source: Policy on Geometric Design of Highways and Streets, AASHTO, 2011

No accommodation is typically required for a special parking space of different dimensions to service compact or motorcycle vehicles. Specially located small-vehicle spaces are typically not effective. When small-vehicle spaces are provided in convenient locations, drivers of average size vehicles tend to park within small-vehicle spaces impeding traffic flow and compromising the turning movements of adjacent vehicles. However, where a significant percentage of compact vehicles or motorcycles exist, special parking space design may be appropriate.

Exhibit 11.7: Parking Utilization Summary Sheet (Sample)

Location Commissary

Date 07/25/15 Start Time 0800 End Time 1800

Parking Duration (HR)	Vehicles		Vehicle Hours Parked		Parking Duration (HR)	Vehicles		Vehicle Hours Parked	
	Number	Percent	Number	Percent		Number	Percent	Number	Percent
0.25	120	17.1	30						
0.50	60	8.5	30						
0.75	200	28.4	150						
1.00	250	35.7	250						
1.50	54	7.7	81						
2.00	15	2.1	30						
2.50	3	0.4	7.5						
3.00	1	0.1	3						
Continued Next Column					Totals	703	100	581.5	100

Average Duration 581.5/703 = 0.83 HR

Legal Time Limit 1.0 HR

Percent Overtime 73/703 x 100 = 10.3

Parking Spaces Available 60

Space Hours Available 600

Efficiency 581.5/600 = 0.97

Providing smaller parking spaces for compact vehicles and motorcycles should be determined based on the amount of current or anticipated volumes of those vehicle types being serviced by the parking location. If the percent of compact vehicle and motorcycle volumes as compared to the total vehicle volume is greater than 40 percent, consideration should be given to provide compact and/or motorcycle parking spaces in the parking design. The number of smaller parking spaces needed to accommodate compact and/or motorcycle vehicles should be 80 percent of the requirement. Standard parking space dimensions for compact and motorcycle vehicles are provided in SDDCTEA Pamphlet 55-17. To use dimensions other than the standard dimensions given by SDDCTEA in the Pamphlet 55-17, a Parking Design Vehicle Study must be performed to determine the predominant vehicle size and subsequent parking stall length. Contact SDDCTEA staff for additional information and assistance in determining non-standard parking space dimensions.

Bicycles—Consideration should be given to provide accommodations for off-street bicycle parking. Proper placement of bicycle storage such as bike racks should consider the volume of bicyclists, the convenient location of facilities and the security of the location. A reference source for bicycle parking planning is the *Guide for the Development of Bicycle Facilities*, AASHTO, 2012.

Accessible Parking Areas—The Architectural Barriers Act (ABA) requires facilities that are designed, built, or altered with federal funds or leased by federal agencies be accessible to the public including people with disabilities. A 2008 Memorandum from the Deputy Secretary of Defense, concerning 'Access for People with Disabilities', adopted ABA Chapters 1 and 2 and Chapters 3 through 10 as the DoD Standards. However, the 2008 memo exempts facilities "designed and constructed for use exclusively by able-bodied military personnel" on military installations, including Reserve and National Guard facilities, from the standards. Facilities obtained by DoD in emergencies and natural disasters are also exempt. DoD nonetheless recommends that exempted military facilities comply with the standards "to the maximum extent that is reasonable and practicable" because facility uses often change over time. Accessible parking spaces should be located on the shortest accessible route from parking to an accessible building entrance.

The ABA Accessibility Standards (which the DoD adopted) covers facilities, not transportation elements. *[Roadway projects receiving Federal funds through the Department of Transportation (DOT) must comply with ADA Standards per the DOT's current regulations.]* In an effort to address design elements found in public rights-of-way and not covered by the ABA guidelines, SDDCTEA recommends that DoD installations utilize the "Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way" (PROWAG) for transportation elements (such as sidewalks along roadways and parking lots), in addition to Unified Facilities Criteria (UFC) 3-201-01 Civil Engineering. *(The United States Access Board published "Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way" (PROWAG) in July 2011 and provided a public comment period in an effort to address design elements found in public rights-of-way and not covered by the ADA and ABA guidelines.)*

Reserved Parking Spaces—Most installations allow reserved parking spaces for vehicles driven by certain base personnel or visiting public. When determining the number of parking spaces for a particular need (i.e., the parking demand), the quantity of reserved spaces to be provided should be taken into consideration to avoid under-sizing the parking lot from the allowable percentage. An example calculation of total required spaces, that accounts for a given number of reserved spaces, is shown below:

Given:

Design criteria for a future parking lot to be constructed for a planned administrative office building is as follows:

- ✓ Provide parking based on 60% of the assigned personnel (UFC 3-201-01 'Civil Engineering' guidelines)
- ✓ Estimated personnel to be assigned to building = 1000
- ✓ Number of reserved spaces to be provided = 100

Solution:

1000 people – 100 reserve spaces = 900 people without spaces (revised assigned personnel)
(900 people X 60%) + 100 reserved spaces = 640 total parking spaces required

Parking Demand Based on Land Use—The parking demand is the number of parking spaces required during the peak hour for the facility that the parking lot services. The UFC 3-201-01 contains parking authorization for land-use functions (i.e., facility types). For future parking lots, installations should use the criteria or service-specific Facility Criteria for calculation of the parking demand. In the event when a parking analysis is allowed or recommended, ITE's *Parking Generation* manual should be used to calculate the demand. This publication contains the best available data on the subject of parking demand related to land use. The manual contains graphs for various land uses to determine parking demand using either the square footage of the building or the number of employees that work within the building.

As previously stated, this type of analysis can also be used to calculate the amount of parking that should theoretically be generated by an existing facility (land use). So, as an example, if an installation has a parking problem at a specific isolated facility, the first step is to conduct a parking inventory to determine the existing available parking spaces. Secondly, the results of the inventory should be compared against the calculated parking demand of the facility to determine the parking shortage.

The data required to determine the theoretical parking demand for a given building within an installation is either:

- ✓ The Gross Floor Area (GFA) = sum (in sq. ft.) of the total area of each floor level in the building; or
- ✓ The number of employees

An example of a parking demand calculation using the ITE *Parking Generation* manual follows:

Given:

- ✓ The number of employees working within the office building = 300

Solution:

From the ITE *Parking Generation 3rd Edition*, page 181, Manual Weekday Peak Period Parking Demand graph for Government Office Building, the theoretical number of parking spaces required is:

Parking Demand = approximately 260 spaces.

The installation personnel should compare the calculated parking demand to the results of the parking inventory study to determine any variance between existing parking spaces that may indicate a shortage of parking spaces. The ITE Parking Generation manual provides approximate parking demand values as other unique characteristics can affect parking demand site-by-site. When designing a parking lot for a new facility, do not consider on-street parking that may be available within the vicinity when calculating the parking demand.

11.5. INTERPRETATION

Interpreting the results of a parking study can provide a variety of information to help evaluate the parking conditions and characteristics within the installation. The parking inventory will provide the amount and location of available parking spaces within the entire installation or at individual parking locations serving a variety of facilities including office, residential, shopping, entertainment, ECFs, medical, etc. By comparing the available parking spaces (parking usage) to the actual peak-hour number of parked vehicles (duration and turnover), an analysis can be made to identify locations where there is either a surplus or shortage of available parking. Determining the parking demand of the entire installation or specific parking location based on the current or anticipated number of employees, or the facility floor space, provides an indication of the number of parking spaces the facility should accommodate or the design amount for a future facility. For on-street parking locations, the overtime percent provides an indication of the percentage of the spaces that are filled with vehicles having parked over the legal time limit, which can be an indication of an enforcement issue or insufficient parking availability. The parking lot utilization ratio (efficiency), which can be derived from a summary of collected parking data, can provide an indication of the extent to which a parking location is being utilized. When expressed as a percent, a rating closer to 100 is indicative of a parking location properly sized for the facility being served.

The physical characteristics of parking lots should be studied for deficiencies similar to the following:

- ✓ Entrance or exit located too close to an intersection
- ✓ Deteriorated pavement surface and poor drainage
- ✓ Inadequate dimensions of stalls, aisles, and entrances or exits
- ✓ Deteriorated stall markings
- ✓ Improper traffic control signing
- ✓ Poor circulation of traffic flow, particularly near driveways
- ✓ Unsafe pedestrian access routes and sight distance

Other factors to consider that may impact the desired parking availability, safety, and flow of vehicles within the parking location are delivery services accommodations, accessible parking requirements, requirement for reserved parking spaces, and adequate signs, markings and lighting for pedestrians.

11.6. APPLICATION

The practical uses of parking studies include determination of:

- ✓ Geographical distribution of parking supply on the installation as found in the parking-inventory study.
- ✓ Existing parking problem areas on the installation through the parking usage study. This type of study also allows comparison of the parking demand with other factors such as installation population or land use.
- ✓ Areas where parking time limits are not consistent with usage and should either be changed or enforced more rigidly, as determined by the parker-duration and turnover data collected in the parking usage study.
- ✓ Whether additional parking supply should be provided closer to parker destinations, through the results of parker interviews or questionnaires.
- ✓ Future parking needs as an integral part of new or expanded installation facilities. This can be done by directly relating existing characteristics such as employment, population, or floor space to the estimated future characteristics.

There should be some surplus parking in any parking facility to reduce cruising or blocking of aisles while waiting for a vacant space and to provide a reasonable level of convenience for the user. The capacity of long-term parking facilities (i.e., employee parking) is taken as 90 percent of its supply (10 percent of the stalls should be available at peak times). The practical capacity of facilities that serve short-term users (i.e., customers or visitors) is 85 percent of the available stalls. When these allowances are made, the total deficiency or shortage (in terms of parking spaces) may be calculated.

Often, present problems may be relieved by better layout and organization of existing facilities. While parking lot design is beyond the scope of this guide, the analyst should consider:

- ✓ Reducing the number of reserved spaces that are not being used often in order to reduce problems for other parkers.
- ✓ Checking the layout dimensions of the facility with those in SDDCTEA Pamphlet 55-17 to see if a different angle of parking will yield added stalls.
- ✓ Setting and enforcing time limits on-street and off-street so that the desired vacancy levels are provided.
- ✓ Recognizing the fact that short duration parkers should be located closer to their destination than those with a longer duration; that is, the longer the parker will be at a destination, the farther he is willing to walk. Place short-time-limit parking stalls close to the destination.
- ✓ Considering the use of temporary, remote parking lots tied into the destination with shuttle-bus routes for peak seasonal parking demands if sufficient bus capacity is available.
- ✓ Developing programs to increase vehicle occupancy and to reduce parking demand through car pools, with preferential parking spaces in best locations for high-occupancy vehicles (four persons or more).

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CHAPTER 12—PEDESTRIAN AND BICYCLE STUDIES

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CHAPTER 12—PEDESTRIAN AND BICYCLE STUDIES

The number of individuals biking or walking for recreation, exercise, and work commute has increased dramatically across the nation. The U.S. Census Bureau estimates that the number of people who commute to work by bicycle increased about 60 percent over the past decade. There is substantial public interest in improving non-motorized transportation and recreation transportation. The national emphasis on healthy living choices, reducing fossil fuel consumption, a cleaner environment, and multi-modal transportation options have prompted many communities to provide or enhance infrastructure that supports safer bicycling and walking. Improving or adding sidewalks; designing pedestrian oriented town centers; installing designated bike lanes, bike racks and walking trails; and implementing bike share programs are all examples of non-motorized travel modes that may complement a military installation transportation system.

12.1. OBJECTIVE

There are multiple objectives for performing pedestrian and bicycle studies including: determining the volume of people walking and biking within specific areas; identifying the location for sidewalks, crosswalks and trails; determining if traffic signals are warranted; implementing safety improvements; and calculating crash rates. Consideration for the safety of non-motorized travel within the installation is of utmost importance. These studies can help improve pedestrian and bicycle travel conditions and reduce the barriers to travel in order to successfully integrate all modes of the installation's transportation network. There are four common types of studies that can monitor the behavior or performance of the pedestrian and cyclist:

- ✓ Volume studies
- ✓ Travel speed studies
- ✓ Gap studies
- ✓ Origin-Destination studies

12.2. INFORMATION NEEDED

Virtually every trip starts and ends with some walking activity. Providing for a safe convergence of pedestrians and bicyclists with vehicular traffic requires special considerations when evaluating travel conditions within the installation. The number of non-motorized travelers and their destination; the volume and type of vehicular traffic; the number of crashes involving pedestrians and bicyclists; the roadway classification and condition; traffic control devices; and the criteria for proper installation and location of markings and signing is information required to determine appropriate measures that will help to reduce potential conflicts between pedestrians and motor vehicles.

12.3. METHOD

12.3.1. Pedestrian and Bicycle Volume

Pedestrian and bicycle volumes are obtained by recording the number of pedestrians or bicycles passing a point, entering an intersection, or using a particular facility such as a crosswalk, sidewalk, or bikeway. Sampling periods usually range from 15 minutes to several hours and is based on the type of count required. The basic method of measuring pedestrian and bicycle volumes is through manual observation.

Manual Observation—Most types of pedestrian and bicyclist counts are taken manually through direct observation. The simplest means of conducting manual counts is to record each observed pedestrian or bicycle with a tick mark on a prepared field sheet. A typical field data sheet to record pedestrian or bicycle counts at intersections is shown in Exhibit 12.1, Pedestrian and Bicycle Field Count Sheet. A timing device is required to cue the observer to the desired count interval. The number of observers required depends on the length of the counting period, type of count, number of pedestrian crossings or bike lanes, and the anticipated volume of both pedestrians and bicycles. Counts should be taken at 15 minute intervals. Typically, one observer can handle a four-way signalized intersection with single approach lanes. Bicycle counts should distinguish the bicyclist traveling in the roadway, from the bicyclist traveling outside of the vehicle lane, i.e., on a sidewalk. The HCM provides a level of service methodology for those bicyclists traveling in the roadway.

Similar to vehicle counts, pedestrian counts should generally be taken over roadway traffic peak travel hours on mid-week days to provide an average travel period. The amount of pedestrians crossing intersections may vary depending on the time of week (weekday vs. weekend), and the proximity of the intersections to various facilities on the installation, i.e. exchange, commissary, office, base residential housing, training, recreation, etc. Pedestrian and bicycle counts near office buildings or other work place locations should be taken during the roadway traffic peak-hour on weekdays at intersections since pedestrian activity is typically higher during that period at those locations. Alternatively, pedestrian and bicycle activity at intersections near recreational and commercial facilities may be higher on weekend days; consequently, pedestrian and bicycle counts should be conducted during those periods of highest usage, even if pedestrian and bicycle activity may not directly coincide with the normal roadway traffic peak-hour on the weekend period. Environmental conditions should also be taken into consideration when conducting field counts. Avoid collecting counts during inclement weather. Bicycle and pedestrian volume may be artificially lower due to rain, snow or other weather event occurring during counts. An increase in vehicular traffic may also occur on days of inclement weather.

Additional data can be collected to distinguish bicyclists and pedestrians using road and off-road trails. Studies on multiuse paths may further include a more detailed identification of the volume of bikers, walkers, and joggers, as well as attributes including age and gender. An example of a field sheet to record and summarize multiple attributes of pedestrian and bicycle studies is shown in Exhibit 12.2.

Following collection, the data must be placed in a form suitable for analysis. This reduction of the data consists of converting tally marks from the field sheet to numbers, summarizing the data by calculating totals for analysis. An example of a field data sheet to record and summarize pedestrian and bicycle movements is shown in Exhibit 12.3.

Electronic and Web-based Devices—Handheld electronic count boards are currently the most common device to aid in the collection of traffic count data, which can include pedestrian and bicyclists. Many electronic count boards are capable of supporting crosswalk, classification, gap, and pedestrian behavior studies. Laptop computers, or web-based access devices can also be used. Laptops, tablets, and "smart" cell phones are convenient devices that allow web-based internet access. Applications (apps) are available on the web market for these devices and provide user-friendly traffic volume counting, including pedestrian and bicycle counts, and analysis programs that can be downloaded on to any web-based device. SDDCTEA does not endorse any particular web application for use, however, these applications may provide a sufficient, convenient and economical means to collect and evaluate traffic study data on the installation. It is recommended to investigate the various apps to determine the most beneficial app for the type of traffic study and analysis data required. As technology is always changing, new and improved versions of these applications will continue to be made available.

Exhibit 12.1: Pedestrian and Bicycle Count Field Count Sheet (Sample)

Location Main St and School Dr

Observer B. Jones

Installation SCOTT Air Force Base

Date Performed Wednesday, August 13, 2015

Type of Control 4-way stop controlled

Time Period 8:00 AM to 9:00 AM

Remarks Cloudy conditions

	8:00-8:15	8:15-8:30	8:30-8:45	8:45-9:00
PEDS	𝍸	𝍸|||	𝍸 𝍸 |||	||
	5	8	13	11
BIKES	||	|||	||||	|
	2	3	4	1

N

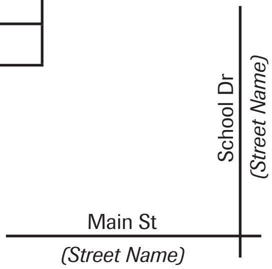
	8:00-8:15	8:15-8:30	8:30-8:45	8:45-9:00
PEDS	|	|||	𝍸||	𝍸|||
	1	3	7	8
BIKES	|	|	||	|
	1	1	2	1

Distance 32 ft.
Raised median
Yes ☐ No ☑

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

PEDS	|||	|	|	||
	3	1	1	2
BIKES				
	0	0	0	0

Distance 24 ft.
Raised median
Yes ☐ No ☑



Distance 24 ft.
Raised median
Yes ☐ No ☑

PEDS	𝍸 𝍸 𝍸||	𝍸 𝍸	𝍸 𝍸	𝍸
	17	10	10	5
BIKES	|	|	||	
	1	1	2	0

PEDS	||||	|||	||	𝍸
	4	3	2	5
BIKES	||			||
	2	0	0	2

Distance 32 ft.
Raised median
Yes ☐ No ☑

PEDS	𝍸 𝍸	𝍸 𝍸 ||	𝍸 𝍸 |||	|||
	10	12	13	3
BIKES	|		||	|
	1	0	2	1

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

Exhibit 12.2: Multi-Use Path Data Collection Sheet (Sample)

Date 7-15-2015 Location Front Street River Trail
Weather Clear/dry Start Time 1500 End Time 1800
Observer B. Jones

Time	Mode									Direction				Age		Gender		Helmet		Use Location		Group	Total
	Pedestrian				Wheeled Device																		
	Walking Only	Jogging / Running	With Pet	With Stroller	Bicycle	Bicycle with Trailer	Roller Blades / Skates	Scooter	Wheelchair	North	South	East	West	Adult	Child	Male	Female	Yes	No	Path	Road	Number in Group	
1500-1530	||	||			|||					|||	||||			|||	||||	|||	||||	|||		|||			7
1530-1600	|||	||	|							||||	|||			卌	|	|||	|||						6
1600-1630	卌	|||		|	|||					卌 |	卌 ||			卌 |	卌 |	卌 |	卌 |	|||		||	|		12
1630-1700	||||	卌	||		卌					卌 |||	卌 |||			卌 卌 ||||	卌 卌 |	卌 ||	卌 ||||	卌		||||	|		16
1700-1730	卌	||			||		||			|||	卌 |||			卌 ||||	||	|||	||||	||		||			7
1730-1800	|||	|||								卌	|			卌	|	||	||||						6
1730-1800																							
Total	22	18	3	1	13		2			29	31			41	16		30	13		10	2		

Exhibit 12.3: Summary of Pedestrian and Bicycle Movements (Sample)

Location Main St and School Dr

Installation SCOTT Air Force Base

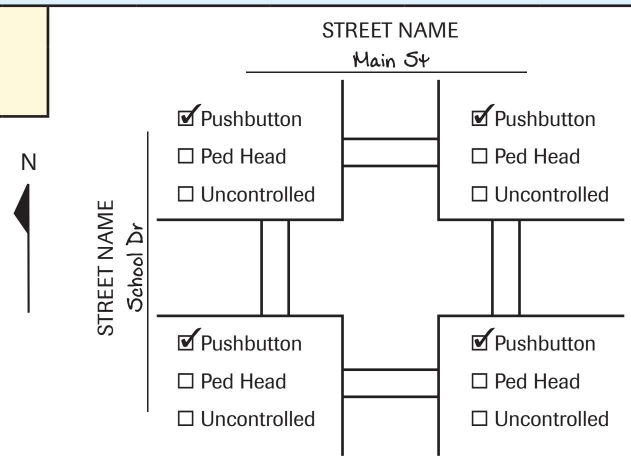
Type of Control 4-way stop controlled

Observer B. Jones

Date Performed Wednesday, August 13, 2015

Time Period 8:00 AM to 9:00 AM

INTERSECTION DIAGRAM



Northwest corner: ☑ Pushbutton ☐ Ped Head ☐ Uncontrolled

Northeast corner: ☑ Pushbutton ☐ Ped Head ☐ Uncontrolled

Southwest corner: ☑ Pushbutton ☐ Ped Head ☐ Uncontrolled

Southeast corner: ☑ Pushbutton ☐ Ped Head ☐ Uncontrolled

Weather: Cloudy

Roadway Width (ft)

N/S: 32 E/W: 32

Median Width (ft):

☐ > 4 feet ☐ < 4 feet ☑ None

Remarks:

PEDESTRIAN/BICYCLE MOVEMENTS

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

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

12.3.2. Uncontrolled Crosswalks

Crosswalk markings should not be used indiscriminately. An engineering study should be performed before they are installed at uncontrolled locations. Uncontrolled refers to the absence of traffic control (i.e., yield, stop or signals) on the approach to a crosswalk.

Locations being considered for a pedestrian crosswalk at midblock or on an uncontrolled approach to an intersection, shall satisfy the following two criteria in conjunction with the proposed marked crosswalk (as outlined in SDDCTEA Pamphlet 55-17):

- ✓ The crosswalk shall provide adequate sight distance; to include vertical, horizontal, and intersection stopping sight distance.
- ✓ The crosswalk shall not cross any part of an auxiliary lane or its transition taper. Auxiliary lanes include left turn, right turn, acceleration and deceleration lanes. Two-way left-turn lanes are not considered auxiliary lanes.

In addition, locations being considered for a crosswalk (midblock or an uncontrolled approach to an intersection) should have a minimum level of traffic and pedestrian volumes. All of the following four criteria should be satisfied prior to installation:

- ✓ Location of midblock crossings should be a minimum of 300 feet (200 feet with an engineering study) from any controlled intersection (i.e., all-way signal/stop/yield control or pedestrian overpass).
- ✓ Pedestrian crossing volumes should meet one of the following conditions:
  - 20 pedestrians per hour during the peak pedestrian hour, or
  - 15 elderly, disabled and/or children per hour during the peak pedestrian hour, or
  - 60 pedestrians total for the highest consecutive pedestrian 4-hour period.

Pedestrian counts should only include pedestrians crossing within 100 feet either side of the proposed crosswalk location in an attempt to capture all potential users of the proposed crosswalk.

- ✓ Two-way traffic volumes should meet the minimum of 1,500 vehicles for the ADT or 150 vehicles in the pedestrian count hour.
- ✓ The current pedestrian crossing is not due to a corrective gap in the sidewalk system.

Exhibit 12.4 was developed for field use to assist in analyzing an uncontrolled location for a potential marked crosswalk. SDDCTEA warrants are not only used to evaluate the installation of a marked crosswalk, but also to evaluate removal of (or justification to keep) an existing crosswalk. Crosswalks should not be installed at locations that could present an increased safety risk to pedestrians without first providing adequate design features and/or traffic control devices. Therefore, after determination is made that a croasswalk is warranted, refer to SDDCTEA Pamphlet 55-17 for additional information regarding enhancements that should be added, as needed, to improve the safety of the crossing. The enhancements are for guidance purposes and should be applied with engineering judgment.

Exhibit 12.4: Warrants for Crosswalk Installation at Uncontrolled (No Traffic Control) Locations—Field Sheet (Sample)

Field Sheet:
Warrants for Crosswalk Installation at Uncontrolled (No Traffic Control) Locations

Location E Main St and A St

Direction East

Date June 6, 2015

Posted Speed 35 mph

Time Period 0400 - 0500

Weather Clear

Observer B. Jones

STEP 1 (Safety Criteria)

Existing stopping sight distance	=	225 ft	If existing stopping sight distance is less than the required stopping sight distance, do not install crosswalk.
Required stopping sight distance	=	250 ft	
Is there an adequate sight distance triangle?		[✓ YES]/NO	If NO, Remove obstacles within sight triangle.
Is the proposed location within an axillary lane?		YES/[✓ NO]	If YES, do not install crosswalk.

If all three safety criteria are satisfied, proceed to Step 2

STEP 2 (Crossing Location from Traffic Control and Alternate Options Criteria)

Distance from nearest signal, stop or yield control on road that crosswalk is being evaluated (side street control does not apply)	=	325 ft	If less than 300 ft from a controlled intersection DO NOT install crosswalk without a Traffic Engineering Study.
Is the current pedestrian crossing due to a correctable gap in the sidewalk system?		YES/[✓ NO]	If YES, do not install crosswalk Correct sidewalk system and observe changes in pedestrian crossings.

If both criteria are satisfied, proceed to Step 3

STEP 3 (Pedestrian and Vehicular Volume Criteria)

Vehicular Volume (one of the two criteria should be met)

Traffic volumes (average daily traffic, two-way)	=		Minimum 1500 vehicles per day
OR			
Traffic volumes (hourly volume, two-way)	=	280 v	Minimum 150 vehicles in an hour (same hour that pedestrian volume criteria is met)

Pedestrian Volume (one of the two criteria should be met)

Pedestrian Hourly Volume (any hour)	=	28	Minimum of 20 pedestrian crossing
OR			
Elderly/disabled/children Hourly Volume (any hour)	=	6	Minimum of 15 elderly, disabled or children crossing
OR			
Pedestrian Volume (highest consecutive 4-hour period)	=	45	Minimum of 60 pedestrian crossing

If both vehicular and pedestrian volumes are not met, a crosswalk is recommended—see SDDCTEA's Pamphlet 55-17 for proper crosswalk enhancements

12.4. ANALYSIS

Simply knowing whether a pedestrian crossing has a low, moderate, or high pedestrian and bicycle volume may be adequate to further investigate and select the proper safety improvement. Pedestrian/bicycle count totals collected at targeted locations within the installation can be analyzed to identify specific locations where high volumes of pedestrian movement may warrant additional pedestrian controls or bicycle accommodations. The pedestrian count can be used to determine the pedestrian crossing volume to verify whether or not it meets the minimum criteria for the installation of a marked crosswalk at an uncontrolled intersection or midblock location, as illustrated in Exhibit 12.4. Consideration should be given to install marked crosswalks at all signalized intersections with pedestrian signal heads and at school crossings where guards are normally stationed to assist with pedestrian crossings. However, the installation of marked crosswalks at controlled (stop/yield) intersections is at the discretion of the installation—considering that the MUTCD does not give specific guidance on when to 'mark' a crosswalk at a (stop/yield) controlled intersection. Nonetheless, drivers expect pedestrians at stop/yield-controlled intersections so they will be more aware.

12.4.1. Pedestrian walking speed

A pedestrian walking speed can be used to help determine the acceptable number of available gaps in traffic, appropriate signal timing, and school crossing analyses. Walking speed is influenced by various human, physical, and environmental, factors including:

- ✓ Age and gender of pedestrians
- ✓ Volume and density of pedestrians
- ✓ Level of physical fitness
- ✓ Grade of roadway
- ✓ Width of pedestrian crossing or path
- ✓ Speed and oncoming distance of vehicle
- ✓ Weather condition

The walking speed analysis is normally conducted at specific locations of interest. The observer should mark a measured distance along the path traveled by the pedestrians and then time individual pedestrians walking over that distance. The data can be analyzed by calculating each individual walking speed by dividing the measured distance by the observed time. An average walking speed can be determined by averaging the number of pedestrians traversing the distance within the time period and comparing this to the recommended walking speed. The recommended walking speed for calculating the pedestrian clearance time within a signalized intersection is 3.5 feet per second under normal conditions for an able-bodied pedestrian. Based on this comparison, an evaluation can be made of the appropriate pedestrian improvements such as pedestrian signal timing adjustment, safety improvements, or other traffic control measures.

The recommended walking speed for calculating the pedestrian clearance time within a signalized intersection is 3.5 feet per second under normal conditions for an able-bodied pedestrian.

12.4.2. Gap Analysis

Gap analysis refers to the determination of the number of available gaps, in traffic passing a point, that are of adequate length to permit pedestrians to safely cross an uncontrolled intersection. Gaps in traffic can help determine locations within the installation where traffic volume conflicts with pedestrian movement and identify areas where pedestrian crossing improvements may be considered. The pedestrian critical gap is defined as the time below which a pedestrian on average will not attempt to begin crossing the street. Pedestrians tend to cross when the perceived gap between vehicles is longer than the critical gap, and not cross when the gap is shorter than the critical gap. The critical gap for a single pedestrian is calculated as:

tc = (L/Sp) + ts
Where
tc = critical gap for a single pedestrian (sec.)
Sp = average pedestrian walking speed (ft/sec) = 3.5 ft/sec (commonly used value)
L = crosswalk length (ft.)
ts = Pedestrian start-up time and end clearance time (sec) = 3 sec (commonly used value)

For example,
Given:
Crosswalk length is 48ft curb to curb
Observed average actual gap in the vehicle traffic stream = 15 seconds
Solution:
Critical Gap tc = (48/3.5) + 3 = 17sec

By recording, through observation, the actual gap times (sec) between vehicles over a period of time (typically the traffic peak hour period), an average gap time can be calculated and compared to the critical gap time for that crossing length. Generally, if the average gap time falls below the calculated critical gap time, consideration may be given to the implementation of pedestrian crossing improvements such as stop/yield or signal head controls, provided other pedestrian warrants are satisfied. From this example, since the actual average gap time of the traffic stream (15 sec) for a pedestrian waiting to cross at an uncontrolled intersection is below the critical gap (17 sec) typically needed to safely cross the intersection, pedestrian crossing improvements would be necessary.

12.5. APPLICATION

Non-motorized pedestrian and bicycle counts can be used to:

- ✓ Track changes in pedestrian and bicycle activity over time
- ✓ Evaluate the effects of new infrastructure on pedestrian and bicycle activity
- ✓ Identify and prioritizing high-priority locations for pedestrian and bicycle facility improvements
- ✓ Determine pedestrian and bicycle safety improvements
- ✓ Provide data for crash analysis
- ✓ Determine appropriate roadway signing and pavement markings
- ✓ Perform pedestrian signal warrants

- ✓ Determine signal timing
- ✓ Design sidewalks, crosswalks, bike lanes, and trails
- ✓ Evaluate before-and-after volumes after a new facility is opened
- ✓ Perform safety analysis of a facility or area
- ✓ Identify the before-and-after safety effects of upgrading a facility

Walking and bicycling as a means of travel within the installation is important to help reduce vehicle congestion and improve air quality. Additionally, it provides increased health benefits for the users. Providing a safe and efficient infrastructure for bicycles within the installation is encouraged. A bicycle count will identify locations of high volume and frequency of bicycle movement. It can help to identify major bike routes within the installation or suggest the need for safety improvements such as a separate bike lane or trail to minimize conflicts with vehicles. Bicycle movement data may be collected with the same methods as pedestrian travel counts. However, since bicyclists share the road with vehicles and follow motor vehicle rules, reducing the areas of conflict between bicyclists and vehicles is important. Types of safety improvements that may be considered within the installation for improved bicycle travel include:

- ✓ Designated separate bike lanes
- ✓ Shared bike lanes
- ✓ Widened roadway shoulders
- ✓ Improved roadway shoulder surface
- ✓ Bicycle signing
- ✓ Bicycle pavement markings
- ✓ Sight distance improvements
- ✓ Bike routing designations
- ✓ Bike racks

Additional information and guidelines regarding type and application of bicycle improvements and treatments can be found at the FHWA website: http://www.fhwa.dot.gov/environment/bicycle_pedestrian/guidance/. Recommendations and implementation of bicycle improvements is at the discretion of the installation. SDDCTEA staff is available for additional direction and assistance in determining improvements that accommodate bicycle travel.

CHAPTER 13—ENTRY CONTROL FACILITY STUDY

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The Entry Control Facility (ECF) is the first point of contact for entrance onto a military installation. An ECF needs to ensure the proper level of access control for all DoD personnel, visitors, and vehicle traffic entering an installation. The objective of an ECF is to secure the installation from unauthorized access and intercept contraband while maximizing vehicular traffic flow. ECFs must balance security, safety and traffic movement onto the installation. The DoD UFC uses the terminology "ECF"; however, the Department of the Army uses the terminology "Access Control Point (ACP)" to refer to the entry point onto an installation. Both terms are interchangeable.

This chapter will summarize the general procedure required to conduct a traffic analysis for determining the required capacity at an ECF. For more specific information on the planning and design of an ECF, refer to SDDCTEA Pamphlet 55-15 *Traffic and Safety Engineering for Better Entry Control Facilities*.

13.1. OBJECTIVE

An ECF study will examine the functionality of the existing facility to help identify transportation deficiencies and recommend potential short term and long term systematic implementable improvements to meet current and future operational demand. Generally, there are four elements in the design of an ECF that should be evaluated.

- ✓ Security
- ✓ Safety
- ✓ Capacity
- ✓ Sustainability/Image

It is important to recognize that the design capacity of an ECF is based on the peak hour traffic volume that the ECF would process without unreasonable congestion. The analysis should consider both current and future traffic demands. The design demand is the existing peak hour traffic volume (which typically occurs during the morning rush hour) plus adjustments for current deployments and local growth, as well as, future installation growth related to new missions/traffic volumes. ECFs are not designed for special event traffic conditions such as graduation ceremonies and other sporadically occurring events. The force protection condition (FPCON) has a great effect on the processing time per vehicle and the traffic volume due to changes in the inspection procedures and the number of authorized vehicles. Since some disruption of ECF processing time is expected at high FPCONs, the UFC requires the ECF to be designed to eliminate congestion at FPCON Bravo and below.

If the final capacity achieved at an ECF/ACP is below the expected peak hour traffic volume, traffic congestion reduction methods (such as implementing tandem processing checks, adding lanes/reversible lanes, encouraging carpooling or staggered work hours) should be considered to improve capacity at the ECF.

13.2. INFORMATION NEEDED

The following elements should be considered when assessing the current conditions of an ECF:

- ✓ Security
- ✓ Functional requirements
- ✓ Safety
- ✓ Service Requirements
- ✓ Traffic flow and congestion
- ✓ Manpower
- ✓ Cost
- ✓ Sustainability/Image
- ✓ Accessibility and Development Plans
- ✓ Installation needs

SDDCTEA Pamphlet 55-15 includes information regarding these areas of focus in the evaluation of the ECF. This chapter will focus on traffic flow and congestion.

Additional specific data should be gathered regarding previous ECF studies, planning data, site mapping, roadway/intersection data, crash data, staffing levels, and traffic volumes. Coordination with all installation stakeholders is critical for a comprehensive evaluation of existing ECF operations. Early discussions with the Installation Command, security forces and safety officers, the engineering office (Department of Public works), and first responders will assure all participants the opportunity to provide information and comment with regard to operational aspects of the facility. Interview the installation force protection and ID check personnel to query additional information concerning the current operations of the ECF, as well as the future intended operations/processing method. Coordination with other external organizations including county, state DOT, and external responders may be beneficial to determine issues involving installation access or congestion on the local road network surrounding the ECF. In addition, information collected from field surveys of traffic conditions and general observation assessments of the ECF will help to document any existing operational characteristics that may negatively impact the functionality and capacity of the ECF.

13.3. METHOD

Performing a traffic engineering analysis is essential to determine the appropriate facility size. For the analysis, data pertaining to the existing ECF traffic throughput volume (i.e., processed traffic) is collected, as well as the volume of unprocessed or queued traffic. From the data, the actual existing demand volume can be calculated. The number of ID check lanes needed today is based on the existing demand volume. Subsequently, the existing demand volume is used to project the future traffic demand (or design demand volume) and future required number of ID check lanes. Additionally, traffic data at the adjacent internal (on-base) and external (off-base) intersections should be collected and analyzed for its affect on the ECF operations.

For example, the first external intersection may be a signalized intersection that is improperly timed affecting the release of traffic to the ECF, and the first internal intersection may require relocation if determined to be within the response zone of the ECF. Volumes at these intersections should be captured using the procedures discussed in chapter 1 for Intersection Turning-Movement Counts (using the same peak hour as that of the ECF). SDDCTEA can provide assistance in determining the effects of these intersections. However, this chapter will assume no effects from the external intersection and focus on calculating an existing demand volume based on the processed traffic volume and the unmet demand at the ID check area.

Traffic data collection efforts at ECFs should include these key elements:

Vehicle Count

Traffic counts are taken on normal operating days (Tuesday–Thursday on non-holiday weeks) in 15-minute intervals over the peak travel periods throughout the day. *An exception to this is at reserve and guard facilities where weekend counts are necessary to capture the military drill volume on a Unit Training Assembly (UTA) weekend.* Traffic counts at ECFs should be conducted during the weekday morning period (such as 0600–0800), afternoon period (such as 1130–1330), and evening period (such as 1530–1730) to capture the various peak traffic periods throughout the day. Typically, the morning peak period will dictate the number of lanes required.

Automatic traffic recorders (ATRs) can be used to count the number of vehicles entering an ECF. The location for the placement of the ATRs will depend on the characteristics of the ECF being studied. Typically, ATRs are placed immediately after the ID check area and the data collected at that location represents the volume of vehicles processed through the ECF. Using this technique, any unmet demand (queue) will need to be added to the processed volume *(using the procedure later discussed in the Analysis section of this chapter)* to determine the total existing demand volume. The traffic queue should be captured separately by either counting the number of vehicles queued at the end of each 15-minute count interval or by estimating the queue volume from an observed queue length (described below). Another option is to place the ATRs far enough away from the ID check area so as to be out of the influence of any queue that may form. A count conducted at a location as such, captures the total existing demand volume for the ECF, inclusive of vehicles processed and vehicles queued, since the vehicle-count was captured as each vehicle arrived. In many situations, existing ECFs are located within close proximity to the first external intersection and where the placement of ATRs outside the influence of the queue is impossible.

Existing Processing Rate

Manual counting of vehicles processed through the ECF check point within a time period can be used to determine the actual lane processing rate. The volume of vehicles processed can then be compared to standard lane processing rates provided in SDDCTEA Pamphlet 55-15. These rates have been established from a compilation of ECF capacity assessments under various FPCON for manual, handheld devices, and automated lanes, and have been validated by the SDDCTEA as acceptable design criteria.

Vehicles can be timed using a stop watch to determine the amount of time between two vehicles moving through a check point. The stop watch is started when a stopped vehicle at the check point begins to move through the check point. The stop watch is stopped when the following vehicle is stopped at the check point. The time recorded on the stop watch is the processing time per vehicle. Manual recordings should be conducted during peak hour periods when the ECF is under constant demand. A number of recordings should be made (approximately 50–100) and the average rate should be determined. The average rate in seconds can be computed into an average rate per hour to approximate the number of vehicles processed per hour.

Length of Queue—Vehicles arriving at an ECF faster than they can be processed result in a queue (i.e., a line of vehicles awaiting their turn to be processed) being formed causing congestion. The goal is to design an ECF with an adequate number of ID checks that does not cause unreasonable queuing during peak hour periods. Excessive queuing may impact external roadways and intersections or impede efficient traffic flow through the ECF producing a safety or security issue. A count of the total queued vehicles (in all lanes) should be recorded at the end of every 15-minute count interval (to coincide with the 15-minute count interval on the ATRs) during the peak hour periods. Rather than counting the number of queued vehicles, a length of the vehicle queue can also be measured to calculate the approximate number of vehicles in the queue. This is done by noting the end of the queue location in the field, determining this length by using measuring tools in aerial imagery (such as IRRIS/TGIS), and then dividing the length by 25 feet (approximate length of a passenger vehicle plus space between queued vehicles) to determine an approximate number of queued vehicles.

Number of queued vehicles = total length of queue / 25 feet

As previously mentioned, the volume of the queue is to be used in determining the size of the facility as well as the number of entry lanes required to provide adequate capacity for the anticipated traffic volume.

Turning Movements—Assessing the first internal intersection and first external intersection adjacent to the ECF entrance may be necessary to determine any congestion due to operational inadequacies of the intersections that may impact vehicle processing, traffic flow, or safety issues. Refer to chapter 1 for Intersection Turning-Movement Counts.

Bike and Pedestrian Movement—Counts of pedestrian and bicycle throughput at an ECF can be recorded to determine significance of non-motorized travel and evaluate the need for improved pedestrian/bicycle accommodations, as well as, separate processing facilities.

24 Hour Traffic Volumes—Traffic volume counts over a 24-hour period may be taken at the ECF to determine daily averages and flow patterns throughout the day or longer periods. 24-hour traffic counts can help identify the number of vehicles entering the installation during the peak hour or during off-peak hours. This data can be used to assess the overall usage of the ECF and determine future capacity needs.

Vehicle Type—Identifying the type and volume of vehicles (i.e., cars, trucks, buses, motorcycles, military) entering the installation can help determine the ECF throughput efficiency. Vehicle classification can be provided through manual observation counts by either hand tally sheet, electronic hand-held devices, or ATR counters. These counts can help determine percentages of the type of vehicles traveling though the ECF and the data can be analyzed to assess the overall usage of the ECF to help identify safety, security and capacity improvements.

Visitor Volume—If applicable to the ECF being studied, the number of visitors to the installation should be counted to determine a processing rate. Visitor counts can typically be obtained from processing personnel. The traffic engineering study should identify the visitor volume during the peak visitor period, and should be a future demand if appropriate. Processing capacity required is based on the peak hourly visitor demand, number of processors, and the time it takes to process based on the installation's procedures. If the processing time is unknown, per UFC 4-022-01, assume a rate of 12 to 20 visitors per hour per processor.

Inspected Vehicles—A count of the number of inspected vehicles, especially commercial vehicles, should be recorded to determine demand requirements and geometrics of inspection areas. Refer to SDDCTEA Pamphlet 55-15 for additional information.

Origin and Destination Study—An OD study can be used to determine existing and future travel patterns between internal and external land uses. Additionally, an OD study can provide information to help determine future locations of ECFs on an installation in relation to the surrounding population centers. Refer to chapter 9 for procedures to conduct an OD Study.

13.4. ANALYSIS

Existing Demand Volume—As discussed in the Method section of this chapter, the existing demand volume for an ECF is determined by counting the number of vehicles processed, and those waiting to be processed, at an ECF during the peak hour periods of a normal weekday. Similar to intersection counts discussed in chapter 1, the peak hour can be derived from the 15-minute count data as the hour with the highest four consecutive 15-minute interval counts. However, with ECFs, the entering queue volume must be added *(if the ATRs captured the count of processed vehicles)* and only the entering volume is considered when determining the peak hour volume for ID check lane requirements. The morning peak period typically contains the highest peak entering volume and therefore controls the design for the number of ID check lanes required.

As discussed in chapter 1, the peak hour factor (PHF) is an adjustment to the peak hour volume and represents the distribution of traffic volume during the peak hour based on the 15-minute interval counts. The closer the PHF is to 1.00 means that the traffic volumes are constant throughout the peak hour. A lower peak hour factor, such as 0.50, implies that traffic was very inconsistent during the hour. A PHF is calculated with the following formula:

$$PHF = V / (4 \times v_{15})$$

Where
V = peak hour volume (vph) *(total of the four highest consecutive 15-minute interval counts)*
v_{15} = highest 15-minute volume (veh/15min) during the peak hour

After determining the PHF, the maximum rate of flow within the hour (v) can be calculated. This is the baseline volume utilized to determine the number of lanes for an ECF and is calculated by using the following formula:

$$\text{Maximum flow rate } v = V / PHF$$

Where
V = peak hour volume (vph)
PHF = peak hour factor

If an installation has an hourly traffic demand count, the equation above could be used to calculate the Existing Demand Volume if assumptions are made about the PHF. Typically, as with an intersection, it is fairly easy to assume. However, considering the large variabilities associated with military installations, SDDCTEA currently does not have significant data to provide recommendations on a PHF to assume.

A more direct way to calculate the Existing Demand Volume is by using the highest 15-minute volume, v_{15}, of the peak hour. Procedures for this calculation are described in the remainder of this section.

The first step is to determine arrival volumes, based on the collected data. If the ATRs were placed well in advance of the ID check area so that traffic does not queue over the count equipment, the volume collected is the arrival volume. If the ATRs were placed immediately after the ID check area, the recorded processed volume and the difference in the queue volume for each 15-minute count interval, must be added together to equal the arrival volume. The peak hour, and the associated peak arrival 15-minute volume $[v_{15\ (arrival)}]$ is then determined using the arrival counts. The last step in determining the Existing Demand Volume is to account for the PHF by multiplying the peak arrival 15-minute volume by four to convert to an hourly format.

Existing Demand Volume = $v_{15\ (arrival)} \times 4$

Where
$v_{15\ (arrival)}$ = highest 15-minute volume during the peak hour = v_{15} + Delta Q15
Delta Q15 = $Q15_{final} - Q15_{initial}$

Example:

Traffic count data was collected at an ECF as shown in columns 1–3 below. Using this data, the remaining columns illustrate the determination of the arrival volumes and the peak hour.

	COUNT TIME INTERVAL	**DEPARTURE VOLUME** (PROCESSED VEHICLE COUNT)	**TRAFFIC QUEUE Q** (VEHICLES) (AT END OF COUNT INTERVAL)	**DELTA Q** ($Q15_{FINAL}$ - $Q15_{INITIAL}$)	**ARRIVAL VOLUME** (DEPARTURE VOLUME + DELTA Q)	
	0600–0615	15	0	0	15	
	0615–0630	50	0	0	50	
	0630–0645	150	10	10 - 0 = **10**	160	PEAK HOUR
	0645–0700	200	15	15 - 10 = **5**	205	
v_{15}	0700–0715	250	30	30 - 15 = **15**	265	
	0715–0730	225	20	20 - 30 = -10	215	
	0730–0745	100	10	10 - 20 = -10	90	
	0745–0800	25	0	0 - 10 = -10	15	
	TOTAL	**1015**			**1015**	

Peak hour = 0630–0730

$v_{15\ (arrival)}$ = 265 vehicles/15-min

Existing Demand Volume = $v_{15\ (arrival)}$ x 4 = 265x 4 = 1060 veh/hour

Note in the example above that a reduction in queue length results in a negative Delta Q value to obtain a true arrival volume. This means that vehicles are being processed faster than they are arriving. Also note, that the summation of departure volumes equals summation of arrival volumes when the traffic queue is back to zero.

Deployments—Traffic data should be collected at a time when the installation population is at a 'normal' condition. Periods of significant deployments should be avoided if possible, but military missions around the world may make that unavoidable. When there are significant deployments, normal demand can be calculated if the deployment percentage is known. The Existing Demand Volume, as calculated above, is adjusted based on the percent of total base population deployed. An example calculation is shown below.

Given:
Deployment Adjustment (DA) = Percent of total base population deployed = 10%
DA = 100% / (100% - DA%) = 100% / (100% - 10%) = 1.11
Adjusted Existing Demand Volume = DA x Existing Demand Volume = 1.11 x 1060 = 1176 veh/hour

Exhibit 13.1 shows a sample worksheet for use in calculating the Existing Demand Volume. This worksheet is intended for use in the office after automatic counting equipment has been downloaded. However, at ECFs with very low volume, this worksheet could also be used in the field for recording vehicle counts.

Exhibit 13.1: ECF Existing Demand Volume Calculation (Sample)

Date 04/06/15 Installation Naval Base

Gate No. 3

TIME INTERVAL	**DEPARTURE VOLUME** (PROCESSED VEHICLE COUNT)	**TRAFFIC QUEUE Q** (VEHICLES) (AT END OF COUNT INTERVAL)	**DELTA Q** ($Q15_{FINAL}$ - $Q15_{INITIAL}$)	**ARRIVAL VOLUME** (DEPARTURE VOLUME + DELTA Q)
1300-1315	8	0	0	8
1315-1330	15	0	0	15
1330-1345	33	8	8 - 0 = 8	41
1345-1400	45	12	12 - 8 = 4	49
1400-1415	52	21	21 - 12 = 9	61
1415-1430	33	15	15 - 21 = -6	27
1430-1445	17	7	7 - 15 = 8	9
1445-1500	10	0	0 - 7 = -7	3
TOTALS	213	*DEPARTURE VOLUME = ARRIVAL VOLUME IF THE LAST INTERVAL RECORDED HAS 0 QUEUE*		213

Peak Hour = 1330-1430

$v_{15\ (Arrival)}$ = 61 veh/15-min

Existing Demand Volume = $v_{15\ (Arrival)}$ x 4 = 244 veh/15-min

Deployment Percent = 10 %

Adjustment (DA) = 100% / (100% - Deployment %) = 1.11

Adjusted Existing Demand Volume = DA x Existing Demand Volume = 270 veh/hour

13.5. INTERPRETATION

Design Demand Volume—Projecting the future demand volume at an ECF requires consideration of other factors that may impact the future population of the installation, positively or negatively. The projected traffic on the installation, and at ECFs should be based on the best available forecast of potential ECF military activities.

Example:

An installation is scheduled for an increase 5 percent in population over the next 15 years. Inclusive of deployments, the Existing Demand Volume of the ECF was determined to be 1200 vehicles/hr. To account for the projected future growth, an adjustment is applied to the Existing Demand Volume as shown below:

Given:
ECF Existing Demand Volume = 1200 vehicles/hr.
Future Growth (FG) = 5%

Solution:
Adjustment factor for FG = (100% + FG%) /100% = (100% + 5%) / 100% = 1.05
ECF Design Demand Volume = 1200 x FG = 1200 x 1.05 = 1260 vehicles/hr.

Lane Requirements—SDDCTEA Pamphlet 55-15 can be used for determination of the number of check lanes that will be necessary to process the calculated future Design Demand Volume for the ECF. The selection process is based on (or includes) other “SMART” factors such as type of processing, security, manpower, automation, allowable queuing, etc. If there is room for queuing within the perimeter of the installation, SDDCTEA recommends designing for a 120-second delay per vehicle. A design as such can be achieved either by doing a Queuing Analysis or simply by using the ACP/ECF SMART Decision Evaluator software.

Bike and Pedestrian Movement—Consideration of non-motorized traffic (i.e. bicycles and pedestrians) entering an ECF should be given when evaluating the traffic conditions at an ECF. Accommodating alternative transportation modes provides a safe and attractive environment for bicyclists and pedestrians, and can help reduce the demand of vehicles seeking entry during peak periods. Simply counting the number of personnel entering the ECF by walking or biking will provide a basis for determining potential accommodations to allow safer passage. A dedicated pedestrian ECF may be warranted when pedestrian volume exceeds 10 users per 15-minute period. Dedicated bicycle lanes can be provided through the ECF to allow a safe mix of vehicular and bike traffic. Additionally, vetting of this non-motorized volume will need to be accounted for in any future design.

13.6. APPLICATION

The demand volume of an ECF can be applied to various access issues that may exist or may develop over time within the installation. The demand volume of an ECF can be calculated to help determine the appropriate number of ID check lanes that may be necessary to efficiently process the number of vehicles entering the installation during the future peak periods.

Maintaining efficient traffic flow onto an installation while providing a safe and secure checkpoint is a DoD requirement and is vital to the overall function of the installation. Insufficient capacity of an ECF will cause vehicle congestion and delay, increase transportation costs and create safety issues especially if the traffic queue extends to the local roadways adjacent to the installation. A study of the traffic utilizing an ECF can provide data to document and analyze traffic management issues for existing installations, or allow for data comparison to general standards when determining appropriate sizing of new ECFs. The traffic data can help to develop and prioritize improvements that will adequately address the concerns such as:

- ✓ Improve traffic flow
- ✓ Increase capacity
- ✓ Reduce congestion
- ✓ Improve air quality
- ✓ Reduce potential crashes
- ✓ Improve security
- ✓ Increase ID check throughput
- ✓ Reduce both traveler and ECF personnel frustration
- ✓ Enhance protection of guards
- ✓ Provide safe access for non-motorized vehicles
- ✓ Provide appropriate location of ECF
- ✓ Provide appropriate size of ECF

For example, an installation has two (2) existing ECFs. The Main Gate experiences high volumes and excessive traffic queues during the peak hour which is impacting the first exterior intersection. As a result, and as determined from an OD study, a portion of the traffic desiring to enter the Main Gate diverts to the other more remote ECF less congested but further from the intended destination within the installation. Installation personnel are in the planning stages for a new Main Gate. Since the OD Study indicated there is a latent demand that could be accounted for in the design of the number of future lanes at the desired Main Gate, this latent demand volume should be included when calculating the Existing Demand Volume (and subtracted from the Existing Demand Volume of the other gate). The OD study indicated that approximately 30% of vehicles entering the East Gate are diverting from the Main Gate. Therefore, when determining the Main Gate lane requirements, the installation should account for 30% of the East Gate peak hour traffic.

Another common use of peak hour traffic volumes used in conjunction with OD Studies is when an installation is considering closing a gate or gate consolidation.

APPENDIX A

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SAMPLE LANGUAGE FOR TRAFFIC ENGINEERING STUDY CONTRACTS

GENERAL PRACTICES AND REQUIREMENTS

General practices and requirements are described below. Specific requirements will need to be identified by the installation in the contract:

- ✓ Coordinate with the installation Point-of-Contact (POC) to schedule and conduct an on-site in-brief, with installation stakeholders, to review the scope of work, obtain necessary approvals and discuss data collection activities and outcomes.
- ✓ Calculate future traffic demand projections utilizing Institute of Transportation Engineers (ITE) trip generation analysis, and independent forecasting based on known Base Realignment and Closure (BRAC), Grow the Army, and/or other known re-stationing. All stationing information shall be obtained through interview with the installation POC and through independent research. The traffic forecast design year shall be full build out year of all known improvements.
- ✓ For studies involving Entry Control Facilities (ECFs), calculate the new lane requirements based on SDDCTEA Pamphlet 55-15, UFC 4-022-01, The Army Standard (AS) for Access Control Points (ACPs), and all other applicable service related requirements, latest versions. Utilize the SMART Decision Evaluator software (available on SDDCTEA's website) to assist in identifying the existing, short-term, and long-term impacts of security, manpower, automation, and traffic.
- ✓ For studies involving ECFs, interview the installation force protection and ID check personnel to query additional information concerning the current operations of internal and external access control points.
- ✓ Provide conceptual scaled drawings of recommendations for new and modified ECFs. When applicable (sight distance triangle requirements, geometric adjustments, striping adjustments, design vehicle accommodations, sidewalks, etc.), provide conceptual scaled drawings of recommendations for intersections and/or roadways that are included as part of this study. This shall include all geometric data used in the roadway alignment, recommended lane configuration, active & passive vehicle barrier placement, striping, signing, environmental constraints, and a statement of feasibility of design. (This is intended to be 11" x 17" foldouts graphically identifying all recommendations—prepared in color to scale with MicroStation CAD software, and overlaid onto an aerial photograph).
- ✓ Traffic and speed data collection, both manually and with automatic data collectors, shall be collected on a 15-minute period basis.
- ✓ Provide existing and future intersection capacity and network analysis utilizing HCS, or SYNCHRO, traffic capacity software. Network analysis may involve large intersection networks; greater than 10 intersections. Provide a summary of results and recommendations based on Level of Service (LOS), with consideration of traffic flow and safety. Intersection summary shall include discussion of lane group LOS as well as intersection LOS. Analysis shall include queuing analysis for all intersection lane groups to identify congestion.
- ✓ Road Safety Assessments shall address, but not be limited to, the following items:
    - Traffic control
    - Lane configuration

  - Signing
  - Striping
  - Design vehicle accommodation
  - Operational concerns
  - Roadside hazards
  - Improper traffic control devices
  - Bicycle and pedestrian access
  - Analysis of most recent five years of crash data, if available.

✓ Categorize short-term, intermediate-term, and long-term recommendations.

Short-term recommendations are improvements that can be executed within six months utilizing normal installation maintenance resources that will provide immediate improvements to capacity, safety, and/or operations. Intermediate-term recommendations are improvements that can be executed within one to two years and require some planning, design, and repair/construction authority to execute. Typically, intermediate-term recommendations can be implemented in stages with minimal impacts. Long term recommendations are improvements that can be implemented in three to five years and require extensive planning, design, and construction authority (i.e. MILCON) to execute.

✓ Provide construction and preliminary engineering cost estimates for all recommendations.

✓ Provide a photographic record of all deficiencies and recommendations, where applicable. Locate them in the report.

✓ Perform desktop analysis of specific safety or traffic engineering related roadway issues based on information and data provided by others.

✓ Sign Management Studies shall include, but not be limited to, the following items:

  - Sign Identification Number (i.e. a unique number identifying the sign panel), developed in coordination with the installation POC
  - GPS coordinates (i.e., GPS latitude and longitude)
  - Roadway Name (i.e., route name on which the sign is located)
  - Installation Date (i.e., date when sign installed)
  - Sign photo
  - Sign code (i.e., the MUTCD designation)
  - Sign message (if unique)
  - Direction of travel (i.e., northbound, southbound, eastbound, westbound)
  - Sign Position (i.e., Location of sign relative to road—left, right, overhead)
  - Lateral offset (i.e., distance from the edge of the traveled way to the near edge of sign panel)
  - Sign dimensions (i.e., width and height of sign panel)
  - Mounting Height (i.e., height measured vertically from the bottom of the sign to the top of the curb, or in the absence of curb, to the elevation of the near edge of the traveled way)
  - ASTM D4956 “Type” and manufacturer of sheeting material (i.e., grade of retroreflective material)

- Sign retroreflectivity (*Sign retroreflectivity shall be measured using one of the approved MUTCD methods with the chosen method identified within the contract.*)
- Number of sign supports
- Type of sign support (i.e., wood post, U-channel steel post, square or round tube steel post, I-beam steel post, etc.)
- Physical condition of sign face (Comment on condition [e.g., cracking, delamination, etc.], fading or discoloration, contrast, retroreflectivity, and damage due to vandalism)
- Rating of the physical condition of sign face (e.g., good, marginal, poor)
- Rating of the physical condition of mounting (e.g., good, marginal, poor)
- Additional field and desktop observations:
  - Is the sign the correct one in accordance with the 2009 Edition of the MUTCD? (i.e., proper application)
  - Is the sign the correct size?
  - Is the sign needed per the 2009 version of the MUTCD? (Provide only the required signage, eliminating redundant and unnecessary signs.)
  - Is the sign correctly positioned with respect to lateral clearance?
  - Is the sign correctly positioned with respect to height above ground?
  - Is the sign correctly positioned with respect to longitudinal placement along road?
  - Is the sign visible, both day and night, at the required distance? If not, indicate cause of problem (e.g., blocked by vegetation, other signs, etc.)
  - Is sign support crashworthy (e.g., breakaway, yielding, or shielded with a longitudinal barrier)? If not, are sign supports located outside the clear zone?

GENERAL REFERENCES

The contractor shall fully consider and ensure studies and plans comply with the most recent and current country, federal, state, and local laws and regulations, and SDDCTEA directives and instructions. Examples include:

- ✓ SDDCTEA Pamphlet 55-8, *Traffic Engineering Study Reference*
- ✓ SDDCTEA Pamphlet 55-15, *Traffic and Safety Engineering for Better Entry Control Facilities*
- ✓ Pamphlet 55-17, *Better Military Traffic Engineering*
- ✓ American Association of State Highway and Transportation Officials (AASHTO)—*A Policy on Geometric Design of Highways and Streets*, 2011
- ✓ AASHTO—*Roadside Design Guide*, 4th Edition, 2011
- ✓ Institute of Transportation Engineers (ITE)—*Traffic Engineering Handbook*—Washington D.C., 2009
- ✓ U.S. Department of Transportation, Federal Highway Administration (FHWA)—*Manual on Uniform Traffic Control Devices* (*MUTCD*) Washington, D.C., 2009
- ✓ Transportation Research Board—*Highway Capacity Manual*, 2010
- ✓ ITE—*Manual of Traffic Signal Design*

- ✓ ITE—*Design and Safety of Pedestrian Facilities*
- ✓ ITE—*Traffic Calming, State of the Practice*
- ✓ ITE—*Parking Generation*
- ✓ All applicable Unified Facilities Criteria (UFCs)
- ✓ State and Department MUTCD Supplements

DELIVERABLES

Following is a list of common deliverables:

- ✓ Contractor Points of Contact
- ✓ Project Schedule
- ✓ In-Brief Presentation/Meeting
- ✓ Out-Brief Presentation/Meeting
- ✓ In/Out-Brief Meeting Minutes
- ✓ Draft Report -*(Shall include adequate text, illustrations, and data to thoroughly document existing conditions & deficiencies; as well as to support the recommended improvements. Recommendations for all necessary improvements shall be shown.)*
- ✓ Draft-Final Report—*(Shall include all necessary changes due to installation out-brief comments and the implementation of remaining data.)*
- ✓ Final Report
- ✓ Monthly Status Report
- ✓ Travel Request
- ✓ Trip Report

APPENDIX B

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MILITARY POLICE TRAFFIC ACCIDENT REPORT

For use of this form, see AR 190-45; the proponent agency is PMG.

PRIVACY ACT STATEMENT

AUTHORITY: Title 10 USC Section 301; Title 5 USC Section 2951; E.O. 9397 dated November 22, 1943 *(SSN)*.

PRINCIPAL PURPOSE: To provide commanders and law enforcement officials with means by which information may be accurately identified.

ROUTINE USES: Your social security number is used as an additional/alternate means of identification to facilitate filing and retrieval.

DISCLOSURE: Disclosure of your social security number is voluntary.

1. PM ACTIVITY CODE/REPORT NO.	2. DATE OF ACCIDENT *(YYYYMMDD)*	3. TIME OF ACCIDENT *(Use 2400 hour)*	4. DAY OF WEEK OF COLLISION *(Sunday, Monday, etc.)*

5. LOCATION OF ACCIDENT

a. MILITARY RESERVATION ☐ YES ☐ NO

b. NAME AND LOCATION OF MILITARY RESERVATION *(Include City and State, etc.)*

c. ROAD OR STREET ON WHICH ACCIDENT OCCURRED

d. NAME OF INTERSECTING STREET IF AT INTERSECTION

e. NAME OF NEAREST INTERSECTING STREET, HIGHWAY, OR OTHER PERMANENT IDENTIFYING LANDMARK IF NOT AT INTERSECTION

f. NO. OF FEET

g. DIRECTION

h. IF ACCIDENT OCCURRED OFF MILITARY RESERVATION, AND OUTSIDE CITY LIMITS, INDICATE:

____________ MILES ☐ N ☐ S ☐ E ☐ W FROM ☐ CITY LIMITS ☐ CENTER OF CITY OR TOWN

i. KIND OF LOCALITY

☐ Troop Billets	☐ Mfg or Industrial	☐ School or Playground	☐ Other *(Specify)*
☐ Residential	☐ Open Country	☐ Business	

6. TYPE OF ACCIDENT

☐ Vehicle-Vehicle	☐ Vehicle-Object	☐ Single Vehicle *(Non Collision)*
☐ Vehicle-Pedicycle	☐ Vehicle-RR Train	☐ Hit and Run
☐ Stolen Vehicle	☐ Vehicle-Pedestrian	☐ Other *(Specify)*

a. SEVERITY

NO. KILLED	NO. INJURED

☐ PROPERTY DAMAGE ONLY

b. TOTAL NO. OF VEHICLES INVOLVED

7. WEATHER, LIGHT, AND ROAD CONDITIONS

VEHICLE 1	VEHICLE 2	DRIVING LANES
☐	☐	One
☐	☐	Two
☐	☐	Three or More
☐	☐	Divided Highway
☐	☐	Other

VEHICLE 1	VEHICLE 2	CHARACTER
☐	☐	Straight
☐	☐	Curve
☐	☐	Level
☐	☐	On Grade
☐	☐	Other

VEHICLE 1	VEHICLE 2	SURFACE
☐	☐	Concrete
☐	☐	Black Top
☐	☐	Brick
☐	☐	Gravel
☐	☐	Other

VEHICLE 1	VEHICLE 2	WEATHER
☐	☐	Clear
☐	☐	Rain
☐	☐	Fog
☐	☐	Snowing
☐	☐	Other

VEHICLE 1	VEHICLE 2	CONDITIONS
☐	☐	Dry
☐	☐	Wet
☐	☐	Mud
☐	☐	Snow
☐	☐	Other

VEHICLE 1	VEHICLE 2	DEFECTS
☐	☐	Holes, Ruts, Bumps, etc.
☐	☐	Loose Material on Surface
☐	☐	Defective Shoulder
☐	☐	No defects
☐	☐	Other

VEHICLE 1	VEHICLE 2	LIGHT
☐	☐	Daylight
☐	☐	Dawn
☐	☐	Dusk
☐	☐	Dark, Street Lights
☐	☐	Dark, No Street Lights

8. TRAFFIC CONTROL

VEHICLE 1	VEHICLE 2	
☐	☐	Stop and Go Signal
☐	☐	No Traffic Signal
☐	☐	Flashing Light
☐	☐	Officer or Watchman
☐	☐	Warning Sign
☐	☐	Solid Center Line
☐	☐	One way Street
☐	☐	Stop Sign
☐	☐	Other *(Explain)*

9a. VEHICLE NO. 1

USA REGISTRATION OR LICENSE NO.	MAKE	YEAR	BODY TYPE
UNIT MARKINGS/DECAL NO.	☐ Privately Owned ☐ Government		

REGISTERED OWNER *(If not driver) (Last, First, MI)*

ADDRESS OF OWNER

NAME AND ADDRESS OF INSURANCE COMPANY OR AGENT

9b. VEHICLE NO. 2

USA REGISTRATION OR LICENSE NO.	MAKE	YEAR	BODY TYPE
UNIT MARKINGS/DECAL NO.	☐ Privately Owned ☐ Government		

REGISTERED OWNER *(If not driver) (Last, First, MI)*

ADDRESS OF OWNER

NAME AND ADDRESS OF INSURANCE COMPANY OR AGENT

10a. DRIVER NO. 1

NAME *(Last, First, MI), Grade and Address)*	SSN
	AGE ☐ Male ☐ Female
DRIVER'S LICENSE/PERMIT NUMBER	STATE
LIMITATIONS ON LICENSE/PERMIT ☐ NO ☐ YES *(Specify)*	YEARS' DRIVING EXPERIENCE

CODES	CAT (1)	INJ (2)	SEAT BELT (3)	SEAT POS (4)

10b. DRIVER NO. 2

NAME *(Last, First, MI), Grade and Address)*	SSN
	AGE ☐ Male ☐ Female
DRIVER'S LICENSE/PERMIT NUMBER	STATE
LIMITATIONS ON LICENSE/PERMIT ☐ NO ☐ YES *(Specify)*	YEARS' DRIVING EXPERIENCE

CODES	CAT (1)	INJ (2)	SEAT BELT (3)	SEAT POS (4)

11. OCCUPANTS

NAME AND ADDRESS	VEH NO.	AGE	SEX	CODES			
				CAT (1)	INJ (2)	SEAT BELT (3)	SEAT POS (4)

CODES

(1) CATEGORY	(2) INJURY CLASS	(3) SHOULDER/LAP BELTS	(4) SEAT POSITION
A . Army Officer	A . No Injury	A . Lap Belt Used	1. Front Left
B. Army Enlisted	B. Dead at Scene	B. Shoulder Harness Used	2. Front Center
C. Other Service Officer	C. Dead on Arrival	C. Both Used	3. Front Right
D. Other Service Enlisted	D. Died in Hospital	D. Not Used	4. Back Left
E. Civilian	E. Incapacitating Injury	E. Not Installed	5. Center Back
F. Dependent	F. Non-incap (evident) Injury	F. Lap Belt Failed	6. Back Right
O. Other	G. Possible Injury	G. Shoulder Harness Failed	7. Other Position *(Bus-Motorcycle)*
	H. Injury Unknown	H. Both Failed	8. Position Unknown
		U. Unknown	

12. PEDESTRIAN

a. NAME AND ADDRESS	b. AGE	c. SEX	d. CATEGORY	e. INJURY

f. PEDESTRIAN WAS GOING ☐ N ☐ S ☐ E ☐ W ☐ ALONG ☐ ACROSS ☐ INTO STREET, ROAD OR HIGHWAY,
FROM *(NW to SW corner, or east to west side, etc.)* ______________ TO ______________.

☐ Crossing With Signal
☐ Crossing Against Signal
☐ Crossing Not at Intersection
☐ Crossing No Signal
☐ Hitching on Vehicle
☐ Playing on Roadway
☐ Standing on Roadway
☐ Coming From Behind Parked Car
☐ Pushing or Working on Vehicle
☐ Walking in Road Against Traffic
☐ Walking in Road With Traffic
☐ Other

13. WITNESSES

a. NAME AND ADDRESS	b. TELEPHONE NUMBER

14. VEHICLE DAMAGE

a. **DAMAGED VEHICLE NO. 1**

☐ Right Front of Car
☐ Right Front Fender
☐ Right Front Door
☐ Right Rear Door
☐ Right Rear Fender
☐ Right Rear of Car
☐ Left Rear of Car
☐ Left Fender
☐ Left Rear Door
☐ Left Front Door
☐ Left Front Fender
☐ Left Front of Car
☐ Hood
☐ Roof
☐ Trunk
☐ Undercarriage
☐ Overturn

DAMAGED VEHICLE NO. 2

☐ Right Front of Car
☐ Right Front Fender
☐ Right Front Door
☐ Right Rear Door
☐ Right Rear Fender
☐ Right Rear of Car
☐ Left Rear of Car
☐ Left Fender
☐ Left Rear Door
☐ Left Front Door
☐ Left Front Fender
☐ Left Front of Car
☐ Hood
☐ Roof
☐ Trunk
☐ Undercarriage
☐ Overturn

DAMAGED TRAILER, MOTORCYCLE ETC.
(Sketch Damage)

b. **SEVERITY OF DAMAGE VEHICLE NO. 1**
☐ Disabling Damage ☐ Other MV Damage
☐ Functional Damage ☐ No Damage

SEVERITY OF DAMAGE VEHICLE NO. 2
☐ Disabling Damage ☐ Other MV Damage
☐ Functional Damage ☐ No Damage

SEVERITY OF DAMAGE OTHER VEHICLE
☐ Disabling Damage ☐ Other MV Damage
☐ Functional Damage ☐ No Damage

c. TOWED BY	TOWED BY	TOWED BY
d. TOWED TO	TOWED TO	TOWED TO

e DAMAGE TO PROPERTY OTHER THAN VEHICLE

f. SKETCH OF COLLISION. (1) Identify roadway and roadway features, vehicles, pedestrians, objects on/off roadway, traffic controls, skidmarks, unusual/temperature conditions *(ice patch, construction areas, etc.).* (2) Locate probable point of impact. (3) Show vehicle, pedestrian or object positions at impact. (4) Show probable vehicle or pedestrian paths before and after collision.
NORTH = ↑

g. DESCRIPTION OF COLLISION. Indicate what probably happened before, during, and after the crash; include information not on sketch, e.g., driver disability, reduced visibility, pedestrian clothing color, construction or repair work, etc.

15a. DRIVER'S ACTION BEFORE ACCIDENT

DIRECTION HEADED

VEHICLE 1
☐ N ☐ S
☐ E ☐ W

VEHICLE 2
☐ N ☐ S
☐ E ☐ W

DRIVER *(Check one or more)*

1	2	
☐	☐	Backing
☐	☐	Going Straight Ahead
☐	☐	Making Left Turn
☐	☐	Skidding
☐	☐	Making Right Turn
☐	☐	Making "U" Turn
☐	☐	Overtaking or Passing
☐	☐	Avoiding Veh/Obj
☐	☐	Slowing or Stopping
☐	☐	Stop in Traffic Lane

DRIVER *(Check one or more)*

1	2	Other *(Specify)*
☐	☐	

VEHICLE *(Specify Feet/MPH)*

1	2	
		Estimated Distance When Danger Was First Noticed
		Estimated Speed When Danger was First Noticed
		Estimated Speed at Impact *(MPH)*
		Distance Traveled After Impact *(Feet)*
		Lawful Speed *(MPH)*

b. CONTRIBUTING CIRCUMSTANCES

DRIVER *(Check one or more)*

1	2	
☐	☐	Exceeding Speed Limit
☐	☐	Speed Excessive for Conditions
☐	☐	Failed to Yield
☐	☐	Disregarded Stop Signal
☐	☐	Vision Obstructed
☐	☐	Following Too Close
☐	☐	Improper Overtaking
☐	☐	No or Improper Signal
☐	☐	Disregarded Traffic Signal
☐	☐	Improper Turn
☐	☐	Unknown
☐	☐	Other *(Specify)*

DRIVER *(Check one or more)*

1	2	
☐	☐	Alcohol Involved
☐	☐	Drugs Involved
☐	☐	Ability Impaired
☐	☐	Ability Not Impaired
☐	☐	Unknown

DRIVER *(Check one or more)*

1	2	
☐	☐	Chemical Test Given
☐	☐	Chemical Test Refused

TEST RESULTS

DRIVER NO. 1		DRIVER NO. 2	
%	BAC	%	BAC

1	2	
☐	☐	See attached DD Form 1920 *(Alcoholic Influence Report)*

VEHICLE *(Check one or more)*

1	2	
☐	☐	Defective Brakes
☐	☐	Defective Head Lights
☐	☐	Tires Worn or Smooth
☐	☐	Tires Punctured or Blown
☐	☐	Other *(Specify)*

16. MILITARY POLICE ACTIVITY

a. NAME OF PERSON(s) APPREHENDED	b. CHARGES	c. REPORT NUMBER

d. TIME MILITARY POLICE NOTIFIED *(Hour)*

e. TIME MILITARY POLICE ARRIVED AT ACCIDENT *(Hour)*

f. WHERE ELSE WAS INVESTIGATION MADE?

g. IF OFF MILITARY RESERVATION, WHO ELSE CONDUCTED AN INVESTIGATION? *(If other agency conducted complete investigation, so indicate)*

	YES	NO
h. DID MILITARY OPERATOR COMPLETE DD FORM 518 *(Accident Identification Card)*?	☐	☐
i. DID MILITARY OPERATOR COMPLETE SF FORM 91 *(Motor Vehicle Accident Report)*?	☐	☐
j. WAS FORM COMPLETED FROM ON SCENE INVESTIGATION? *(If not, explain)*	☐	☐

k. DATE

l. TYPED OR PRINTED NAME AND GRADE OF INVESTIGATOR

m. INVESTIGATOR'S SIGNATURE AND GRADE

n. DATE APPROVED

o. APPROVED BY

p. ENCLOSURES

q. DISTRIBUTION

INSTRUCTIONS FOR COMPLETING DA FORM 3946

1. For detailed instructions on completing this form, see FM 19-26.

2. Special instructions are as follows:

a. "Injury Class" and "Severity of Damage." Traffic accidents are classified according to severity in terms of degree of injuries or property damage sustained. Definitions of the terms are contained in Appendix B, AR 190-5.

b "Sketch of Collision." Draw the collision scene exactly as you observed it. If opinions about the events that led up to the collision can be substantiated with observable facts, indicate these on the sketch. When required by local policy, a detailed, scaled diagram may accompany this form; recommended format is contained in FM 19-26.

c. "Description of Collision."

(1) Will include information not on sketch or not on other parts of the form. Describe special conditions or events associated with the collision such as vehicle(s) on fire, immersed or submerged, roadway lights not operating, operator restrictions, color *(shade)* of clothing of pedestrians, etc. If not sufficient space, supplemental pages may be attached.

(2) When form is completed from information received after vehicle(s) have been moved, or removed from the accident scene or from reports from other agencies *(e.g., civil police, etc.),* the report will be completed in as much detail as possible; the source of the information will be identified in "Description of Collision."

3. Release of Information. AR 25-55 controls the release of information and records from Army files and traffic accident information will not be released outside the provisions of the regulation. This form contains statements of fact and information normally releaseable to victims, subjects, witnesses or other persons having interest in a particular accident. Copies of the form may be released to those individuals. Coordination with local staff judge advocate should be made prior to all releases.

4. Distribution:

a. Original: Forward to the commander concerned, utilizing DA Form 3975 *(Military Police Report)* as the transmitting document.

b. A copy of the form is maintained in the originating office.

c. A third copy will be made for release as required by AR 340-17.

Original Military Police Traffic Accident Report form can be found at
http://www.apd.army.mil/pub/eforms/pdf/A3946.pdf.

DA FORM 3946, DEC 1998

APD LC v1.02ES

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APPENDIX C

CHAPTER 1—TRAFFIC VOLUME STUDIES

CHAPTER 3—CRASH STUDY

CHAPTER 7—TRAVEL-TIME AND DELAY STUDIES

CHAPTER 8—SPOT SPEED STUDIES

CHAPTER 10—PUBLIC TRANSPORTATION STUDY

CHAPTER 11—PARKING STUDY

CHAPTER 12—PEDESTRIAN AND BICYCLE STUDIES

CHAPTER 13—ENTRY CONTROL FACILITY STUDY

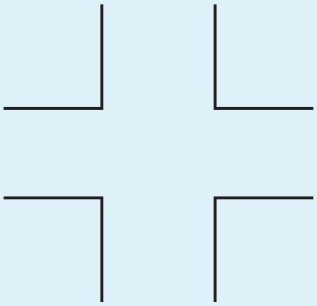
Typical Turning Movement Count Field Sheet

Location ________________________

Date ___________________________

Time ___________ to ____________

Observer ______________________

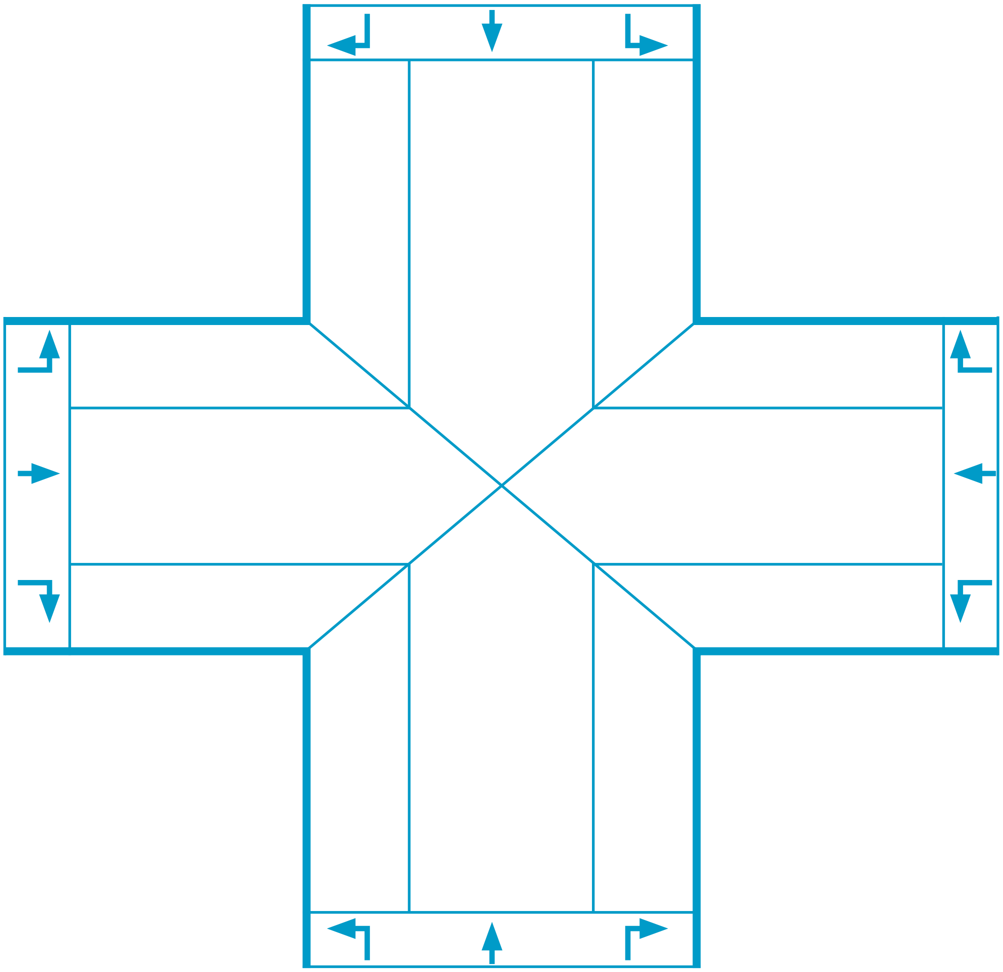


Time		Vehicle Queue		Vehicle Queue		Vehicle Queue

Typical Abbreviated Turning Movement Count Field Sheet

Location ______________________________ Date _______________

Time ________ to _______ Weather _______________ Observer _____________________________

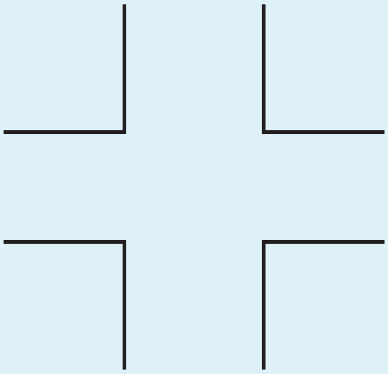


Turning Movement Vehicle Classification Count Field Sheet

Location ______________________________
Date ________________________________
Time _____________ to ______________
Observer ____________________________

Legend:

Group	Vehicle Type
1	Passenger cars (including Recreational Vehicles)
2	Buses
3	Trucks
4	Bicycles



Time												

Intersection Turning Movement Count Summary

Intersection: ______________________

Date: ______________________

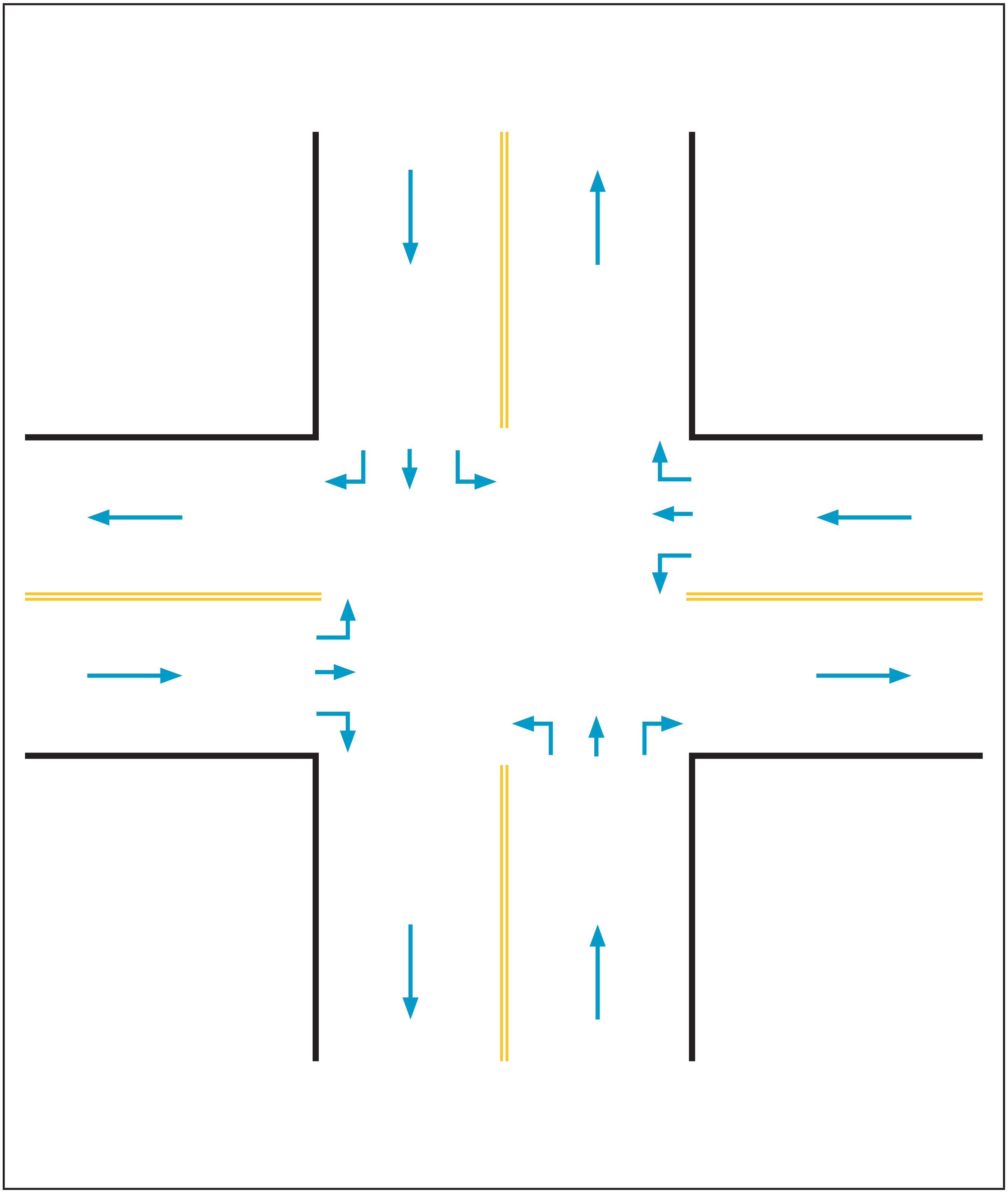
Weather: ______________________

Peak hour period = ______________________

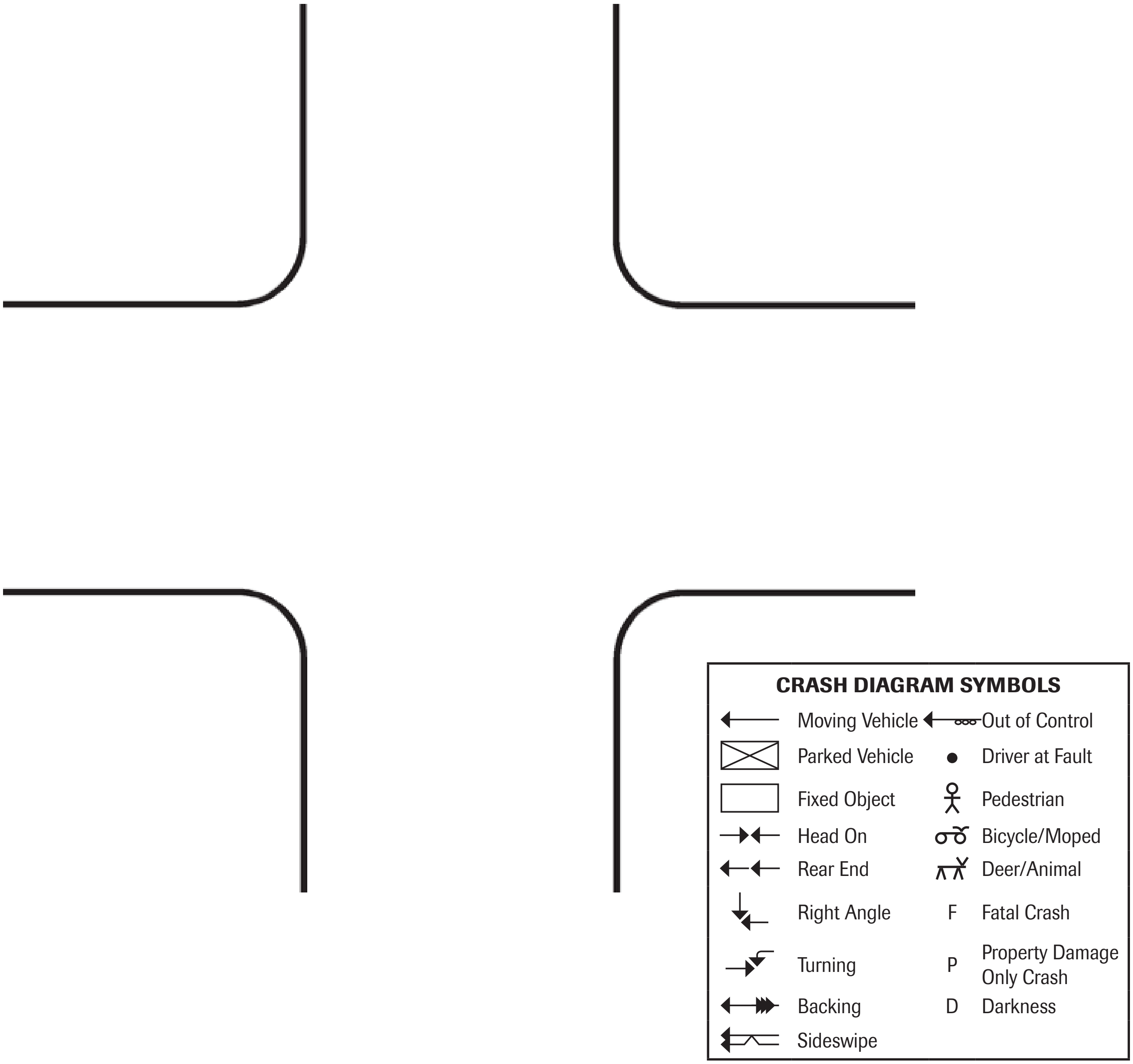
V, Peak hour volume (vph) = ______________________

Begin Time	Eastbound				Westbound				Northbound				Southbound				Total
	Left	Thru	Right	Peds	Left	Thru	Right	Peds	Left	Thru	Right	Peds	Left	Thru	Right	Peds	
Total																	

Peak Hour Turning Movement Diagram



Crash Diagram



Travel-Time and Delay Study Field Sheet

Location ____________________________ Weather __________________________ Peak / Off Peak

Date __________________ Time Period ________ to ________ Observer__________________________

Control Point	Major Cross Street	Run ________ Direction ________			Run ________ Direction ________			Run ________ Direction ________		
		Elapsed Time	Delay Time	Delay Cause	Elapsed Time	Delay Time	Delay Cause	Elapsed Time	Delay Time	Delay Cause

Delay Cause Symbols:
SS—Stop Sign
PV—Parking Vehicle
T—General
TS—Traffic Signal
RR—Railroad
PD—Pedestrian
IO—Insufficient Capacity
BS—Backup Signal
PL—Passenger Loading
RT—Right Turning Vehicle
MP—Police Control
OT—Other Cause
LT—Left Turning Vehicle

Travel-Time Work Sheet

Location ______________________ Weather ______________________ Peak / Off Peak

Date ______________ Start Time __________ Start Time __________

Control Point	Major Cross Street	Distance (ft)	Seg. #	Elapsed Time (Min:Sec)	Elapsed Time (Min:Dec)	Travel-time (Min.Dec)	Travel Speed (mph) = $\frac{\text{Distance (ft)}}{\text{Travel-time x 88}}$

Summary Sheet for Roadway Segments with Significant Delays

Roadway	Mileage	Terminal Points	Segment No a/	Time Period b/	Posted Speed (mph)	Overall Speed (mph)	Delay Cause Symbols c/	Overall Time (min)	Delay Time (min)
		to		Morning Peak					
				Off peak					
				Evening Peak					
		to		Morning Peak					
				Off peak					
				Evening Peak					
		to		Morning Peak					
				Off peak					
				Evening Peak					
		to		Morning Peak					
				Off peak					
				Evening Peak					
		to		Morning Peak					
				Off peak					
				Evening Peak					
		to		Morning Peak					
				Off peak					
				Evening Peak					
		to		Morning Peak					
				Off peak					
				Evening Peak					

a/ Numbers used to identify route segments

b/ Morning- and evening-peak speed and delay runs were made in the direction of the maximum traffic flow

c/ **Delay Cause Symbols:**

TS–Traffic Signal
SS–Stop Sign
PD–Pedestrian
BS–Backup at Signal
RR–Railroad Train
RT–Right Turning Vehicle
MP–Police Control
PL–Passenger Loading (car or bus)
LT–Left Turning Vehicle
PK–Parking Vehicle
OT–Other Cause
IO–Insufficient Capacity

d/ Minus sign indicates that travel time was greater for the off-peak run than for the peak-hour

Speed Study Field Data Sheet Using Measured Distances

Date__________ Weather ______________ Road Surface________________ Direction __________________

Location ______________________ Time Period _______ to _______ Posted Speed Limit ___________(mph)

Distance _____________ (ft) Observer _____________________________

Time (sec)	**Speed (mph)** $S = \frac{Distance}{1.47xT}$	**Vehicle Count**	**No. of Vehicles**	**% of Total**	**Cum. %**	**Notes**
Total						
10 MPH Pace	**To**	**85th Percentile Speed**				
		Average Speed				

Speed Study Field Data Sheet Using Speed Gun

Date__________ Weather ______________ Road Surface________________ Direction __________________

Location ______________________ Time Period _______ to _______ Posted Speed Limit ___________(mph)

Distance _____________ (ft) Observer _____________________________

<table>
<tr><th>Speed (mph)</th><th colspan="2">Vehicle Count</th><th>No. of Vehicles</th><th>% of Total</th><th>Cum. %</th></tr>
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<tr><td></td><td colspan="2"></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Total</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">10 MPH Pace</td><td rowspan="2">To</td><td>85th Percentile Speed</td><td></td><td></td><td></td></tr>
<tr><td>Average Speed</td><td></td><td></td><td></td></tr>
</table>

Boarding Count Field Sheet

Route ______________________ Block Number ______________________
Day ______________________ Date ______________________
Weather ______________________ Observer ______________________

Route Segment		Boarding Passengers					
From	To	Full Fare	Reduced Fare	Transfer	Full + Transfer	Reduce + Transfer	All Passes
Total							

Point Check Field Sheet

Route(s) ______________________________
Bus Stop Number ______________________________
Day ______________________________
Date ______________________________
Weather ______________________________
Observer ______________________________
Departing Load ☐
Arriving Load ☐

Route Number	Direction	Block Number	Vehicle Capacity	Arriving Time				Passengers
				Scheduled		Actual		

Ride Check Field Sheet

Route(s) ________________________ Bus Stop Number ________________________

Day ________________________ Date ________________________

Weather ________________________ Observer ________________________

Direction of Trip ________________________ Schedule Start Time ________________________

From	To	Passengers			Time Check	Remarks
		On	Off	Load		
Total						

Installation Parking Inventory Summary Sheet

Installation ____________________ Date ____________________
Location of Parking Inventory[1] ____________________

Total Parking Spaces ____________ **Reserved** ____________ **Open** ____________
On-Street (Curb) Spaces ____________ **Reserved** ____________ **Open** ____________
Off-Street (Lot) Spaces ____________ **Reserved** ____________ **Open** ____________

On-Street					**Off-Street**				
Location[2]	**Number of Spaces**				**Lot / Area**	**Number of Spaces**			
	Reserved	**Open**	**Parallel**	**Angle[3]**		**Reserved**	**Open**	**Angle[3]**	**Paved[4]**

1. Location, lot, or area by name keyed to a coded map on a site plan.
2. Extent of parking (name of street; i.e., John Street between A Street and B Street, north side.
3. Relates to stall or parking angle (i.e., 90 degrees; 60 degrees; 45 degrees).
4. Use check mark (√) if yes; (x) if no.

Parking Utilization Field Sheet

Date ____________________ Location ____

Weather __________________ Start Time __________ End Time __________

Observer _____________________________

	Time						
License Plate Number of Vehicles							

✓ = Repeated License Plate

Parking Inventory and Usage Table (by parking category)

TOTAL PARKING SPACES		% RESERVED													
	BY CATEGORY	RESERVED													
		GENERAL													
		% FILLED													
	BY USE	FILLED													
		EMPTY													
		TOTAL													
ON STREET	RESERVED	FILLED													
		EMPTY													
	GENERAL	FILLED													
		EMPTY													
OFF STREET	RESERVED	FILLED													
		EMPTY													
	GENERAL	FILLED													
		EMPTY													
		ZONE													TOTAL

*Data collected during the ___________

Parking Utilization Summary Sheet

Location ______________________________

Date ________________ Start Time ____________ End Time _____________

Parking Duration (HR)	Vehicles		Vehicle Hours Parked		Parking Duration (HR)	Vehicles		Vehicle Hours Parked	
	Number	Percent	Number	Percent		Number	Percent	Number	Percent
Continued Next Column					Totals				

Average Duration ______________________ Parking Spaces Available ____________________

Legal Time Limit _______________________ Space Hours Available _______________________

Percent Overtime _______________________ Efficiency _________________________________

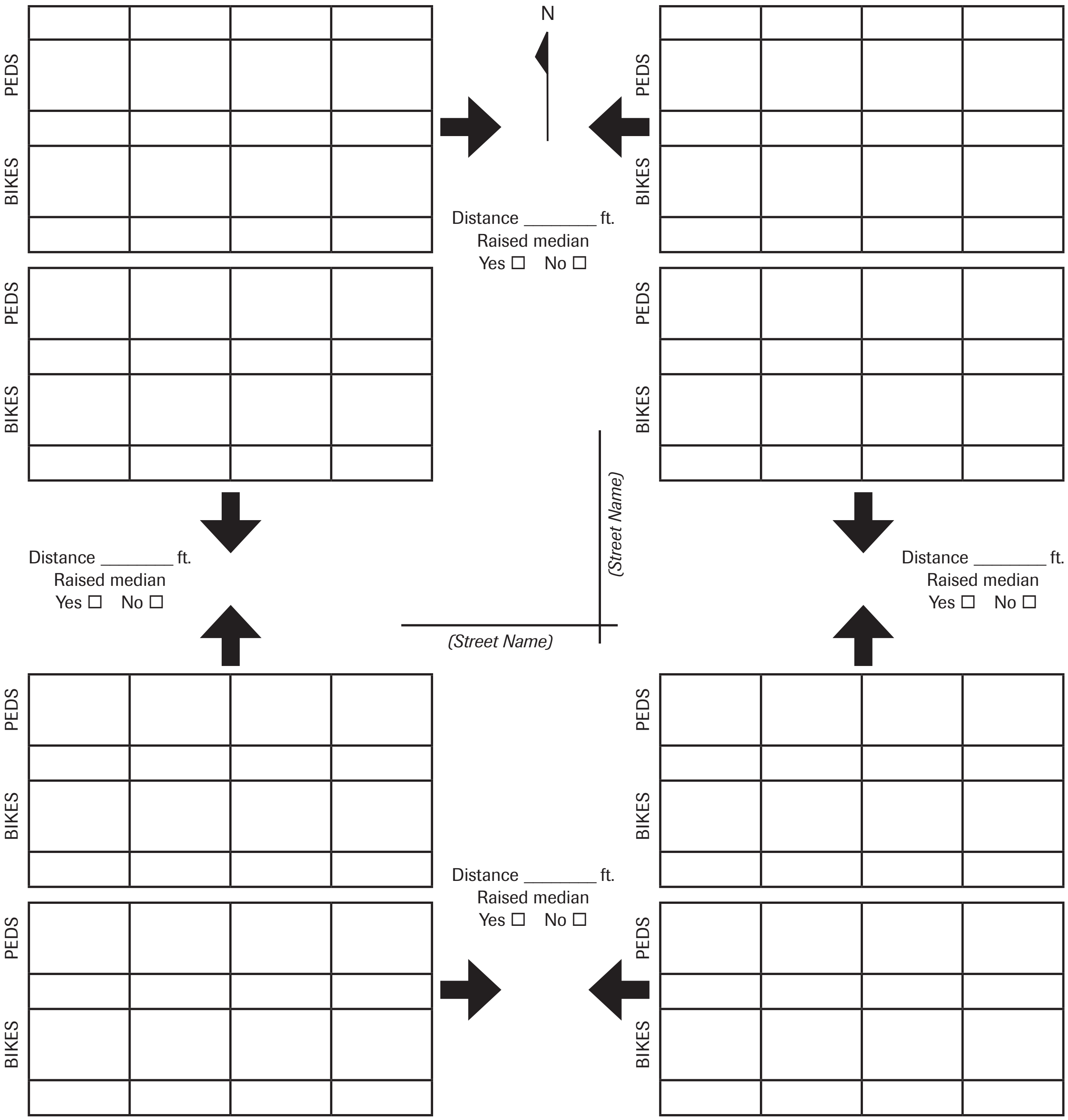
Pedestrian and Bicycle Count Field Count Sheet

Location ______________________________ Observer ______________________________

Installation ______________________________ Date Performed ______________________________

Type of Control ______________________________ Time Period ____________ to ____________

Remarks ____



Distance ________ ft.
Raised median
Yes ☐ No ☐

Distance ________ ft.
Raised median
Yes ☐ No ☐

Distance ________ ft.
Raised median
Yes ☐ No ☐

Distance ________ ft.
Raised median
Yes ☐ No ☐

Multi-Use Path Data Collection Sheet

Date ______
Location ______
Weather ______
Start Time ______
End Time ______
Observer ______

		Total								
Group		**Number in Group**								
Use Location		**Road**								
		Path								
Helmet		**No**								
		Yes								
Gender		**Female**								
		Male								
Age		**Child**								
		Adult								
Direction		**West**								
		East								
		South								
		North								
Mode	**Wheeled Device**	**Wheelchair**								
		Scooter								
		Roller Blades / Skates								
		Bicycle with Trailer								
		Bicycle								
	Pedestrian	**With Stroller**								
		With Pet								
		Jogging / Running								
		Walking Only								
Time										**Total**

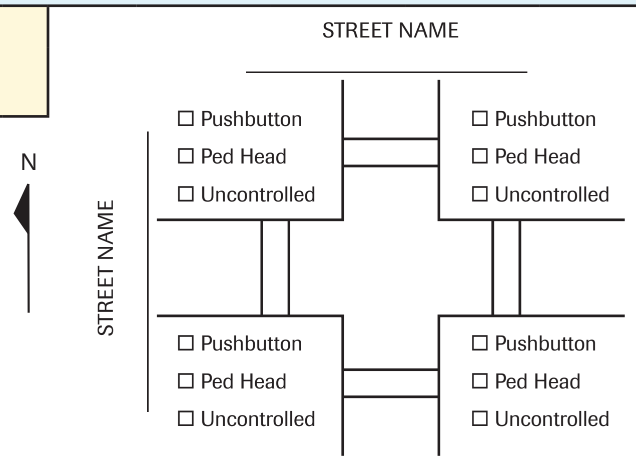
Summary of Pedestrian and Bicycle Movements

Location ____________________ Observer ____________________

Installation ____________________ Date Performed ____________________

Type of Control ____________________ Time Period __________ to __________

INTERSECTION DIAGRAM



☐ Pushbutton
☐ Ped Head
☐ Uncontrolled

☐ Pushbutton
☐ Ped Head
☐ Uncontrolled

☐ Pushbutton
☐ Ped Head
☐ Uncontrolled

☐ Pushbutton
☐ Ped Head
☐ Uncontrolled

Weather: ____________________

Roadway Width (ft)
N/S: __________ E/W: __________

Median Width (ft):
☐ > 4 feet ☐ < 4 feet ☐ None

Remarks:

PEDESTRIAN/BICYCLE MOVEMENTS

TIME	NORTH APPROACH		SOUTH APPROACH		EAST APPROACH		WEST APPROACH	
	PEDS	BIKES	PEDS	BIKES	PEDS	BIKES	PEDS	BIKES
APPROACH TOTALS								

INTERSECTION TOTALS	**PEDS**	**BIKES**

Warrants for Crosswalk Installation at Uncontrolled (No Traffic Control) Locations—Field Sheet

Field Sheet:
Warrants for Crosswalk Installation at Uncontrolled (No Traffic Control) Locations

Location ________________________________ Direction ___________

Date________________________________ Posted Speed ___________

Time Period____________________ Weather ______________ Observer ___________

STEP 1 (Safety Criteria)

Existing stopping sight distance	=	If existing stopping sight distance is less than the required stopping sight distance, do not install crosswalk.
Required stopping sight distance	=	
Is there an adequate sight distance triangle?	YES/NO	If NO, Remove obstacles within sight triangle.
Is the proposed location within an axillary lane?	YES/NO	If YES, do not install crosswalk.

If all three safety criteria are satisfied, proceed to Step 2

STEP 2 (Crossing Location from Traffic Control and Alternate Options Criteria)

Distance from nearest signal, stop or yield control on road that crosswalk is being evaluated (side street control does not apply)	=	If less than 300 ft from a controlled intersection DO NOT install crosswalk without a Traffic Engineering Study.
Is the current pedestrian crossing due to a correctable gap in the sidewalk system?	YES/NO	If YES, do not install crosswalk Correct sidewalk system and observe changes in pedestrian crossings.

If both criteria are satisfied, proceed to Step 3

STEP 3 (Pedestrian and Vehicular Volume Criteria)

Vehicular Volume (one of the two criteria should be met)

Traffic volumes (average daily traffic, two-way)	=	Minimum 1500 vehicles per day
OR		
Traffic volumes (hourly volume, two-way)	=	Minimum 150 vehicles in an hour (same hour that pedestrian volume criteria is met)

Pedestrian Volume (one of the two criteria should be met)

Pedestrian Hourly Volume (any hour)	=	Minimum of 20 pedestrian crossing
OR		
Elderly/disabled/children Hourly Volume (any hour)	=	Minimum of 15 elderly, disabled or children crossing
OR		
Pedestrian Volume (highest consecutive 4-hour period)	=	Minimum of 60 pedestrian crossing

If both vehicular and pedestrian volumes are not met, a crosswalk is recommended—see SDDCTEA's Pamphlet 55-17 for proper crosswalk enhancements

ECF Existing Demand Volume Calculation

Date ______________________ Installation ____

Gate No. _________

TIME INTERVAL	DEPARTURE VOLUME (PROCESSED VEHICLE COUNT)	TRAFFIC QUEUE Q (VEHICLES) (AT END OF COUNT INTERVAL)	DELTA Q ($Q15_{FINAL}$ - $Q15_{INITIAL}$)	ARRIVAL VOLUME (DEPARTURE VOLUME + DELTA Q)
TOTALS		*DEPARTURE VOLUME = ARRIVAL VOLUME IF THE LAST INTERVAL RECORDED HAS 0 QUEUE*		

Peak Hour = ____________________

$v_{15\ (Arrival)}$ = ____________ veh/15-min

Existing Demand Volume = $v_{15\ (Arrival)}$ x 4 = ____________ veh/15-min

Deployment Percent = ________ %

Adjustment (DA) = 100% / (100% - Deployment %) = ___________

Adjusted Existing Demand Volume = DA x Existing Demand Volume = veh/hour

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APPENDIX D

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BIBLIOGRAPHY

The following publications are considered applicable and provide a valuable source of information on subjects pertinent to this pamphlet:

DoD Literature

42 70. 1-M, Construction Criteria Manual

Multi-Service Regulations

DSAR 4500.19, Highways for National Defense, Dec 2003

AR 55-80/0PNAVINST 11210. 1/AFR 75-88/MCO 11210. 2A/

Army Regulations

AR 210-4, Personnel Parking Facilities Program and DA Ridership Program, Jan 2013

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TM 5-803-1, Installation Master Planning, (UFC 2-100-01 May 2012)

TM 5-803 -10, Family Housing (UFC 4-711-01 Jul 2006)

TM 5-803-14, Site Planning-General, Oct 1994

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AFM 86-4, Standard Installations Facility Requirements

AFM 86-6, Air Base Master Planning

Field Manuals

FM 19-25, Military Police Traffic Control

FM 19-26, Traffic Accident Investigation

Other publications

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Better Military Traffic Engineering, Military Surface Deployment and Distribution Command, Transportation Engineering Agency, Pamphlet 55-17, (2011)

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Transportation and Land Development, 2nd Edition, Institute of Transportation Engineers, (2002)

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Manual on Uniform Traffic Control Devices, U.S. Department of Transportation, Federal Highway Administration, (2009)

Highway Safety Manual, Volumes 1 -3, American Association of State Highway and Transportation Officials, (2010)

A Policy on Geometric Design of Highway and Streets, 6th Edition, American Association of State Highway and Transportation Officials, (2011)

The Dimensions of Parking, 5th Edition, Urban Land Institute, (2010)

Parking Generation, 3rd Edition, Institute of Transportation Engineers (2004)

Parking Manual, Weant & Levinson

Resource Organizations

American Association of State Highway and Transportation Officials (AASHTO)
341 National Press Building
Washington, DC 20004

American Automobile Association (AAA)
811 Gatehouse Road
Falls Church, VA 22042

US Department of Transportation Federal Highway Administration
c I o FHWA Office of Traffic Operations
400 - 7th Street, SW Washington, DC 20590

Highway Research Board (HRB)
210 1 Constitution Avenue, NW
Washington, DC 20003

Highway Users Federation for Safety and Mobility (HUFSAM)
200 Ring Building
Washington, DC 20036

Illuminating Engineering Society
345 East 47th Street
New York, NY 10017

Institute of Traffic Engineers (ITE)
1815 N Fort Myer Drive, Suite 905 Arlington, VA 22209

Insurance Institute for Highway Safety (IIHS)
2600 Virginia Avenue, NW
Washington, DC 20037

Public Administration Service American
Public Works Association 1313 East 60th Street
Chicago, IL 60637

National Safety Council (NSC)
425 North Michigan Avenue Chicago, IL 60611

Superintendent of Documents US Government Printing Office
Washington, DC 20402

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MILITARY SURFACE DEPLOYMENT AND DISTRIBUTION COMMAND

TEA

TRANSPORTATION ENGINEERING AGENCY