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Traffic Monitoring:
A Guidebook

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16. Abstract

Traffic Monitoring: A Guidebook discusses different approaches to traffic monitoring and helping decisions to be made are based on the quality of the traffic data being collected and how well that traffic data reflects the actual events that are occurring. This guidebook should aid the user in developing a basic understanding of traffic data collection principles and procedures. This guidebook will provide an overview of traffic monitoring through simple descriptions which explain the various basic concepts related to a successful traffic monitoring program. Furthermore, this document investigates some of the challenges associated with a traffic monitoring program including variability in traffic, adjustment factors, and strategies for assisting with under-funded programs. This guidebook does not attempt to cover every aspect and detail of traffic monitoring but provides a starting point that leads the user to a successful traffic monitoring program.

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Technology Deployment Report

Report Number FHWA-WFL/TD-10-002

Traffic Monitoring:

A Guidebook

Technology Deployment Program
Western Federal Lands Highway Division
Federal Highway Administration
610 East 5th Street
Vancouver, WA 98661

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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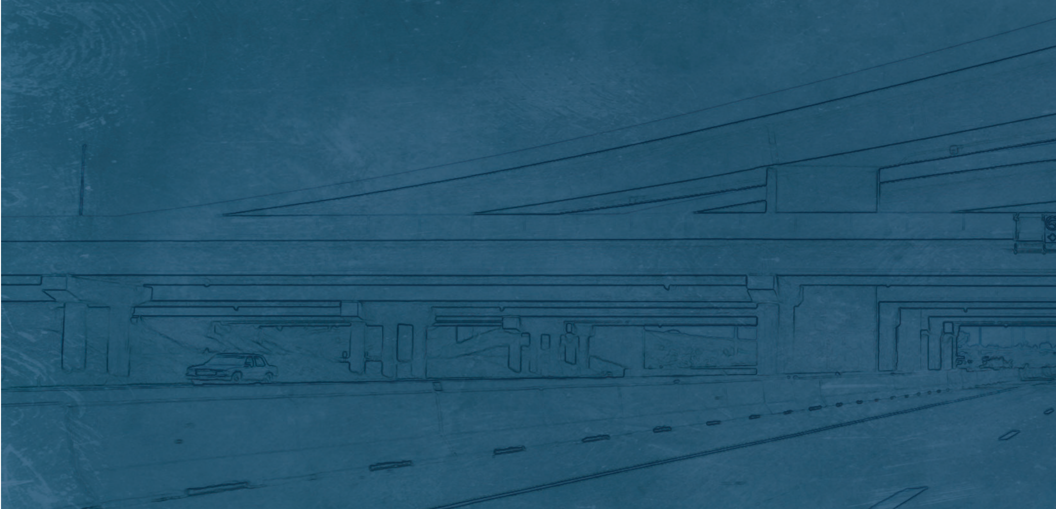


INTRODUCTION

The collection of traffic data plays a vital role in the decision making process of the agency responsible for utilizing this information. The decisions to be made are based on the quality of the traffic data being collected and how well that traffic data reflects the actual events that are occurring. This guidebook should aid the user in developing a basic understanding of traffic data collection principles and procedures and should assist in the development of a successful traffic monitoring program.

This guidebook will provide an overview of traffic monitoring through simple descriptions which explain the various basic concepts related to a successful traffic monitoring program. The intent of this guidebook is to consolidate and simplify technical and highly detailed traffic monitoring information into a document that can be used as a first step or introduction toward understanding traffic monitoring and the traffic data collection process. Examples of the various traffic monitoring types are described and summarized, along with a description of traffic monitoring equipment capabilities and limitations. Furthermore, this document investigates some of the challenges associated with a traffic monitoring program including variability in traffic, adjustment factors, and strategies for assisting with under-funded programs.

A successful traffic monitoring program begins with a plan that includes a set of goals as outlined by an agency. To properly attain these goals, quality control and assurance related to personnel, equipment used, and data collected must be considered. Only then can decisions be decided upon that determine an appropriate course of action.

This guidebook does not attempt to cover every aspect and detail of traffic monitoring. Instead, this document provides a starting point that leads the user to the locations of relevant and more detailed information to assist in the establishment of a successful traffic monitoring program.

TRAFFIC MONITORING BASICS

Who Needs Traffic Monitoring?

Traffic monitoring is used by various federal, state, and local governmental agencies, as well as private businesses which require information pertaining to travel patterns in their respective regions. Federal agencies, such as the Federal Highway Administration (FHWA) for example, require states to collect data used to estimate total vehicle miles of travel (VMT) in order to determine the apportionment of Federal-Aid funds. States and local government agencies will typically collect additional data that is used to determine pavement design, planning of future roadways, air quality, and maintenance needs.

What Is Traffic Monitoring?

Traffic monitoring is the collection of information to describe the use and performance of the roadway system based on the following:

> Traffic volumes – number of vehicles;
> Vehicle classification (VC) – type of vehicle (e.g., car, motorcycle, truck, etc.);
> Vehicle occupancy – number of riders in a vehicle;
> Truck weight volumes – number of heavy vehicles by weight classification;
> Pedestrian volumes – number of people walking; and
> Bicycle volumes – number of bicycle riders.

Traffic Monitoring carried out to collect data on the number of vehicles and/or pedestrians that pass a point on a roadway facility during a specified time period. This same collected data may also be put into categories, for example:

> Vehicle occupancy rates (number of passengers divided by number of vehicles);
> Directional movement of vehicles (into or out of park facility); and
> Pedestrian age.

Where Is Traffic Monitoring Needed?

Traffic monitoring is needed in various settings and locations depending on the use for the information that is collected. For example, traffic monitoring can be performed on the following:

Highways/Freeways

To determine the planning of highway activities;
To measure the current traffic demand; and
To evaluate existing traffic flow.

Arterial/Local Roads

To determine intersection improvements;
To change a speed limit on a particular road; and
To develop parking regulations.

Parking Areas

To determine the need for additional access locations;
To determine the location of pedestrian crosswalks, Parks and Recreational Areas;
To determine the variability in usage of park roads;
To assist in developing schedules due to change in facility usage; and
To optimize traffic routing.

When Is Traffic Monitoring Performed?

Traffic monitoring is measured at various increments of time depending on the intended use of the collected information. The choice of time periods can vary from as little as 5 minutes to as much as a year and are derived from the following:

Time-of-Day

Minute intervals – 5, 15, and 30 minute intervals are common;
Peak hour volume (PHV) – highest traffic volume in a consecutive 60 minutes;
Peak period – highest traffic volume in a consecutive 180 minutes;
Average daily traffic (ADT) – average of 24 hour counts collected over a number of days greater than one but less than a year;
Average annual daily traffic (AADT) – average of 24 hour counts collected every day in the year; and
Off-peak hours – traffic volumes not within the peak period hours of a day.

Day-of-week

Weekday (Monday through Friday); and
Weekend (Saturday and Sunday).

Seasonal

Winter, spring, summer, fall.
Holidays
July 4, Labor Day, Memorial Day, etc.
Spring break, Thanksgiving break, etc.

Note: This information may be collected over the entire period of time or a "sample" that represents the specific time period. "Sampling" requires specific guidelines that should be followed to ensure accurate collection of traffic information.

Why Is Traffic Monitoring Performed?

Traffic monitoring is performed in order to provide the factual information needed to make proper assessments and appropriate decisions related to travel patterns. Traffic monitoring assists in the following types of decisions and examples of applications:

Planning Decisions

To determine if a traffic signal is needed at an intersection;
To determine traffic control devices needed, such as speed limit signs; and
To determine the functional classification of a roadway to reflect principal use.

Design Decisions

To determine the number of lanes needed on a roadway;
To determine the load weight of a bridge to be built; and
To determine where improvements are needed.

Construction Decisions

To determine lane closures to minimize travel impacts; and
To determine routing alternatives around closed roadways.

Operational Decisions

To determine the signal phasing at an intersection;
To determine maintenance schedules for pavement patching and repair; and
To evaluate air quality conditions.

How Is Traffic Monitoring Performed?

Traffic monitoring is performed using one of the following available techniques based upon the length of the sampling period. The available techniques include manual counting and mechanical or automated counting which utilizes specialized equipment to collect the traffic information.

Manual Counting

Trained observer at each location

Short sampling period (less than 10 hours of data at any location)

Lower cost to perform

Less effort to implement

Equipment needs

Tally sheets

Mechanical or electronic count boards

Watch or stopwatch

Automated Counting

Automatic data collection equipment at each location

Longer sampling period (24 hours a day)

Higher cost to perform

More effort to implement due to equipment setup and retrieval

Equipment needs

Portable counters (24 hours a day, up to several weeks)

Sensor detectors include pneumatic tubes, piezoelectric strips, tape switches, and temporary induction loop detectors.

Permanent counters (24 hours a day, 365 days a year)

Sensor detectors include induction loop detectors, bending plates, radar, microwave, and video imaging.

TRAFFIC MONITORING 101

What Does Traffic Monitoring Do for Me?

Traffic monitoring can provide travel related information to anyone needing to make informed decisions based on travel pattern information. The information obtained from the collection of traffic data can assist in finding solutions to transportation related problems once the extent and magnitude of that problem has been identified. Traffic monitoring can also be used to determine improvements to various transportation facilities based on the collection of accurate information in order to present a clear and objective description of how a facility operates.

What Resources Are Available?

There are multiple resources available to assist in the development of a useful and successful traffic monitoring program. Most of these resources were developed by engineering and transportation professionals to assist in the design, construction, and operation of the highway system. These same strategies can be applied to most instances where traffic related information is being collected. Several of the most informative resources pertaining to traffic monitoring guidance include the following web sites and/or publications:

Federal Highway Administration

Travel Monitoring. Policy information web page.
http://www.fhwa.dot.gov/policy/ohpi/travel/index.cfm

Traffic Monitoring Guide. FHWA-PL-01-021.
http://www.fhwa.dot.gov/ohim/tmguide/index.htm

Traffic Detector Handbook: Third Edition. FHWA-HRT-06-108.
http://www.tfhrc.gov/its/pubs/06108/index.htm

Highway Performance Monitoring System Field Manual for the Continuing Analytical and Statistical Database.
http://www.fhwa.dot.gov/ohim/hpmsmanl/hpms.cfm

Institute of Transportation Engineers

Manual of Transportation Engineering, 1994.
Traffic Engineering Handbook, 4th Edition, 1992

What Are the Types of Traffic Monitoring?

There are several types of traffic monitoring alternatives that can be carried out depending on the anticipated use of the data to be collected. These types of alternatives include vehicle volume counts which range from short term counts to continuous counts, vehicle classification and occupancy counts, truck weight counts, pedestrian counts, bicycle counts, and others that may be determined for a specific need. These different counts will be discussed in the following sections.

Vehicle Volume Counts

Vehicle volume counts can provide a vast amount of information which can assist in the decision making processes related to a highway or a system of highways. The data obtained provides an estimate of the number of vehicles traveling a section of highway over a specified period of time. Typically vehicle volume counts will be in the range from short term counts to long term continuous counts.

Short Term Counts at a Large Number of Locations

Short term counts are vehicle volume counts that are performed for intervals less than an hour (e.g., 5, 15, 30 minutes). It is not feasible to collect continuous data on all roadways due to the cost involved. Short term volume counts allow for a larger number of locations to be surveyed given that the counting equipment is not monopolized by just a few locations. Short term volume counts are typically used to determine peak volume characteristics or to estimate annual traffic characteristics. Short term counts are typically performed manually by observation or with portable automatic counting equipment.

Continuous Counts at Select Locations

Continuous counts are vehicle volume counts that are performed for longer intervals (e.g., daily, weekly, and seasonally). These counts are carried out on a continuous basis utilizing automatic counting equipment and are sometimes referred to as permanent count stations. Continuous volume counts allow for a fewer number of locations to be surveyed since the counting equipment is generally permanent and is continuously operating at a limited number of locations. Continuous volume counts are typically used to determine fluctuations in weekly/seasonal traffic or to determine growth rates of traffic.

PURPOSE AND USE

TYPES OF VEHICLE VOLUME COUNTS			
SHORT TERM COUNTS	**PEAK-HOUR COUNTS**	**24-HOUR COUNTS**	**CONTINUOUS COUNTS**
Analyze maximum rates of flow and variation within peak hours	Determine deficiencies in capacity	Measure present demand for service	Determine fluctuations of daily/weekly/ seasonal flow
Determine capacity limitations in urban areas	Aid in geometric design	Evaluate present traffic conditions (e.g., signals)	Determine annual growth rate of traffic
Determine characteristics of peak volumes	Develop traffic operation programs	Aid in highway planning	Determine varying demand for facility
	Determine signal phasing at intersections	Validate travel models	Determine freeway operations

Source
North Central Texas Council of Governments

The chart above summarizes the range of vehicle volume counts available and the respective purpose and use of each.

Vehicle Classification/Occupancy Counts

Vehicle classification counts are counts that determine the type of vehicle at a count location and are useful in determining seasonal variations. These counts can be performed manually through classifying the vehicle type by visual observation or by automatic counting equipment that measures the length of a vehicle or that measures the number of axles on a vehicle, depending

NPS CLASS	FHWA CLASS
Motorcycles	Class 1: Motorcycles
Passenger Cars	Class 2: Passenger Cars
Recreational Vehicles	Not Applicable
Vehicles/RV pulling Trailer	Not Applicable
Transit/Shuttle Bus	Class 4: Buses
Tour Buses	Class 4: Buses
Light-Duty Trucks	Class 3: Other two-axle, four-tire single unit vehicles Class 5: Three-axle, six-tire, single-unit trucks
Heavy-Duty Trucks	Class 6: Three-axle single-unit trucks Class 7: Four or more axle single-unit trucks Class 8: Four or fewer axle single-trailer trucks Class 9: Five-axle single-trailer trucks Class 10: Six or more axle single-trailer trucks Class 11: Five or fewer axle multi-trailer trucks Class 12: Six-axle multi-trailer trucks Class 13: Seven or more axle multi-trailer trucks

on the type of sensor used. Vehicles are typically classified into 13 vehicle classification categories as defined by Federal Highway Administration (FHWA). However, vehicle classification categories can be changed to accommodate other reporting needs, such as in parks and recreational areas where vehicle types may significantly differ from customary roadway usage.

Vehicle occupancy counts

Vehicle occupancy counts are counts that determine the number of people in each vehicle at a count location and help in determining travel modes and person movement within a region. These counts are usually performed manually by personnel monitoring from the roadside. It is customary to concurrently determine the vehicle classification and the number of people in each respective vehicle while conducting vehicle occupancy counts.

Truck Weight Counts

Truck weight counts are counts that determine vehicle weight loads and are useful in determining where heavy loaded vehicles are traveling. These counts are performed by automated equipment known as weigh-in-motion (WIM) detectors. Sites chosen for this type of detector generally reveal directional rutting in pavements; increased truck traffic and/or high proportion of trucks; proximity to special truck traffic generators; and seasonal influences of heavy loads (11).

Pedestrian Counts

Volume counts of pedestrians are made at locations such as sidewalks, cross walks, and transit stations. The counts are performed manually and are usually taken at these locations when the evaluation of existing or proposed pedestrian facilities is being considered. Pedestrian activity can be a major component in the safety, design, and operation of sidewalks, bridges, and underpasses.

Bicycle Counts

Volume counts of bicycles are made at locations with high bicycle activity such as parks and recreational areas. The counts are performed manually and are usually taken along trail sections, bicycle lanes, or at bicycle staging locations. These counts assist in determining the impacts bicycles have when interacting with other modes of travel, such as at intersections, and in planning for future amenities related to bicycling.

TRAFFIC MONITORING EQUIPMENT CAPABILITIES & LIMITATIONS

Manual Recording – Tally, Mechanical, Electronic

The basic form of a manual count involves personnel recording information on a field sheet using a tally mark. It can include data related to a vehicle passing a particular point, making a particular turning movement at an intersection, the classification type of a vehicle, or the number of pedestrians utilizing a cross-walk. Tally marks should only be used for very low volume locations, but they are a relatively inexpensive form of counting.

Mechanical board counters may also be used for manual counts. This device is referred to as a multi-denominator tally and mechanically records a count from the push of a button. This device allows a person to count a higher volume location and typically can accommodate up to eight different categories. At predetermined time intervals, the cumulative information is manually recorded by personnel on a field sheet. The information can then be put into a spreadsheet for analysis purposes. Collecting more than eight categories will involve the use of more personnel to obtain the data.

Electronic board counters are similar in operation to mechanical board counters. However, the electronic board counter has internal memory and will automatically store the collected information at desired time intervals. Upon completion of a count, the data can be downloaded to a computer for analysis purposes. The electronic Board counter is supplied with a manufacturer program that allows for easy transfer and output of the field data.

Accumulative Count Recorder

Accumulative count recorders (ACRs) are automatic counters that can be set up at a location and count continuously for short periods of time (short term counts) up to several weeks. These devices utilize temporary sensors such as piezoelectric strips, tape switches, temporary induction loop detectors, or pneumatic tubes placed in the roadway. These sensors can easily be positioned for counting and then retrieved for future use at other locations. The most commonly used sensor for an ACR is the pneumatic tube or “road tube.” The ACR is easy and quick to install at locations and is relatively inexpensive to operate. However, the road tube sensors will degrade over time, are not as accurate for speeds less than 10 mile per hour (mph), and are less accurate when recording on multiple lanes at one time.

Automated Traffic Recorder

Automated traffic recorders (ATRs) are automatic vehicle counters that operate for longer periods of time and are set up for more permanent function (continuous counts). These devices utilize permanent sensors, such as induction loop detectors, which are installed directly into each lane of pavement at a count location. An inductive-loop detector senses the presence of a metal object by inducing currents in the object. The ATR sensors tend not to degrade as rapidly as the ACR temporary sensors. The automated traffic recorder produces accurate data and works well where vehicle volumes are high. The data is often used to analyze travel trends at a particular location, as well as to adjust short term count data into estimates of annual, design, or average conditions (2). Power and a communication link must be available at each location to allow for the continuous operation of the ATR.

Automated Vehicle Classification Recorder

Truck and recreational vehicle traffic often generates different seasonal or day-of-week trends than do total volumes, which are likely dictated by automobile traffic trends. Automated vehicle classification (AVC) recorders can record the type of vehicle based on a defined set of length or axle parameters. These devices utilize permanent sensors (such as a set of induction loop detectors in each lane) that monitor each lane of travel at a count location. Classification is typically separated by lane, direction, and sorted into the standardized FHWA 13-category classification scheme; however, most devices allow for sorting up to 14 user-defined classifications. Classification data can be easily converted to vehicle volume counts when needed. While these devices perform best at locations with speeds around 45 mph, they do not function well for locations where traffic is moving too fast or too slow due to miscounts. Power and a communication link must be available at each location to allow for the continuous operation of the AVC recorder.

Weigh-in-Motion Recorder

Weigh-in-motion (WIM) recorders are devices that can determine the weight of a moving vehicle, in addition to recording vehicle classification and volume. These devices utilize permanent sensors (such as bending plates) or temporary sensors (such as piezoelectric strips) that monitor each lane of travel at a count location. WIM recorders are highly accurate, typically within 10 percent of gross vehicle weight (GVW). While these devices provide the most accurate travel information, they also require greater investment for equipment, installation, and site preparation, in addition to greater maintenance needs. Power and a communication link must be available at each location to allow for the continuous operation of the WIM recorder.

Other Devices

There exist other types of sensors for automated counting equipment not listed in the previous sections. These other types of sensors are generally more expensive than the ones listed above and typically require power and a communication link at each location. Video imaging and active infrared detectors utilize optical data capturing to perform vehicle classification or vehicle turning movements at intersections. Unfortunately, these devices perform badly in poor weather conditions and in high density locations due to occlusion (high profile vehicles obstructing the detector’s line-of-site of other vehicles). Acoustic detectors are devices which utilize sound waves to count vehicles, but perform poorly in echo-filled environments. Remote traffic microwave sensors (RTMSs) are miniature radar devices which utilize low-power microwave signals to detect vehicle classifications. The microwave sensor is not affected by poor weather and does not have issues related to occlusion. Finally, cellular and satellite communications equipment is being utilized to provide vehicle tracking information and could be useful in remote areas, but this technology is still being developed.

SUCCESSFUL TRAFFIC MONITORING

A successful traffic monitoring program includes a plan which outlines and provides details of the objectives that determine a successful outcome. A good plan will help to keep costs low and improve the quality of the collected traffic information that supports the decision-making process. For example, if the traffic volume is expected to be low on a roadway, then a manual count performed periodically may be a simple solution as opposed to the cost, installation, and maintenance associated with an automatic counter. A good study plan should include an inventory of existing data, a field site visit to potential count locations, and a defined set of goals. Detailing this information will assist in determining personnel and equipment needs and help define data analysis and data storage requirements in a cost-effective manner.

Existing Inventory

An agency can avoid unnecessary expenditure of money and time through a greater understanding of the traffic data that is currently available. Improved communication and coordination within an agency and with other agencies can help minimize the amount of data that needs to be collected. Other agencies, especially state governmental agencies, collect large amounts of traffic data throughout their respective jurisdiction. Data collected on nearby state highways could be used to assist in determining patterns that may exist near potential traffic monitoring sites or to develop adjustment factors that could be used to approximate traffic conditions near potential sites.

Field Site Visit

A potential site for traffic monitoring requires an on-site field visit to verify existing conditions and determine any available infrastructure. The field site visit is used to determine if a potential site is suitable for collecting traffic information, the type of data collection to be performed (manual or automatic), and all related characteristics needed to acquire good traffic data. For instance, an unobstructed view of the roadway is an important characteristic for conducting successful manual counts. For automatic counts, it is important to determine the traffic mix (including the number and type of trucks), geometrics of the roadway (number of lanes, lane widths, curvature of roadway, etc.), the pavement condition (is rutting evident) which could affect the operation of a road tube, and the power and data communication capabilities.

Determination of Goals

A traffic monitoring program requires a set of goals that will help accomplish the desired outcome. For one agency, that goal may be to determine the total traffic on multiple roads year to year, while another agency may be more interested in determining the type of vehicles that are using one particular section of roadway. Each agency needs to determine the type and amount of data to collect that will best support the decisions to be made to ensure a successful outcome. Upon determining the type and amount of data to be collected, an agency can then decide the best methodology to collect the data and the types of equipment that will be needed to accomplish this task, which should include the consideration of personnel, cost, and budget issues.

Quality Control/Quality Assurance

The objective of a traffic monitoring program is to provide good quality traffic information to support the future decisions of an agency. The information obtained from the traffic monitoring program is only as good as the quality assurance of the personnel, the equipment, and the traffic count data. The documenting of methodology and procedures of the various components of the traffic monitoring program can provide an avenue for facilitating training, reviewing performance, and identifying opportunities that can lead to corrective action when necessary.

Personnel

Traffic monitoring personnel represent a critical component of a successful program. Personnel will require training to effectively perform their duties. The training should include the following:

> Proper procedures for conducting traffic counts;
> Procedures for placing, retrieving, and maintaining automatic counters;
> Proper procedures for monitoring performance standards of equipment;
> Proper procedures for data analysis, sample estimations, and factoring; and
> Proper procedures related to safety considerations.

Properly educating personnel will lead to a more motivated and dedicated work team generating consistent quality in data and greater safety awareness of staff resources. Reference materials are available to assist in this training and some have been listed in the back of this document.

Equipment

Traffic monitoring equipment is another critical component of a successful program. All equipment must be properly functioning and personnel must have a good working knowledge of the equipment to ensure valid data. Performance standards should be established to address factors such as equipment tolerances and failure rates and equipment down time durations to assist in determining availability and scheduling of equipment. Testing schedules should be established to ensure all equipment is operating properly. This can be performed by conducting a manual count simultaneously during an automatic count and comparing the results.

A general rule-of-thumb to follow is that the equipment is working properly if a comparison manual count is:

> Within ± 10 percent of a portable (road tube) automatic count;
>
> Within ± 2 percent of a permanent (inductive loop sensor) automatic count;
>
> Within ± 10 percent of a vehicle classifier automatic count; and
>
> Within ± 15 percent of a weigh-in-motion GVW automatic count.

Quality assurance can be achieved through the establishment of procedures which document all activities related to a traffic monitoring program.

Equipment maintenance records provide the basis for evaluating equipment performance, anticipating problems, developing replacement cycles, evaluating new equipment, and documenting budget issues. (AASHTO Guidelines, 1992)

Count Data

Count data that is collected from the traffic monitoring program must be checked for validity to ensure quality control has been achieved. Corrupted data should not be included in the database. Corrupted data can be caused by an equipment malfunction due to a power failure, a sensor malfunction, or a communication error. These malfunctions will typically show up in the data as a series of "0" recordings or as a series of extremely high values for vehicle volume locations. In weigh-in-motion counts, invalid data recordings may be due to vehicles not passing over the sensor properly. This data should not be included in any summarization reports, but should be retained for training and audit purposes.

Data collected during holidays, sporting events, parades, or traffic incidents are referred to as "atypical" (10). This type of data should be analyzed with scrutiny and may need to be excluded from any summarization reports, unless the specific purpose was to monitor this type of event. Extended periods of inclement weather are also considered "atypical" and are usually excluded from analysis, especially for short term counts.

Data Analysis, Summarization, & Reporting

Data analysis and summarization of the data collected from traffic counts is another critical part of a traffic monitoring program. General principles have been established to ensure that traffic data is analyzed and summarized in a consistent manner from one agency to the next. Data analysis involves the examination of the traffic data to determine any variability in traffic that can be used to identify travel patterns or trends over time. Understanding and identifying the variability in traffic will assist in determining, applying, and evaluating adjustment factors for traffic counts.

Variability in Traffic

The variability in traffic is inherently derived from a large transportation system that enables a diverse multitude of users to travel at various times and days. That is, traffic can vary from day-to-day, week-to-week, and season-to-season. Additionally, traffic can vary by location, such as comparing traffic data from different road types or comparing traffic data from different regions within a state.

This variability in traffic must be taken into account when trying to compare traffic counts from one location to another because different types of counts and equipment may have been used at different locations. For instance, one site may use a permanent counter which counts traffic everyday of the year. This site could be used to examine the seasonal variability and trends that may exist at that location. This information could then be used to develop seasonal adjustment factors that can be applied to other locations within the area that use short-duration counts.

In another example, a count location may use a portable counter that collects classification data over several weeks. This site could be used to examine the variability in vehicle type that may exist at that location. This information could then be used to develop axle correction factors that can be applied at other count locations within the area to estimate traffic volumes more accurately.

Factoring Counts

Adjustment factors are needed to modify traffic counts in order to account for the variability in traffic. Adjustment factors can be calculated for various uses including adjusting seasonal variations in traffic, adjusting axle counts to vehicle volumes, and providing annual growth estimates.

It should be noted that care must be taken when using adjustment factors to ensure the proper application of the factors in order to reach an accurate conversion. Most State highway agencies have established traffic monitoring programs and have the experience to assist in correctly applying adjustment factors.

Initially, “factor groups” are developed within a traffic monitoring program to determine how continuous and short-duration counts can be compared to other similar locations. One method is done by grouping roadway types by their respective functional classification. This allows for the adjustment factors from a “sample” roadway that behaves or operates in a particular manner to be applied to similar roadway types in the same region. Another method is referred to as a cluster analysis. This method determines which count stations are most similar based on a statistical algorithm. It may be that neither of these methods will work as a “factor group” for a particular area. In that case, the agency will have to determine an appropriate “factor group” plan.

Short-duration traffic counts are conducted in order to help reduce costs of traffic monitoring programs by extending the use of staff and equipment to multiple locations for shorter periods of time. Consequently, adjustment factors are needed to adjust short-duration traffic counts, which may include only a

few days of data, into an annual estimate of daily traffic. This is typically performed by utilizing appropriate adjustment factors derived from nearby continuous count locations, such as ATR locations, which have a similar “factor group.”
The most common approach to converting a short-duration count to an annual average daily traffic (AADT) estimate utilizes the following equation:

$$AADT_{hi} = VOL_{hi} * M_h * D_h * A_i * G_h$$

where

AADThi = the annual average daily travel at location i of factor group h
VOlhi = the 24 hour axle volume at location i of factor group h
Mh = the applicable seasonal (monthly) factor for factor group h
Dh = the applicable day of-week factor for factor group h (if needed)
Ai = the applicable axle correction factor for location i (if needed)
Gh = the applicable growth factor for factor group h (if needed)

Source
Traffic Monitoring Guide, FHWA, May 2001.

Conversely, the same equation can be used to compute a particular adjustment factor (i.e., seasonal, day-of-week, axle-correction or growth) from a continuous count location. To calculate this, the observed AADT from an ATR is divided by the various factors (if applicable) to obtain the desired adjustment factor to be used for that particular “factor group.”

Factoring Methods within Parks

Park and recreational roadways typically have different travel variability and travel patterns than rural or urban roadways. Therefore, it may not be appropriate to arbitrarily apply the same methodology as used on highways, to collect and adjust short-duration counts on park and recreational roadways.

Extending Count Period

Many park facilities only collect 48-hour short-duration counts, typically due to budget constraints and/or personnel limitations. While this methodology may apply well for urban commuter routes where travel patterns are more predictable, it does not effectively capture the variability of recreational traffic in and around parks.

It is suggested that to accurately capture day-of-week variations in recreational traffic, the traffic monitoring program should conduct short-duration counts for a period longer than 48 continuous hours (preferably one-week) made in different months.

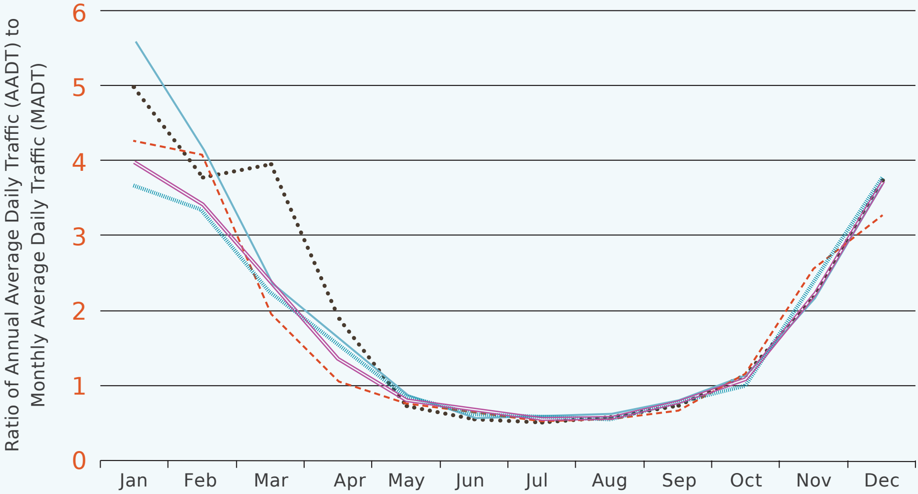
While this practice may include a longer and more costly short term budget, research has shown that within a given park "the traffic patterns observed during each day-of-week and month-of-year combination were not statistically different from one year to the next" (16). This implies that short-duration counts could be adjusted using historical AADT data, if that data is more statistically valid, and therefore, fewer counts might be conducted from year to year.

Interagency Cooperation

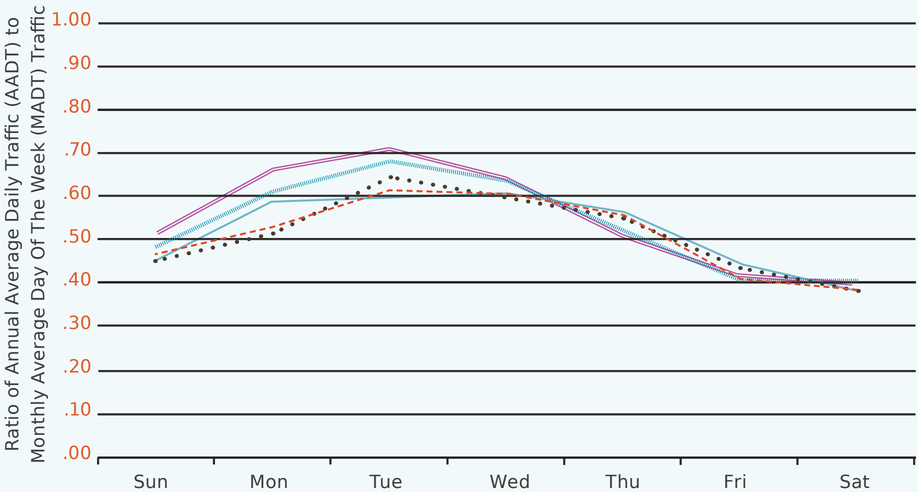
In some instances there may not be a continuous counter available, for example within a park facility, that can be used to acquire adjustment factors which could then be applied to short-duration count locations within the park.

It may be appropriate to utilize nearby continuous counters from another agency (i.e. State, County, City, etc.) to obtain adjustment factors that could be applied to the short-duration counts within the park.

Through inter-agency cooperation, costs to collect the count information could be reduced by sharing the effort between different agencies. It has been shown that roadways located within close proximity (less than 20 miles) of parks have similar variability characteristics (16). Once again, the "factor group" must be considered when utilizing adjustment factors that are obtained from outside "similar" locations. Recreational traffic in and around parks will have different variability when compared to the traffic on rural or urban roads not within the immediate vicinity of the park.



Monthly Adjustment Factors at Yosemite National Park



Day-of-Week Adjustment Factors for July at Yosemite National Park

Reporting Data

Reporting of traffic count data is performed after it has been collected, analyzed, and summarized. Quality traffic related decisions can be made and improved through the effective reporting of the traffic data. Presentation of the data can take many forms including standard reports, tables, and graphical representations. The reports and tables might include summaries of vehicle volume, vehicle classification, or weight measurements as relevant to decision maker needs.

Graphical presentation of data will help to show the representation of adjustment factors more clearly. Seasonal factors being shown from month to month will show the differences in travel patterns related to seasonal influences while day-of-week factors will show the variations of travel on a daily basis (see example figures).

Data Storage

Retention and storage of traffic data is another important aspect of a successful traffic monitoring program. Data retention guidelines are generally based on length requirements set forth by the agency that is performing the traffic monitoring program and are based on the following (*9*):

- The legal requirements of a governmental (county, state, federal, etc.) agency;
- The required data retention periods of other related data;
- The utilization of the data;
- The availability of computer resources;
- The life expectancy, space requirements, and cost of data storage resources; and
- The available budget for the current and future years.

At a minimum, data to retain should include all original or "raw" traffic data collected as well as dates and times of efforts, all adjustment factors, and all adjusted traffic data including data that has been analyzed and summarized into reports. This information may be accessed in the future to determine trend patterns over time. Additionally, all methodology and guidelines related to the traffic monitoring program should be retained for auditing and training purposes.

Over time a traffic monitoring program will collect a large amount of data that needs to be stored (or warehoused) on a medium which can be easily accessed at a later date. Data storage can include such common current storage devices as a computer server drive, a portable hard drive, or digital video disk (DVD). These generally low cost storage devices allow for dependable long-term storage of data while providing the functionality needed to access the data for analysis. In some instances, various companies offer a secure web site for the storage of large amounts of data. The medium chosen to store the data should be updated to new formats that conform to the modernization of technology as needed. It is suggested that off-site storage of duplicate data can provide additional protection from fire or other actions deemed hazardous.

STRATEGIES FOR UNDER-FUNDED PROGRAMS

Some of the costs associated with a traffic monitoring program remain relatively constant for any implemented plan including the costs associated with data analysis, summarization, storage, and retention. However, some traffic monitoring costs that can vary greatly include the cost of the automatic counter type in combination with the detector type, and need to be chosen to best meet the needs of an agency. Automatic traffic counter models differ in costs depending on the sophistication of the equipment. Some general cost estimates that can be expected for automatic traffic counters per unit as of 2004 include:

> Portable accumulative count recorder (ACR) $900
>
> Permanent automated traffic recorder (ATR) $1,615
>
> Permanent automated vehicle classifier (AVC) $1,855
>
> Portable weigh-in-motion (WIM) recorder $8,606
>
> Permanent weigh-in-motion (WIM) recorder $65,000

A good quality traffic monitoring program will incorporate strategies that utilize a mix of data collection techniques that best meet the needs of the agency. Automated traffic recording devices and corresponding detector types can be selected for various situations that will enable an agency on a limited budget to obtain the needed traffic information. For example, a portable accumulative count recorder (ACR) and pneumatic road tube sensors are an inexpensive yet extremely easy and useful set of traffic data collection tools. This combination of traffic monitoring equipment can be placed, retrieved, and moved to obtain short-duration traffic related information at numerous locations.

Another strategy to explore is the use of simple manual traffic counts that may be collected on a monthly basis, for instance visitation counts to a park or recreational area. This data can be manually collected easily in the form of a user-defined vehicle classification count and/or vehicle occupancy count. This type of data collection effort can provide a range of information to be used by an agency, for instance, in determining peak hour vehicle trends or the total number of persons at a particular location at any given time. Additionally, monthly variation can be derived if the visitation information is collected on a consistent basis. From this information, monthly adjustment factors can be acquired that could be applied to other short-duration counts within the area.

As stated previously in this document, another strategy to reduce costs of a traffic monitoring program is to coordinate with external agencies to acquire useful information, such as data from nearby traffic count locations managed by State department of transportation agencies. Such coordination will help reduce the effort and limit possible redundant collection of travel information. This data can be a good source for establishing adjustment factors which could be used to adjust traffic data from short-duration daily counts to annual count estimates.

Detector Type Example Products	Detection Accuracy		
	COUNT	WEIGHT	CLASSIFICATION
Inductive Loop Detectors (ILDs)	EXCELLENT	NA	FAIR
	Not affected by weather performs well under high and low volume traffic		
Video Image Detectors (VIDS)	FAIR	NA	POOR
Peek Video Track 900 Autoscope 2004 Eliop Trafico EVA 2000	Occlusion and light conditions reduce accuracy weather related problems poor performance in high density locations		
Active Infrared Detectors	EXCELLENT	NA	FAIR
Schwartz Autosense I	Weather related problems poor performance in high density locations		
Microwave Detectors	EXCELLENT	NA	NA
Remote Traffic Microwave Sensor (RTMS) Peek PODD Whelen TDN-30	Not affected by weather		
Passive Acoustic Detectors	FAIR	NA	POOR
Smartsonic TSS-1 SmarTek SAS-1	Poor performance in echo-filled environment		
Passive Magnet Detectors	EXCELLENT	NA	FAIR
3M Canoga Vehicle Detection System 702	Not affected by weather performs well under high and low volume traffic		
Piezoelectric Detectors	EXCELLENT	EXCELLENT	EXCELLENT
	Accurate date to within ± 15% GVW		
Bending Plate for WIM	EXCELLENT	EXCELLENT	EXCELLENT
	Accurate date to within ± 10% GVW		
Pneumatic Detector	FAIR	NA	FAIR
Road Tube	Weather related problems poor performance under low speeds performs well under moderate volume traffic		
Manual Data Collection	EXCELLENT	NA	EXCELLENT
Personal Labor and Equipment	Not affected by weather performs well under high and low volume traffic for short periods of time		

The above table compares various detector types available and their corresponding capabilities, limitations, and estimated costs as of the year 2004.

Installation		Maintenance Needs	Costs *	
SETUP	**CALIBRATION**		**INSTALLATION**	**MAINTENANCE**
MODERATE	EASY	HIGH	HIGH	MEDIUM
Must block traffic for installation high rate of installation errors		Weakens pavement	$1447 per lane to install	
DIFFICULT	MODERATE	MEDIUM	HIGH	MEDIUM
Requires a pole for mounting			$1178 per lane to instal	
EASY	MODERATE	LOW	HIGH	HIGH
Requires a pole for mounting			$1658 per lane to install	
EASY	MODERATE	MEDIUM	MEDIUM	LOW
Requires a pole for mounting can be mounted overhead or on side of road (sidefire)			$1086 per lane to install	
EASY	EASY	LOW	MEDIUM	LOW
Requires a pole for mounting can be mounted overhead or on side of road (sidefire)			$913 per lane to install	
EASY	EASY	LOW	LOW	LOW
Can be installed under pavement by horizontal drilling or installed under overpass			$755 per lane to install	
DIFFICULT	DIFFICULT	HIGH	HIGH	HIGH
Must block traffic for installation stringent site requirements			$ 1894 (AVC) per lane to install $3360 (WIM) per lane to install	
DIFFICULT	DIFFICULT	HIGH	HIGH	HIGH
Must block traffic for installation stringent site requirements		Frequent recalibration	$3360 (WIM) per lane to install	
EASY	EASY	MEDIUM	LOW	LOW
Cannot be used in rutted pavement locations		Road tubing replacement	up to $100 per locations to setup and retrieve	
NA	NA	NA	MEDIUM	LOW
			Varies due to cost of personnel and type of count performed	

Notes: NA - Not Applicable
*cost estimates for comparison purposes only and include sensor and installation costs (labor, travel, and misc. parts). Estimate does not include cost of traffic control or power and communications installation as dependant upon location.

LIST OF RESOURCES FOR ASSISTANCE

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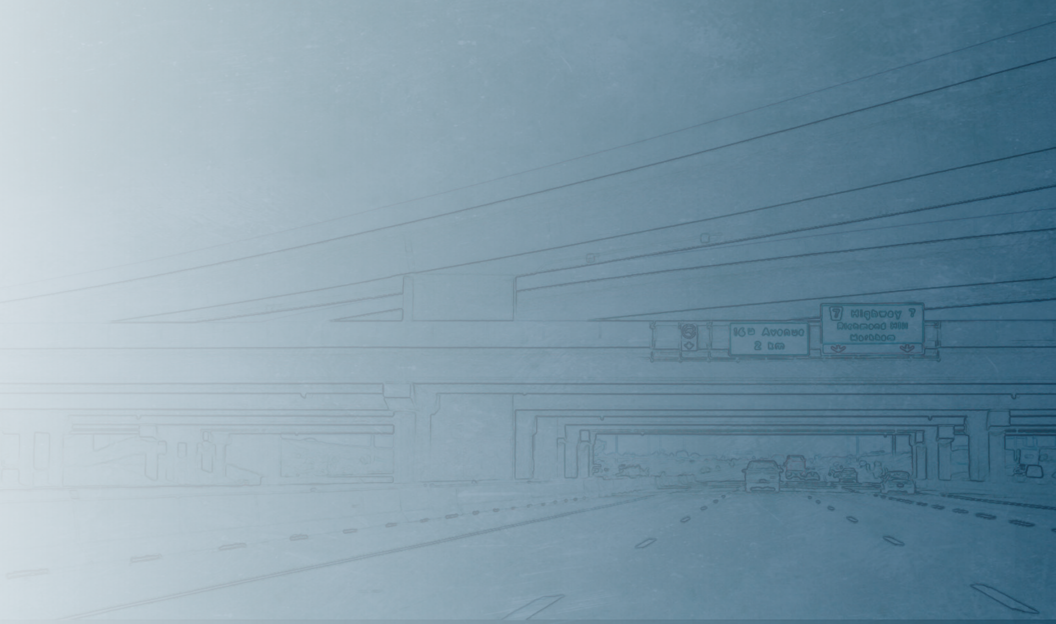
17. Highway Capacity Manual. Transportation Research Board. National Research Council, Washington D.C. 2000.

NOTES

ACRONYMS	
AADT	Annual Average Daily Traffic
ACR	Accumulative Count Recorder
ADT	Average Daily Traffic
ATR	Automatic Traffic Recorder
AVC	Automatic Vehicle Classifier
DVD	Digital Video Disc
FHWA	Federal Highway Administration
GVW	Gross Vehicle Weight
NPS	National Park Service
PHV	Peak Hour Volume
RTMS	Remote Traffic Microwave Sensor
VC	Vehicle Classification
VMT	Vehicle Miles Traveled
WIN	Weigh-In-Motion



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