CHAPTER TWO

2. INTRODUCTION TO TRAFFIC ENGINEERING

2.1 Introduction

The availability of highway transportation has provided several advantages that contribute to a high standard of living. However, several problems related to the highway mode of transportation exist. These problems include highway-related crashes, parking difficulties, congestion, and delay. To reduce the negative impact of highways, it is necessary to adequately collect information that describes the extent of the problems and identifies their locations. Such information is usually collected by organizing and conducting traffic surveys and studies.

Traffic studies involve the collection of data under operational conditions and include studies of speed, traffic volume, travel time and delay, parking, and crashes.

Types of traffic facilities

- *Uninterrupted Traffic facility- includes freeways where there are no intersections at grade, no STOP and Yield signs, etc; some rural highways; and multilane highways.*
- *Interrupted Traffic facility- incorporate external interruptions such as traffic signals, Un-signalized streets with STOP and YIELD signs, pedestrian walkways and transit lanes.*

2.2 Study Areas of Traffic Engineering

Traffic studies may be grouped into three main categories:

- ✓ Inventories,
- ✓ Administrative studies, and
- ✓ Dynamic studies.

1. Inventories: provide a list or graphic display of existing information, such as:
    - street widths,
    - parking spaces,

- transit routes,
- traffic regulations.

2. Administrative studies use existing engineering records, available in government agencies and departments.

include the results of surveys, which may involve:

- field measurements and/or
- aerial photography.

3. Dynamic traffic studies involve the collection of data under operational conditions.

- include studies of:
  - speed,
  - traffic volume,
  - travel time and delay,
  - parking, and
  - crashes.
- NB: dynamic studies are carried out by the traffic engineer to evaluate current conditions and develop solutions.

2.2.1 Spot Speed Studies

Spot speed is a point velocity at a given location. Spot speed studies are conducted to estimate the distribution of speeds of vehicles in a stream of traffic at a particular location on a highway. The speed of a vehicle is defined as the rate of movement of the vehicle; it is usually expressed in miles per hour (mi/h) or kilometers per hour (km/h). A spot speed study is carried out by recording the speeds of a sample of vehicles at a specified location. Speed characteristics identified by such a study will be valid only for the traffic and environmental conditions that exist at the time of the study. Speed characteristics determined from a spot speed study may be used to:

- Establish parameters for traffic operation and control, such as speed zones, speed limits (85th-percentile speed is commonly used as the speed limit on a road), and passing restrictions.

- Evaluate the effectiveness of traffic control devices, such as variable message signs at work zones.
- Monitor the effect of speed enforcement programs, such as the use of drone radar and the use of differential speed limits for passenger cars and trucks.
- Evaluate and/or determine the adequacy of highway geometric characteristics, such as radii of horizontal curves and lengths of vertical curves.
- Evaluate the effect of speed on highway safety through the analysis of crash data for different speed characteristics.
- Determine speed trends.
- Determine whether complaints about speeding are valid.

Locations for Spot Speed Studies

The following locations generally are used for the different applications listed:

i. Locations that represent different traffic conditions on a highway or highways are used for basic data collection.
ii. Mid-blocks of urban highways and straight, level sections of rural highways are sites for speed trend analyses.
iii. Any location may be used for the solution of a specific traffic engineering problem.

When spot speed studies are being conducted, it is important that unbiased data be obtained. This requires that drivers be unaware that such a study is being conducted.

Time of Day and Duration of Spot Speed Studies

The time of day for conducting a speed study depends on the purpose of the study. In general, when the purpose of the study is to establish posted speed limits, to observe speed trends, or to collect basic data, it is recommended that the study be conducted when traffic is free-flowing, usually during off-peak hours. However, when a speed study is conducted in response to citizen complaints, it is useful if the time period selected for the study reflects the nature of the complaints.

The duration of the study should be such that the minimum number of vehicle speeds required for statistical analysis is recorded. Typically, the duration is at least 1 hour and the sample size is at least 30 vehicles.

Sample Size for Spot Speed Studies

The larger the sample size, the greater the probability that the estimated mean is not significantly different from the true mean. It is therefore necessary to select a sample size that will give an estimated mean within acceptable error limits.

These data are used to obtain speed characteristics. These characteristics are the average speed, the median speed, the modal speed, the 85thpercentile speed, the pace, and the standard deviation of the speed.

a) **Average Speed** which is the arithmetic mean of all observed vehicle speeds (which is the sum of all spot speeds divided by the number of recorded speeds)
b) **Median Speed** which is the speed at the middle value in a series of spot speeds that are arranged in ascending order. 50 percent of the speed values will be greater than the median; 50 percent will be less than the median.
c) **Modal Speed** which is the speed value that occurs most frequently in a sample of spot speeds.
d) The ***i*th-percentile Spot Speed** which is the spot speed value below which *i* percent of the vehicles travel; for example, 85th-percentile spot speed is the speed below which 85 percent of the vehicles travel and above which 15 percent of the vehicles travel.

Sample Size

The Selection of sample size depends on desired confidence level and the minimum sample size to satisfy the project requirements can be determined as:

$$N = \left(\frac{Z\sigma}{d}\right)^2 \qquad (5.1)$$

Where:

N= number of sample size

Z = number of standard deviations corresponding to the required confidence = 1.96 for 95 percent confidence level (Table 2.1)

σ = standard deviation (mi/h)

d = limit of acceptable error in the average speed estimate (mi/h)

Table 2.1: Constant Corresponding to Level of Confidence

Confidence Level (%)	*Constant Z*
68.3	1.00
86.6	1.50
90.0	1.64
95.0	1.96
95.5	2.00
98.8	2.50
99.0	2.58
99.7	3.00

Methods for Conducting Spot Speed Studies

The methods used for conducting spot speed studies can generally be divided into two main categories: manual (e.g. speed gun) and automatic. The automatic conducting methods include road detectors, radar-based traffic sensors, electronic-principle detectors, etc

Road Detectors

These devices can be used to collect data on speeds at the same time as volume data are being collected. The advantage of the detector meters is that human errors are considerably reduced. The disadvantages are that (1) these devices tend to be rather expensive and (2) when pneumatic tubes are used, they are rather conspicuous and may, therefore, affect driver behavior, resulting in a distortion of the speed distribution.

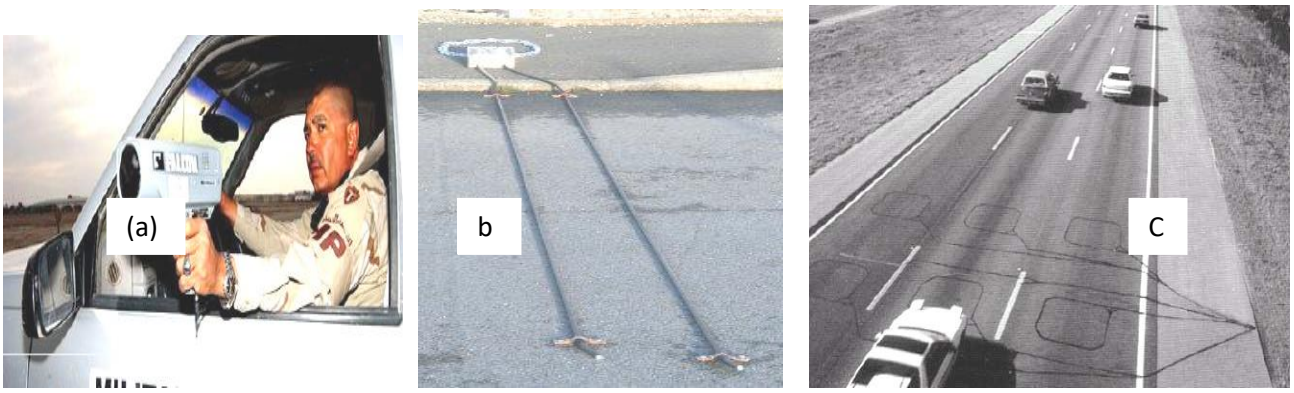


Fig. 2.1: (a) Radar speed gun (b) Pneumatic road tubes and (c) induction loops

Presentation and Analysis of Spot Speed Data

The data collected in spot speed studies are usually taken only from a sample of vehicles using the section of the highway on which the study is conducted, but these data are used to determine the speed characteristics of the whole population of vehicles traveling on the study site. It is therefore necessary to use statistical methods in analyzing these data.

2.2.2 Volume Studies

Traffic volume studies are conducted to collect data on the number of vehicles and/or pedestrians that pass a point on a highway facility during a specified time period. This time period varies from as little as 15 minutes to as much as a year depending on the anticipated use of the data. Traffic volume studies are usually conducted when certain volume characteristics are needed, some of which follow:

a) **Average Annual Daily Traffic** (AADT) is the average of 24-hour counts collected every day of the year.
b) **Average Daily Traffic** (ADT) is the average of 24-hour counts collected over a number of days greater than one but less than a year.
c) **Peak Hour Volume** (PHV) is the maximum number of vehicles that pass a point on a highway during a period of 60 consecutive minutes.
d) **Vehicle Classification (VC):** Records volume with respect to the types of vehicles.
e) **Vehicle Miles (Kilometers) of Travel (VMT, VKT):** A measure of travel along a section of road. A product of roadway in miles to which the volume is applicable.

Function of traffic volume studies

Study	Application of the study
AADT	▪ Estimation of highway user revenues ▪ Computation of crash rates in terms of number of crashes per 100 million vehicle miles ▪ Establishment of traffic volume trends ▪ Evaluation of the economic feasibility of highway projects ▪ Development of freeway and major arterial street systems ▪ Development of improvement and maintenance programs
ADT	▪ Planning of highway activities ▪ Measurement of current demand ▪ Evaluation of existing traffic flow
PHV	▪ Functional classification of highways ▪ Design of the geometric characteristics of a highway, for example, number of lanes, intersection signalization, or channelization ▪ Capacity analysis ▪ Development of programs related to traffic operations, for example, one-way street systems or traffic routing ▪ Development of parking regulations

Methods of Conducting Volume Counts

Traffic volume counts are conducted using two basic methods: manual and automatic.

Manual Method

Manual counting involves one or more persons recording observed vehicles using a counter. With this type of counter, the short and complicated count such as both the turning movements at the intersection and the types of vehicles can be recorded.

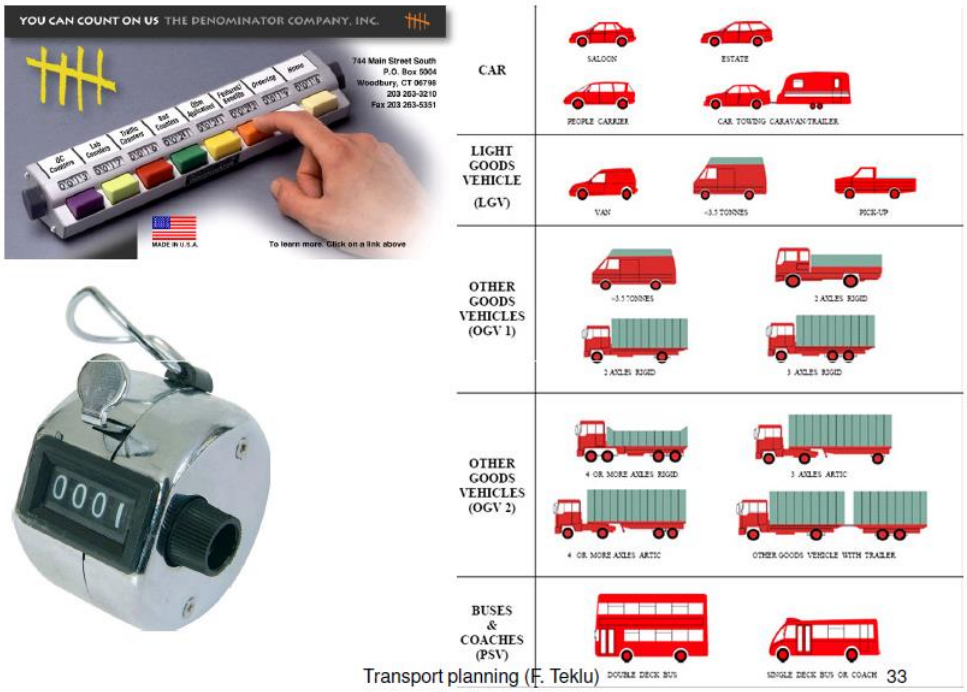


Fig. 2.2: Manual traffic volume count method

Automatic Method

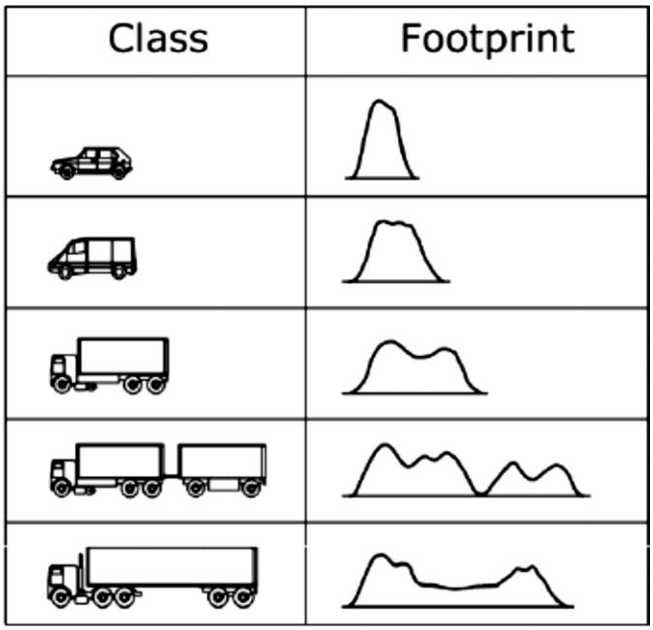


Figure 2.3: Induction loop (vehicle classification by length & chassis profile)

Automatic counters can be classified into two general categories: those that require the laying of detectors (surface or subsurface), and those that do not require the laying of detectors. Automatic counters that require the laying of surface detectors (such as pneumatic road tubes) or subsurface detectors (non invasive, such as magnetic or electric contact devices) on the road, detect the passing vehicle and transmit the information to a recorder, which is connected to the detector at the side of the road.

Types of Volume Counts

Different types of traffic counts are carried out, depending on the anticipated use of the data to be collected. These different types are discussed in the following table.

Cordon counts	When vehicle accumulation pattern within an area is needed
Screen line counts	When changes in traffic flow from one area to another need to be evaluated
Intersection counts	When turning movements are needed
Pedestrian volume counts	When pedestrian demand needs to be evaluated/ is to be undertaken
Periodic volume counts	When traffic volume characteristics are needed: Continuous, control, and coverage counts e.g AADT

Traffic Volume Characteristics

A continuous count of traffic at a section of a road will show that traffic volume varies from hour to hour, from day to day, and from month to month. However, the regular observation of traffic volumes over the years has identified certain characteristics showing that although traffic volume at a section of a road varies from time to time, this

variation is repetitive and rhythmic. These characteristics of traffic volumes are usually taken into consideration when traffic counts are being planned so that volumes collected at a particular time or place can be related to volumes collected at other times and places. Knowledge of these characteristics also can be used to estimate the accuracy of traffic counts.

For example, the monthly variation of traffic volume during January and February are very low volumes due to winter weather and peak volume is observed during August due to vacation.

2.2.3 Travel Time and Delay Studies

Definitions

Travel time is the time taken by a vehicle to traverse a given section of a highway.

Delay is the time lost by a vehicle due to causes beyond the control of the driver.

A travel time study determines the amount of time required to travel from one point to another on a given route. In conducting such a study, information may also be collected on the locations, durations, and causes of delays. When this is done, the study is known as a travel time and delay study. Data obtained from travel time and delay studies give a good indication of the **level of service** on the study section. These data also aid the traffic engineer in identifying problem locations, which may require special attention in order to improve the overall flow of traffic on the route.

Delay is often used to estimate economic losses --- more fuel consumption and low productivity of operation. Delay is also a very important MOE (measure of effectiveness) in traffic engineering.

Applications of Travel Time and Delay Data

The data obtained from travel time and delay studies may be used in any one of the following traffic engineering tasks:

- ✓ Determination of the efficiency of a route with respect to its ability to carry traffic

- ✓ Identification of locations with relatively high delays and the causes for those delays
- ✓ Performance of before-and-after studies to evaluate the effectiveness of traffic operation improvements
- ✓ Determination of travel times on specific links for use in trip assignment models
- ✓ Compilation of travel time data that may be used in trend studies to evaluate the changes in efficiency and level of service with time
- ✓ Performance of economic studies in the evaluation of traffic operation alternatives that reduce travel time

Methods for Conducting Travel Time and Delay Studies

Several methods have been used to conduct travel time and delay studies. These methods can be grouped into two general categories: (a) those using a test vehicle and (b) those not requiring a test vehicle.

Methods Requiring a Test Vehicle

Floating-Car Technique: In this method, the test car is driven by an observer along the test section so that the test car "floats" with the traffic. The driver of the test vehicle attempts to pass as many vehicles as those that pass his test vehicle. The time taken to traverse the study section is recorded. This is repeated, and the average time is recorded as the travel time.

The minimum number of test runs can be determined using an equation similar to Eq. 5.1, using values of the *t* distribution rather than the *z* values. The reason is that the sample size for this type of study is usually less than 30, which makes the *t* distribution more appropriate. The equation is

$$N = \left(\frac{t_\alpha \times \sigma}{d}\right)^2 \qquad (5.2)$$

where

N = sample size (minimum number of test runs)
σ = standard deviation (mi/h)
d = limit of acceptable error in the speed estimate (mi/h)
t_α = value of the student's t distribution with $(1 - \alpha/2)$ confidence level and $(N - 1)$ degrees of freedom
α = significance level

Example

An engineer, wishing to determine the travel time and average speed along a section of an urban highway as part of an annual trend analysis on traffic operations, conducted a travel time study using the floating-car technique. How many test runs are required to obtain a standard deviation of ±2.5 mi/h in the speeds? Assume a 5% significance level. ($t_a = t_{1-0.025}$) (t_a is 2.365, 2.306, 2.262, 2.228, 2.201, 2.179, 2.160, 2.145 for 7 up to 14 degree of freedom)

Average-Speed Technique: This technique involves driving the test car along the length of the test section at a speed that, in the opinion of the driver, is the average speed of the traffic stream. The time required to traverse the test section is noted.

It is easier method than floating car and the number of sample size (minimum number of test run) can be determined similar to float cat method (equation 5.2).

In each of these methods, it is first necessary to clearly identify the test section. The way the travel time is usually obtained is that the observer starts a stopwatch at the beginning point of the test section and stops at the end. A second stopwatch also may be used to determine the time that passes each time the vehicle is stopped. The sum of these times for any test run will give the stopped-time delay for that run.

Methods Not Requiring a Test Vehicle

License-Plate Observations: The license-plate method requires that observers be positioned at the beginning and end of the test section. Each observer records the last three or four digits of the license plate of each car that passes, together with the time at which the car passes. The reduction of the data is accomplished in the office by matching

the times of arrival at the beginning and end of the test section for each license plate recorded. The difference between these times is the traveling time of each vehicle. The average of these is the average traveling time on the test section. It has been suggested that a sample size of 50 matched license plates will give reasonably accurate results.

Interviews: The interviewing method is carried out by obtaining information from people who drive on the study site regarding their travel times, their experience of delays, and so forth. This method facilitates the collection of a large amount of data in a relatively short time. However, it requires the cooperation of the people contacted, since the result depends entirely on the information given by them.

2.2.4 Parking Studies

Any vehicle traveling on a highway will at one time or another be parked for either a relatively short time or a much longer time, depending on the reason for parking. The provision of parking facilities is therefore an essential element of the highway mode of transportation. The need for parking spaces is usually very great in areas where land uses include business, residential, or commercial activities. The growing use of the automobile as a personal feeder service to transit systems ("park-and-ride") has also increased the demand for parking spaces at transit stations. In areas of high density, where space is very expensive, the space provided for automobiles usually has to be divided between that allocated for their movement and that allocated for parking them.

Parking studies are used to determine the demand for and the supply of parking facilities in an area, the projection of the demand, and the views of various interest groups on how best to solve the problem.

Types of Parking Facilities

Parking facilities can be divided broadly into two main groups: public and private parking.

a) Public parking is again divided in to on-street and off-street parking.

On-Street Parking Facilities

These are also known as curb facilities. Parking bays are provided alongside the curb on one or both sides of the street. Unless kerb parking facility has been adequately designed in advance while planning a new town, it might lead to a lot of in convenience and congestion due to decreased road capacity as well as increased accidents.

These bays can be unrestricted parking facilities if the duration of parking is unlimited and parking is free, or they can be restricted parking facilities if parking is limited to specific times of the day for a maximum duration. Parking at restricted facilities may or may not be free. Restricted facilities also may be provided for specific purposes, such as to provide handicapped parking or as bus stops or loading bays.

Off-Street Parking Facilities

Off-street parking facilities are parking facilities that are provided at separate place away from the kerb. The main advantage of these parking is that there is no due congestion and delay on the road as in kerb parking. But the main drawback is some of the owner will have to walk a greater distance after parking the vehicle.

These facilities may be privately or publicly owned; they include surface lots and garages. Self-parking garages require that drivers park their own automobiles; attendant-parking garages maintain personnel to park the automobiles.

b) Private parking includes home or apartment building garages, stalls and drive ways or affiliate specific parking.

Methodology of Parking Studies

Parking studies include financial feasibility, functional design, structural design and demand studies. A comprehensive parking study usually involves

a. Inventory of existing parking facilities,
b. Collection of data on parking accumulation, parking turnover and parking duration,
c. Identification of parking generators, and
d. Collection of information on parking demand. Information on related factors, such as financial, legal, and administrative matters, also may be collected.

a. Inventory of Existing Parking Facilities

An inventory of existing parking facilities is a detailed listing of the location and all other relevant characteristics of each legal parking facility, private and public, in the study area. The inventory includes both on- and off-street facilities. The relevant characteristics usually listed include the following:

- Type and number of parking spaces at each parking facility
- Times of operation and limit on duration of parking, if any
- Type of ownership (private or public)
- Parking fees, if any, and method of collection
- Restrictions on use (open or closed to the public)
- Other restrictions, if any (such as loading and unloading zones, bus stops, or taxi ranks)
- Probable degree of permanency (can the facility be regarded as permanent or is it just a temporary facility?)

b. Collection of Parking Data

Parking accumulation is the number of parked vehicles in a study area at any specified time. Accumulation data are obtained by checking the amount of parking during regular intervals on different days of the week. The checks are usually carried out on an hourly or 2-hour basis between 6:00 a.m. and 12 mid night. The selection of the times depends on the operation times of land-use activities that act as parking generators.

Turnover and Duration:

Parking duration is the length of time a vehicle is parked at a parking bay. **Parking turnover** is the rate of use of a parking space. It is obtained by dividing the parking volume for a specified period by the number of parking spaces.

Information on turnover and duration is usually obtained by collecting data on a sample of parking spaces in a given block. This is done by recording the license plate of the vehicle

parked on each parking space in the sample at the ends of fixed intervals during the study period. The length of the fixed intervals depends on the maximum permissible duration.

c. Identification of Parking Generators

This phase involves identifying parking generators (for example, shopping centers or transit terminals) and locating these on a map of the study area.

d. Parking Demand

Information on parking demand is obtained by interviewing drivers at the various parking facilities listed during the inventory. An effort should be made to interview all drivers using the parking facilities on a typical weekday between 8:00 a.m. and 10:00 p.m. Information sought should include (1) trip origin, (2) purpose of trip, and (3) driver's destination after parking. The interviewer must also note the location of the parking facility, times of arrival and departure, and the vehicle type.

Parking Analysis

Parking analyses include surveys about:

a. Parking accumulation
b. Parking duration
c. Parking load- short term and long-term parking hourly load

The general procedure for parking analysis is to find the above 3 characteristics.

2.3 3E'S of Traffic Engineering

The three" E's" of traffic management are

(1) education

(2) engineering, and

(3) enforcement.

Education

The preferred mode of prevention is education, though high-risk drivers are the least receptive to this traffic management strategy. Law enforcement agencies offer a variety of public traffic safety programs taught by their officers through civic groups, schools, and community organizations around the country.

One of the best-known programs is the high school driver education elective offered by school districts. However, not all students participate in this excellent safety and lifesaving experience. High school driver education programs are particularly relevant to this high-risk student population. Police officers who participate in high school driver education programs provide a meaningful and important contribution to a lifesaving effort.

Engineering

This aspect aims to improve the existing transportation infrastructure and factor in safety when designing new transportation infrastructure. Engineering measures include:

1. Identifying and developing solutions for known road safety problem areas.
2. Reviewing standards for road development and moving towards a safety conscious road form, customized for local conditions.
3. Conducting road safety audits

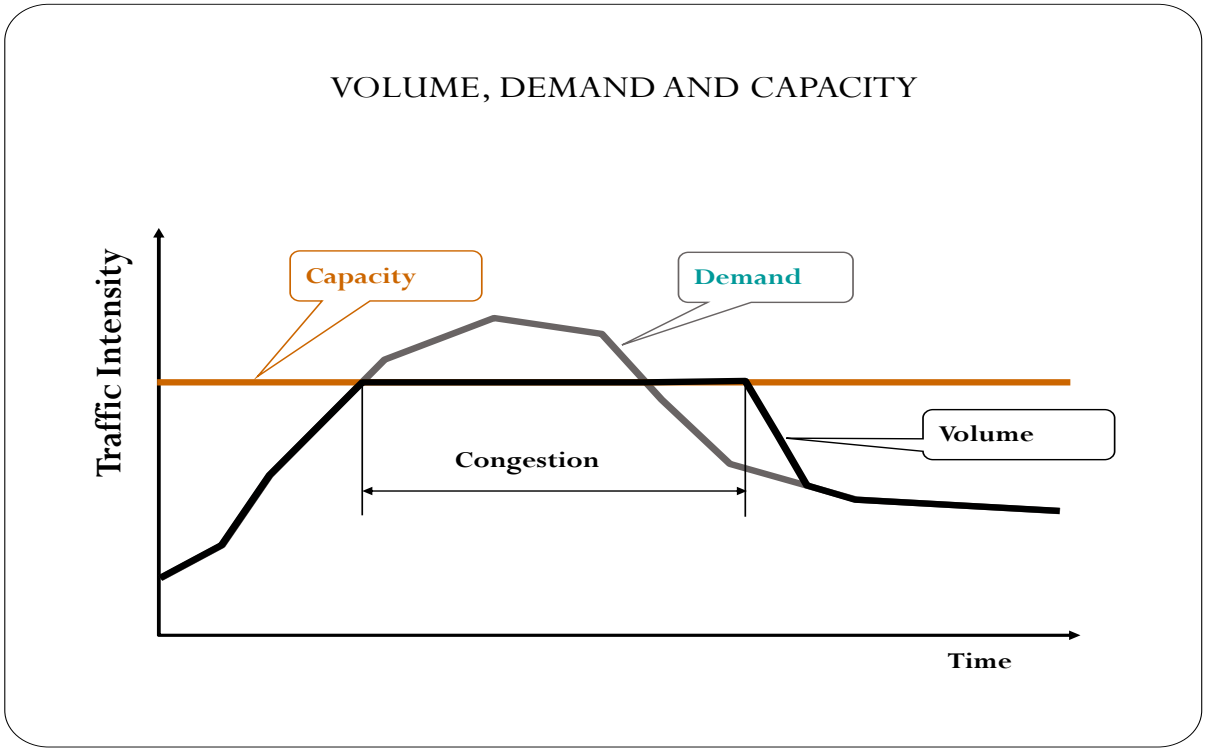
Enforcement

It is the act of compelling observance of or compliance with a law, rule, or obligation. Improvements in traffic law enforcement should be part of an integrated road safety policy and have been shown to lead to rapid reductions in deaths and injuries when applying best practice. Exceeding speed limits, drink or distracted driving and failure to wear a seat belt are still the leading causes of death and serious injury all over the world and need enforcement.

2.4 Highway capacity

The fundamental diagram of traffic flow was used in Chapter 6 to illustrate the relationship between flow and density. It was shown that traffic flows reasonably well when the flow rate is less than at capacity, but excessive delay and congestion can occur when the flow rate is at or near capacity. This phenomenon is a primary consideration in the planning and design of highway facilities, because a main objective is to design or plan facilities that will operate at flow rates below their optimum rates. This objective can be achieved when a good estimate of the optimum flow of a facility can be made. Capacity analysis therefore involves the quantitative evaluation of the capability of a road section to carry traffic, and it uses a set of procedures to determine the maximum flow of traffic that a given section of highway will carry under prevailing roadway traffic and control conditions.

Definition

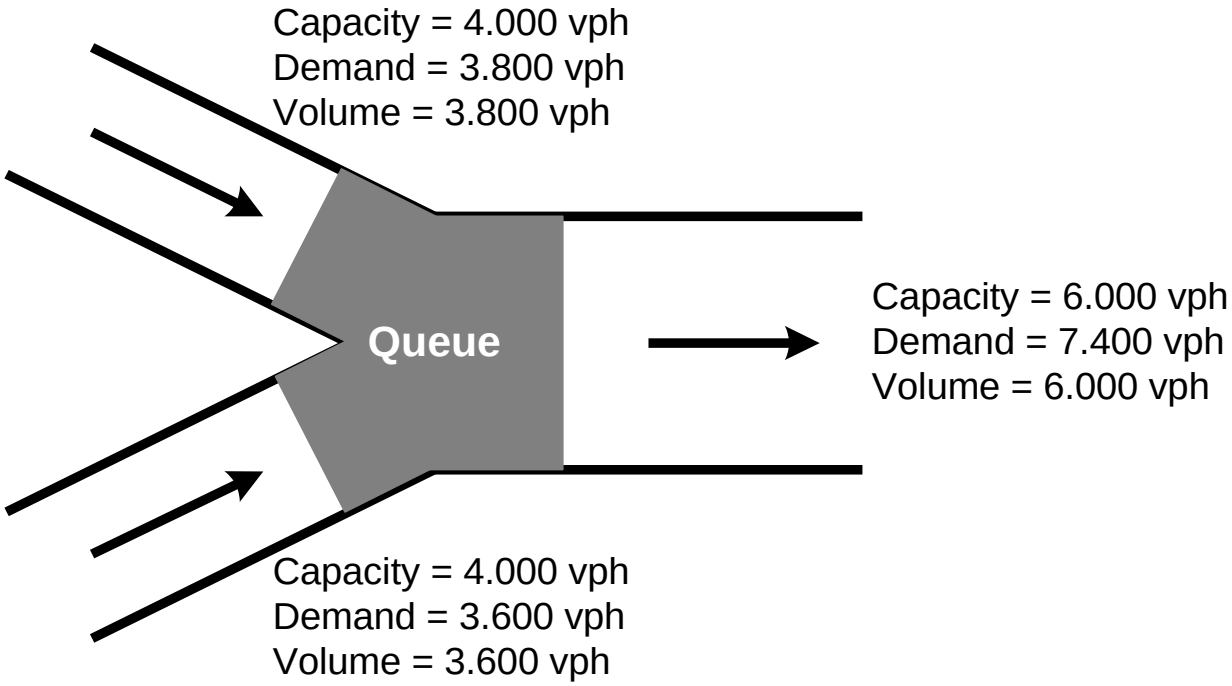


Volume – number of vehicles (persons) passing a point during a specified time period which is usually one hour.

Capacity – maximum and repeatable volume of vehicles/travelers that can traverse a point or short segment during a specified time period

Demand – number of vehicles (persons) that desire to travel past a point during a specified period also usually one hour. It is a volume not influenced by highway capacity

NB. Theoretically, actual volume can never be observed at levels higher than the true capacity of the section



Capacity of Two-Way Highway

Generally, HCM 2000 defines capacity as:

"The capacity of the facility is the maximum hourly rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions"

NB. HCM = Highway Capacity Manual – It is a standard for capacity analysis

The two-lane, two-way rural highway is the only type of highway link on which traffic in one direction has a distinct operational impact on traffic in the other direction. Rural two-lane highways serve two primary functions in the nation's highway network:

- ✓ Mobility
- ✓ Accessibility



Many two-lane rural highways, however, serve low volumes, sometimes under 100 veh/day. The primary function of such highways is to provide for basic all-weather access to remote or sparsely-developed areas. Because of the broad diversity of use on these highways, HCM 2000 has created two distinct classes of rural two-lane, two-way highways:

Class I: These are highways on which motorists expect to travel at relatively high speeds, including major intercity routes, primary arterials, and daily commuter routes.

Class II: These are highways on which motorists do not necessarily expect to travel at high speeds, including access routes, scenic and recreational routes that are not primary arterials, and routes through rugged terrain.

The capacity of a two-lane highway under base conditions is now established as 3200 pc/h in both directions, with a maximum of 1700 pc/h in one direction. The base conditions for which this capacity is defined include:

- 3.6 m (or greater) lanes
- 1.8 m (or greater) usable shoulders
- Level terrain
- No heavy vehicles
- No traffic interruptions
- 50/50 directional split of traffic

As with all capacity values, these standards reflect "reasonable expectancy" (i.e., most two-lane highway segments operating under base conditions should be able to achieve such capacities most of the time). Isolated observations of higher volumes do not negate the standard.

Level of Service of Highway

Level of Service (LOS) expresses the performance of a highway at traffic volumes less than capacity. The “level of service” (LOS) of a highway, which is a qualitative measure of flow and ranging from A (highest) to F (lowest), characterizes both operational conditions within a traffic stream and highway users’ perception. Level-of-service criteria are applied to travel during the peak 15 minutes of travel and on highway segments of significant length.

Level of service for two-lane rural highways is defined in terms of two measures of effectiveness:

Average travel speed (ATS)

Percent time spent following (PTSF)

Average travel speed is the average speed of all vehicles traversing the defined analysis segment for the specified time period, which are usually the peak 15-minutes of a peak hour. When analysis of both directions is used, the average travel speed includes vehicles in both directions. When analysis of single direction is used, the average travel speed includes those vehicles in the analysis direction only.

Percent time spent following, similar to "percent time delay," is the aggregate percentage of time that all drivers spend in queues, unable to pass, with the speed restricted by the queue leader. A surrogate measure for PTSF is the percentage of vehicles following others at headways of 3.0 s or less.

Table 14.4: Level-of-Service Criteria for Two-Lane Rural Highways

Level of Service	Class I Facilities		Class II Facilities
	Average Travel Speed (mi/h)	Percent Time Spent Following (%)	Percent Time Spent Following (%)
A	>55	≤35	≤40
B	>50–55	>35–50	>40–55
C	>45–50	>50–65	>55–70
D	>40–45	>65–80	>70–85
E	≤40	>80	>85

NB. For Class I highways, the LOS is determined by the measure yielding the poorest result.

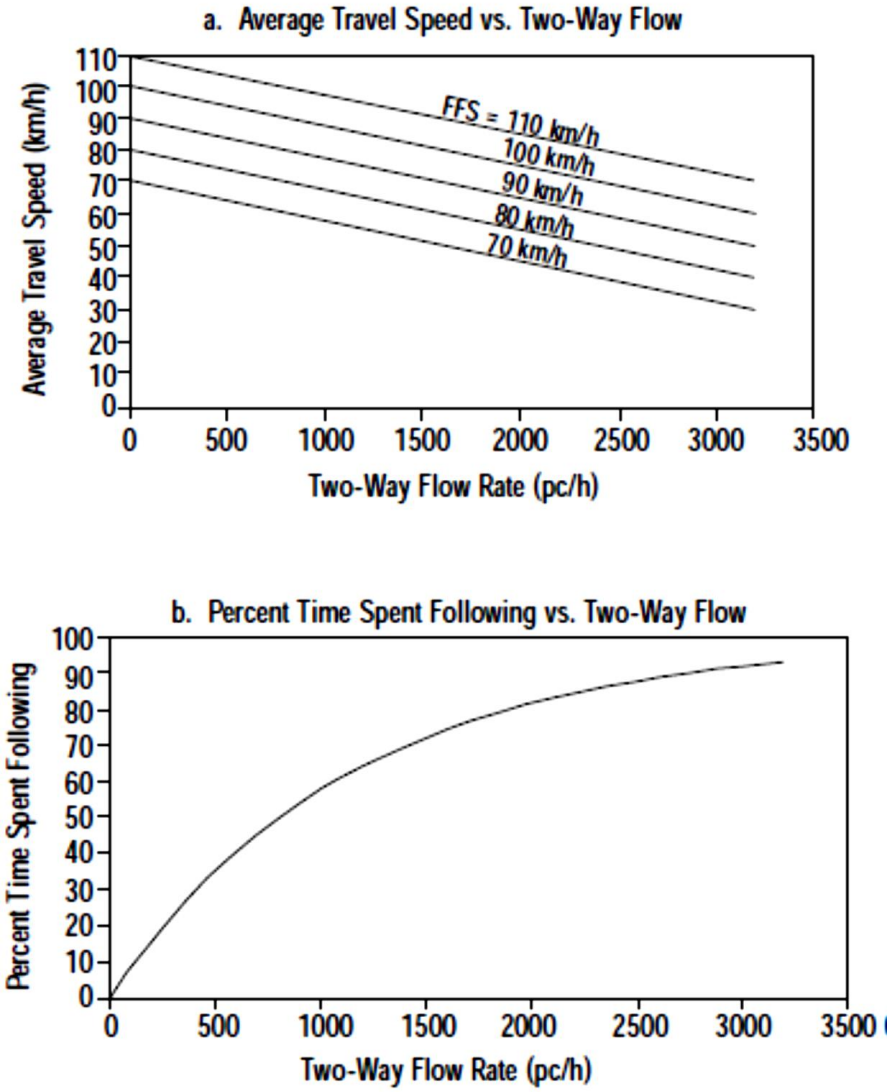


Figure: (a) Flow versus Average Travel Speed and (b) Percent Time Spent Following for Two-Lane Highways

Level of service A describes the highest quality of traffic service occurs when motorists are able to drive at their desired speed. Passing demand is well below passing capacity, and almost no platoons of three or more vehicles are observed. A maximum flow rate of 490 pc/h, total in both directions, may be achieved under base conditions.

Level of service B characterizes the region of traffic flow wherein speeds of 80 km/h or slightly higher are expected on level terrain on Class I highways. Passing demand needed to maintain desired speeds becomes significant and approximately equals the passing

capacity at the lower boundary of level of service B. Service flow rates of 780pc/h, total in both directions, can be achieved under base conditions.

Level of service C describes further increases in flow resulting in noticeable increases in platoon formation, platoon size, and frequency of passing impediment. While traffic flow is stable, it is becoming susceptible to congestion due to turning traffic and slow-moving vehicles. A service flow rate of up to 1190 pc/h, total in both directions, can be accommodated under base conditions.

Level of service D describes unstable traffic flow. The two opposing traffic streams essentially begin to operate separately at higher volume levels, as passing becomes extremely difficult. Passing demand is very high, while passing capacity approaches zero. Maximum service flow rates of 1830 pc/h, total in both directions, can be maintained under base condition.

Level of service E represents traffic flow conditions at which the highest volume (that is with capacity of the highway, generally 3200 pc/h, and total in both directions) can be attained.

Passing is virtually impossible under level of service E conditions, and platooning becomes intense when slower vehicles or other interruptions are encountered. Operating conditions at capacity are unstable and difficult to predict.

Level of service F represents heavily congested flow with traffic demand exceeding capacity. Volumes are lower than capacity and speeds are highly variable.