TRAFFIC CHARACTERISTICS

Unit I
Overview

Traffic stream Characteristics
Overview of Traffic Stream Components

- To begin to understand the functional and operational aspects of traffic on streets and highways it is important to understand **how the various elements of a traffic system interact**.

- Further, the characteristics of traffic streams are heavily influenced by the characteristics and limitations of each of these elements.
Overview of Traffic Stream Components

- There are five critical components that interact in a traffic system:
  - Road users - drivers, pedestrians, bicyclists, and passengers
  - Vehicles - private and commercial
  - Streets and highways
  - Traffic control devices
  - The general environment
Dealing with Diversity

- Traffic engineering would be a great deal simpler if the various components of the traffic system had uniform characteristics.
- Traffic controls could be easily designed if all drivers reacted to them in exactly the same way.
- Safety could be more easily achieved if all vehicles had uniform dimensions, weights, and operating characteristics.
Dealing with Diversity

- Drivers and other road users, however, have widely varying characteristics.
- The traffic engineer must deal with elderly drivers as well as 18-year-olds, aggressive drivers and timid drivers.
- Simple subjects like reaction time, vision characteristics, and walking speed become complex because no two road users are the same.
- Most human characteristics follow the normal distribution.
Dealing with Diversity

- Just as road-user characteristics vary, the characteristics of vehicles vary widely as well.
- Highways must be designed to accommodate motorcycles, the full range of automobiles, and a wide range of commercial vehicles, including double- and triple-back tractor-trailer combinations.
- Thus, lane widths, for example, must accommodate the largest vehicles expected to use the facility.
Dealing with Diversity

- Some control over the range of road-user and vehicle characteristics is maintained through licensing criteria and state standards on vehicle design and operating characteristics.

- While these are important measures, the traffic engineer must still deal with a wide range of road-user and vehicle characteristics.
Traffic Stream Characteristics

- Dealing with traffic, therefore, involves an element of variability.
- A flow of water through channels and pipes of defined characteristics will behave in an entirely predictable fashion, in accord with the laws of hydraulics and fluid flow.
- A given flow of traffic through streets and highways of defined characteristics will vary with both time and
Thus, the critical challenge of traffic engineering is to plan and design for a medium that is not predictable in exact terms—one that involves both physical constraints and the complex behavioral characteristics of human beings.

Fortunately, while exact characteristics vary, there is a reasonably consistent range of driver and, therefore, traffic stream behavior.

Drivers on a highway designed for a safe speed of 60 mi/h may select speeds in a broad range (perhaps 45-65 mi/h); few, however, will travel at 80 mi/h or at 20 mi/h.
In describing traffic streams in quantitative terms, the purpose is to both understand the inherent variability in their characteristics and to define normal ranges of behavior.

To do so, key parameters must be defined and measured.

Traffic engineers will analyze, evaluate, and ultimately plan improvements in traffic facilities based on such parameters and their knowledge of normal ranges of behavior.
Traffic stream parameters
Traffic stream parameters

- Traffic stream parameters fall into two broad categories
  1. *Macroscopic parameters* describe the traffic stream as a whole
  2. *Microscopic parameters* describe the behavior of individual vehicles or pairs of vehicles within the traffic stream
Traffic stream parameters

- **Macroscopic parameters:**
  - Volume or rate of flow \((Q)\),
  - Speed \((v)\), and
  - Density \((K)\)

- **Microscopic parameters:**
  - The speed of individual vehicles,
  - Time Headway, and
  - Space Headway
Macroscopic Parameters
Volume or rate of Flow
Traffic volume or rate of Flow (Q) is defined as the number of vehicles passing a point on a highway, or a given lane or direction of a highway, during a specified time interval.

It is often expressed as “vehicles per unit time.”

Units of time used most often are “per day” or “per hour.”
Daily Volumes

- Daily volumes are used to document annual trends in highway usage.
- Forecasts based upon observed trends can be used to help plan improved or new facilities to accommodate increasing demand.
- There are four daily volume parameters that are widely used in traffic engineering:
  - *Average annual daily traffic (AADT)*
  - *Average annual weekday traffic (AAWT)*
  - *Average daily traffic (ADT)*
  - *Average weekday traffic (AWT)*
Daily Volumes

- **Average annual daily traffic (AADT):**
  - The average 24-hour volume at a given location over a full 365-day year; the number of vehicles passing a site in a year divided by 365 days (366 days in a leap year).

- **Average annual weekday traffic (AAWT):**
  - *The* average 24-hour volume occurring on weekdays over a full 365-day year; the number of vehicles passing a site on weekdays in a year divided by the number of weekdays (usually 260).
Daily Volumes

- **Average daily traffic (ADT):**
  - *The average 24-hour volume at a given location over a defined time period less than one year; a common application is to measure an ADT for each month of the year.*

- **Average weekday traffic (AWT):**
  - *The average 24-hour weekday volume at a given location over a defined time period less than one year; a common application is to measure an AWT for each month of the year.*
Hourly Volumes

- Daily volumes, while useful for planning purposes, cannot be used alone for design or operational analysis purposes.
- Volume varies considerably over the 24 hours of the day, with periods of maximum flow occurring during the morning and evening commuter “rush hours.”
- The single hour of the day that has the highest hourly volume is referred to as the *peak hour*.
- *The traffic volume* within this hour is of greatest interest to traffic engineers for design and operational analysis usage.
Highways and controls must be designed to adequately serve the peak-hour traffic volume in the peak direction of flow.

Since traffic going one way during the morning peak is going the opposite way during the evening peak, both sides of a facility must generally be designed to accommodate the peak directional flow during the peak hour.

$$PHF = \frac{\text{hourly volume}}{\text{max. rate of flow}}$$
Speed and Travel Time

- Speed is the second macroscopic parameter describing the state of a traffic stream.
- Speed is defined as a rate of motion in distance per unit time.
- Travel time is the time taken to traverse a defined section of roadway.

\[ S = \frac{d}{t} \]

where:
- \( S \) = speed, mi/h or ft/s
- \( d \) = distance traversed, mi or ft
- \( t \) = time to traverse distance \( d \), h or s
In a moving traffic stream, each vehicle travels at a different speed.

Thus, the traffic stream does not have a single characteristic value, but rather a distribution of individual speeds.

The traffic stream, taken as a whole, can be characterized using an *average or typical* speed.
There are two ways in which an average speed for a traffic stream can be computed:

- **Time mean speed (TMS):** The average speed of all vehicles passing a point on a highway or lane over some specified time period.

- **Space mean speed (SMS):** The average speed of all vehicles occupying a given section of highway or lane over some specified time period.
In essence, time mean speed is a point measure, while space mean speed describes a length of highway or lane.
To measure time mean speed (TMS), an observer would stand by the side of the road and record the speed of each vehicle as it passes.

Given the speeds and the spacing shown in Figure 5.1, a vehicle will pass the observer in lane A every \( \frac{176}{88} = 2.0 \) sec.

Similarly, a vehicle will pass the observer in lane B every \( \frac{88}{44} = 2.0 \) sec.

Thus, as long as the traffic stream maintains the conditions shown, for every \( n \) vehicles traveling at 88 ft/s, the observer will also observe \( n \) vehicles traveling at 44 ft/s.
The TMS may then be computed as:

\[ TMS = \frac{88.0n + 44.0n}{2n} = 66.0 \text{ ft/s} \]
To measure space mean speed (SMS), an observer would need an elevated location from which the full extent of the section may be viewed.

Again, however, as long as the traffic stream remains stable and uniform, as shown, there will be twice as many vehicles in lane B as there are in lane A.
Therefore, the SMS is computed as:

\[ SMS = \frac{(88.0n) + (44 \times 2n)}{3n} = 58.7 \text{ mi/h} \]
In effect, space mean speed accounts for the fact that it takes a vehicle traveling at 44.0 ft/s twice as long to traverse the defined section as it does a vehicle traveling at 88.0 ft/s.

The space mean speed weights slower vehicles more heavily, based on the amount of time they occupy a highway section.

Thus, the space mean speed is usually lower than the corresponding time mean speed, in which each vehicle is weighted equally.
The two speed measures may conceivably be equal if all vehicles in the section are traveling at exactly the same speed.
Density
Density

- Density, the third primary measure of traffic stream characteristics, is defined as the number of vehicles occupying a given length of highway or lane, generally expressed as vehicles per mile or vehicles per mile per lane.

- Density is difficult to measure directly, as an elevated vantage point from which the highway section under study may be observed is required.

- It is often computed from speed and flow rate measurements.
Density

- Density, however, is perhaps the most important of the three primary traffic stream parameters, because it is the measure most directly related to traffic demand.
- Drivers select speeds that are consistent with how close they are to other vehicles.
- The speed and density combine to give the observed rate of flow.
- Density is also an important measure of the quality of traffic flow, as it is a measure of the proximity of other vehicles, a factor which influences freedom to maneuver and the psychological comfort of drivers.
Occupyancy

- While density is difficult to measure directly, modern detectors can measure occupancy, which is a related parameter.

- Occupancy is defined as the proportion of time that a detector is "occupied," or covered, by a vehicle in a defined time period.
In Figure 5.2, $L_v$ is the average length of a vehicle (ft), while $L_d$ is the length of the detector (which is normally a magnetic loop detector).

If “occupancy” over a given detector is “0,” then density may be computed as:

$$D = \frac{5.280 \times O}{L_v + L_d}$$
Microscopic Parameters
While flow, speed, and density represent macroscopic descriptors for the entire traffic stream, they can be related to microscopic parameters that describe individual vehicles within the traffic stream, or specific pairs of vehicles within the traffic stream.
Spacing is defined as the distance between successive vehicles in a traffic lane, measured from some common reference point on the vehicles, such as the front bumper or front wheels.

- Measured in meters.
The *average spacing in a traffic lane* can be directly related to the density of the lane:

$$D = \frac{5,280}{d_a}$$
Time Headway / Headway (h)

- The time between successive vehicles in a traffic stream as they pass some common reference point on the road.
- Measured in seconds.
Flow (Q) & Time Headway (h)

- The *average headway in a lane is directly related* to the rate of flow:

\[ Q \cdot v = \frac{3,600}{h_{ave}} \]
Summary

- Traffic Stream Parameters:
  - Flow (Q)
  - Speed ($v_s$)
  - Density (K)
  - Space headway (s)
  - Time headway (h)
Relationship between the traffic Stream parameters
Consider a stream of traffic with a total flow of $Q$, consisting of subsidiary streams with flows $q_1, q_2, q_3 \ldots q_c$ and speeds $v_1, v_2, v_3 \ldots v_c$.

On Board - Notes
Fundamental diagram of traffic flow
Fundamental diagram of traffic flow

- The relation between
  - Flow(Q) and Density (K)
  - Density(K) and Speed(v)
  - Speed(v) and Flow(Q)
  - can be represented with the help of some curves.

- They are referred to as the fundamental diagrams of traffic flow.

- They will be explained in detail one by one below.
Flow-density curve

1. When the density is zero, flow will also be zero, since there are no vehicles on the road.
2. When the number of vehicles gradually increases the density as well as flow...
When more and more vehicles are added, it reaches a situation where vehicles can't move.

This is referred to as the jam density or the maximum density.

At jam density, flow will be zero because the vehicles are not moving.
Flow-density curve

- There will be some density between zero density and jam density, when the flow is maximum.
- The relationship is normally represented by a parabolic curve as shown in figure.
Flow-density curve

- $q_{max}$
- $k_0$
- $k_1$
- $k_{max}$
- $k_2$
- $k_{jam}$

Diagram showing the relationship between flow and density.
The point O refers to the case with zero density and zero flow.

The point B refers to the maximum flow and the corresponding density is $k_{\text{max}}$.

The point C refers to the maximum density $k_{\text{jam}}$ and the corresponding flow is zero.
Flow-density curve

- OA is the tangent drawn to the parabola at O, and the slope of the line OA gives the mean free flow speed, i.e. the speed with which a vehicle can travel when there is no flow.

- It can also be noted that points D and E correspond to the same flow but have two different densities.
Further, the slope of the line OD gives the mean speed at density $k_1$ and slope of the line OE will give mean speed at density $k_2$.

Clearly the speed at density $k_1$ will be higher since there are less number of vehicles on the road.
Similar to the flow-density relationship, speed will be maximum, referred to as the free flow speed, and when the density is maximum, the speed will be zero.

The most simple assumption is that this variation of speed with density is linear as shown by the solid line in the graph.
Speed-density diagram

- Corresponding to the zero density, vehicles will be flowing with their desire speed, or free flow speed.
- When the density is jam density, the speed of the vehicles becomes zero.
- It is also possible to have non-linear relationships as shown by the dotted lines.
Speed flow relation

- The flow is zero either because there is no vehicles or there are too many vehicles so that they cannot move.
- At maximum flow, the speed will be in between zero and free flow speed.
- The maximum flow $q_{\text{max}}$ occurs at speed $u$. It is possible to have two different speeds for a
Speed flow relation

- The flow is zero either because there is no vehicles or there are too many vehicles so that they cannot move.
- At maximum flow, the speed will be in between zero and free flow speed.
Relationship between traffic stream parameters
Combined diagram
Linear relationship between speed and density

- Greenshields equation for speed and density relation - Follow L.R. Kadiyali for this Topic
- On board – notes

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