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TRAFFIC FLOW CHARACTERISTICS WITH TRANSPORTATION PLANS COMPONENTS

SUMMARY

Knowledge of traffic characteristics is useful to the highway engineer in developing highway and transportation plans, performing economic analyses, establishing geometric design criteria, selecting and implementing traffic control measures, and evaluating the performance of transportation facilities. Dozens of measures have been employed to describe the quality and quantity of traffic flow. This paper presents information on those flow characteristics that fundamentally bear on the planning, design, and operation of highway and transport facilities: traffic speed, travel time, volume, and density.

1. INTRODUCTION

Speed of travel is a simple and widely used measure for the quality of traffic flow. Basically, speed is the total distance travelled divided by the time of travel. Speed is commonly expressed in kilometres (miles) per hour or metres (feet) per second. Its reciprocal, travel time, is usually expressed in units of minutes per kilometre (mile). There are three basic classes or measures of travel speed: spot speed, overall speed and running speed.

2. SPEED AND TRAVEL TIME

Spot speed is the "instantaneous" speed of a vehicle as it passes a specified point along a street or highway. There are practical difficulties in measuring instantaneous speed since, by definition, speed is the distance travelled divided by the travel time. Spot speeds may be determined by manually measuring the time required for a vehicle to traverse a relatively short specified distance. A variety of electromechanical and electronic devices are commonly employed to measure spot speeds. Such devices typically involve some sort of vehicle detectors that have stop timing mechanism, the time of travel or speed being printed on a tape or recorded on a graph.

Radar meters have also been widely used by traffic engineers and enforcement officers to measure spot speeds.

The average of a series of measures of spot speeds can be expressed in two *ways*, as *time-mean speed* and *space-mean speed*. Time-mean speed is the arithmetic mean of speeds of all vehicles passing a point during a specified interval of time. The time-mean speed is

$$\bar{u}_t = \frac{\sum_{i=1}^{n} u_i}{n} \qquad (1)$$

where:

u_i – the observed speed of ith vehicle
n – the number of observed vehicles.

The space-mean speed is the arithmetic mean of speeds of vehicles occupying a relatively long section of a street or a highway at a given instant. It is the average of vehicle speeds weighted according to how long they remain on the section of the road. The space-mean speed is

$$\bar{u}_s = \frac{n\,d}{\sum_{i=1}^{n} t_i} \qquad (2)$$

where:

d – the length of the roadway section
t_i – the observed time for the ith vehicle to travel distance d.

Space-mean speed and time-mean speed are not equal. In fact, Wardrop has shown that

$$\bar{u}_t = \bar{u}_s + \frac{\sigma_s^2}{u_s} \qquad (3)$$

where:

σ_s^2 – the variance of space distribution of speeds.

For general usage, no distinction is normally made between time-mean and space-mean speeds. For theoretical and research purposes, the type of mean should be specified.

Overall speed and *running speed* are speeds over a relatively long section of street or highway between an origin and a destination. These measures are used in

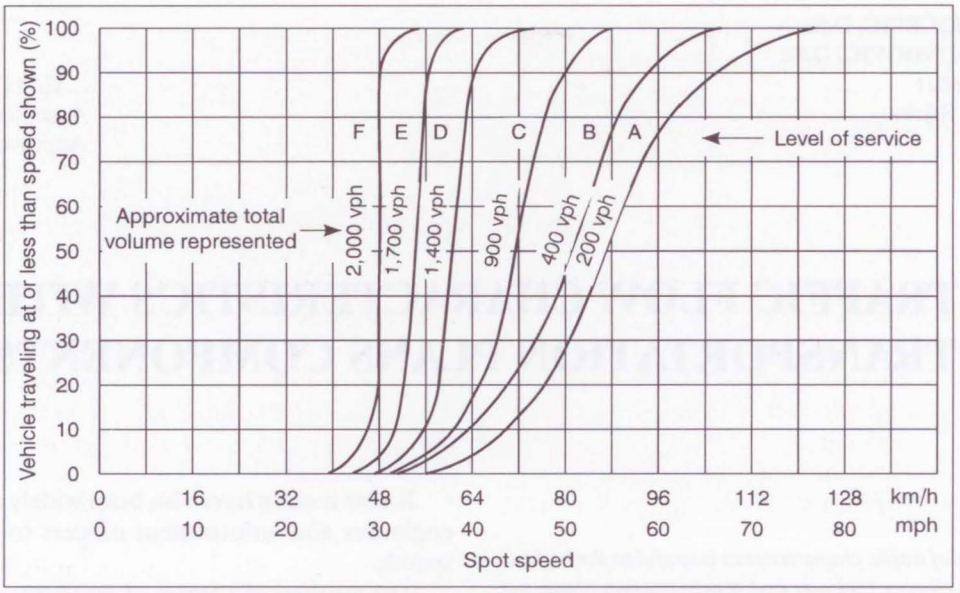

Figure 1 - Typical distribution of passenger car speeds in one direction of travel under ideal uninterrupted flow condition on freeways and expressways. (Courtesy Transportation Research Board.)

travel studies to compare the quality of service between alternative routes. Overall speed is defined as the total distance travelled divided by the total time required, including traffic delays. Running speed is defined as the total distance travelled divided by the running time. The running time is the time the vehicle is in motion; excluding time for stop-delays.

Overall and running speeds are normally measured by means of a test vehicle that is driven over the test section of a roadway. The driver attempts to travel at the average speed of the traffic stream or to "float" in the traffic stream, passing as many vehicles as pass the test vehicle. A passenger uses a stopwatch to record time of travel at various previously chosen points along the course. Distances are usually recorded by the vehicle's odometer. The test drive is repeated several times and the average travel time is used to compute the overall and running speeds.

Spot speeds vary with time, location, and environmental and traffic conditions. Following a petroleum embargo and the subsequent imposition of a nationwide speed limit, the average speed on the main rural highways decreased to 90 km/hr (55.6 mph) in 1983 but has risen gradually since that time. In 1992, the average speed on rural interstate highways was about 95 km/hr (59 mph), but 17.5 percent of the drivers were exceeding 105 km/hr (65 mph).

Speed varies with the quality of traffic service, being generally higher along expressways and other well-designed facilities and during times when traffic congestion is not an influencing factor. Oppenlander found that mean spot speeds along two-lane rural highways were positively related to the lane width and minimum sight distance and negatively related to the degree of curvature, gradient and the number of roadside establishments per mile of highway.

At a given time and location, speeds are widely dispersed and can generally be represented by a normal probability distribution. As Figure 1 illustrates, the range of speeds decreases with the increase in traffic volume.

3. TRAFFIC VOLUME AND THE FLOW RATE

Traffic volume is defined as the number of vehicles that pass a point along a roadway or traffic lane per unit of time. The quantity of traffic flow, volume is commonly measured in units of vehicles per day, vehicles per hour, vehicles per minute, and so forth.

Two measures of traffic volume are of special significance to the highway engineer: average daily traffic (ADT) and design hourly volume (DHV). The average daily traffic is the number of vehicles that pass a particular point on a roadway during a period of 24 consecutive hours averaged over a period of 365 days.

ADT is a fundamental measurement of traffic that is used for determining the vehicle-kilometres (or vehicle-miles) of travel on the various categories of highway systems. Vehicle-kilometres (or vehicle-miles) are important for the development of highway financing or taxation schedules, the evaluation of safety programs, and as a measure of the service provided by a highway transportation system.

The design hourly volume is the future hourly volume that is used for design. It is usually the 30th-highest hourly volume of the design year. Traffic volumes are much heavier during certain hours of the day or year, and it is for these peak hours that the highway is designed.

It has been found that, for the United States as a whole, traffic on the peak day is approximately 233 percent of the annual average daily traffic, and traffic volume during the peak hour is approximately 25 percent of the annual average daily traffic. In order to design a highway properly, it is necessary to know the capacity that must be provided in order to accommodate the known traffic volume.

The relation between peak hourly flows and the annual average daily traffic on rural highways is shown in Figure 2.

Experience has indicated that it would not be economical to design the average highway for an hourly volume greater than that which is exceeded only during 29 hours throughout a year. The hourly traffic volume chosen for design purposes, then, is the one occurring during the 30th-highest hour.

An approximate value of the 30th-highest hour can be obtained by applying an empirically based percentage to the future ADT. The 30th-highest hour, as a percentage of the average daily traffic, ranges from 8 to 38 percent, with an average for the United States of 15 percent for rural locations and 12 percent for urban locations.

Early studies indicated that the relationship between the 30th-highest hour and the annual average daily traffic remained unchanged from year to year. However, later studies suggest that the 30th-highest hour factor has a tendency to decline slightly with time. If this trend continues, appropriate adjustments will have to be made in the design hourly volume for any future year.[1]

Urban arterial flow is characterised by pronounced peaks during the early morning and late afternoon hours, primarily due to commuter traffic. The peaking pattern is not generally evident on weekends, and such facilities experience lowest flows on Sundays. Rural highways tend to experience less pronounced daily peaks, but they may accommodate heaviest traffic flows on weekends and holidays because of recrea-

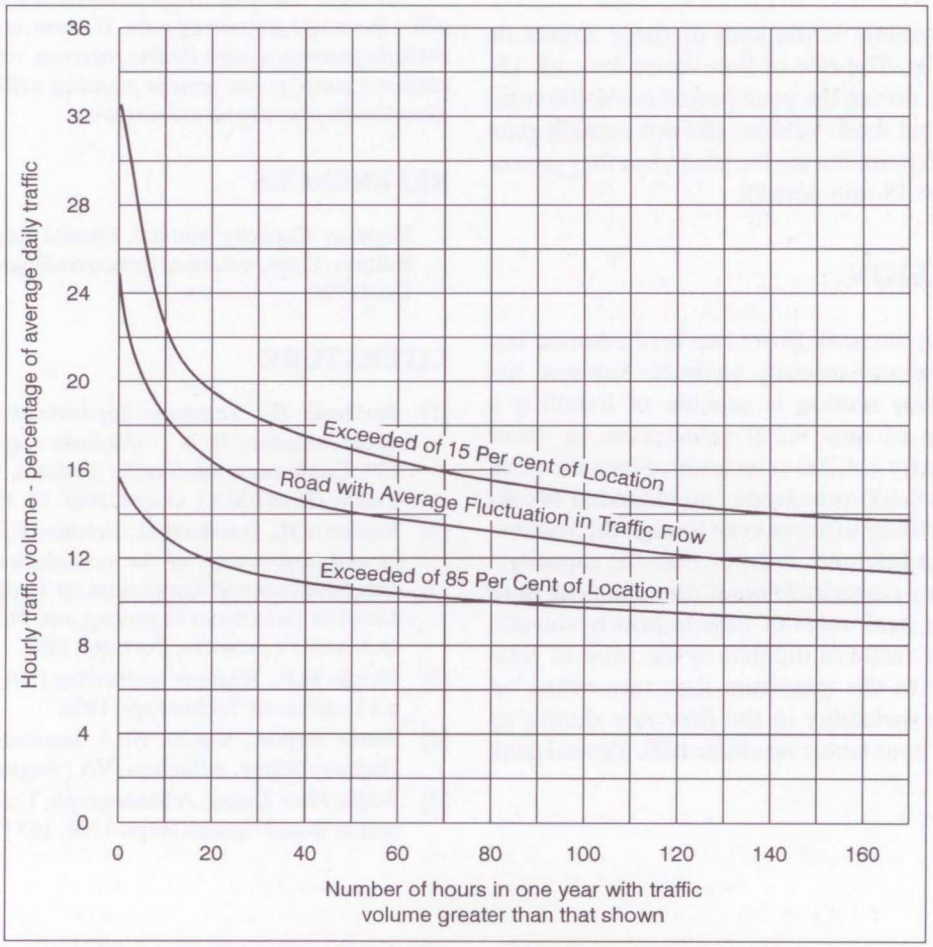

Figure 2 - Relation between peak hourly flows and annual average daily traffic on rural highways. (Courtesy Federal Highway Administration)

tional travel. Highway facilities must generally accommodate heaviest flows during the summer months. Peaks typically occur during July or August. As may be expected, the seasonal fluctuations are most pronounced for rural recreational routes.

The term *of flow* accounts for the variability or the peaking that may occur during periods of less than 1 hr. The term is used to express an equivalent hourly rate for vehicles passing a point along a roadway or for traffic during an interval shorter than 1 hr, usually 15 min.

The distinction between volume and rate of flow may be illustrated by an example. Suppose the following traffic counts were made during a study period of 1 hr:

Time Period	*Number of Vehicles*	*Rate of Flow (vehicles/hr)*
8:00-8:15	1,000	4,000
8:15-8:30	1,100	4,400
8:30-8:45	1,000	4,000
8:45-9:00	900	3,600
Total	4,000	

The total volume is the sum of these counts or 4,000 vehicles/hr. The rate of flow varies for each 15-min period and during the peak period it is 4,400 vehicles/hr. Note that 4,400 vehicles did not actually pass the observation point during the study, but they pass *at that rate* for one 15-min period.

4. CONCLUSION

Considering the peak flow rates is of extreme importance in highway capacity analyses. Suppose the example roadway section is capable of handling a maximum rate of only 4,200 vehicles/hr. In other words, its capacity is 4,200 vehicles/hr. Since the peak rate of flow is 4,400 vehicles/hr, an extended breakdown in flow is likely to occur even though the volume, averaged over a full hour, is lower than the capacity.

The *Highway Capacity Manual* uses the *peak hour factor* to relate peak rates of flow to hourly volume. The peak hour factor is defined as the ratio of total hourly volume to the maximum flow rate within an hour. With no variability in the flow rate during an hour, the peak hour factor would be 1.00. Typical peak hour factors for 2-lane roadways range from about 0.83 to 0.96.

Traffic density, also referred to as traffic concentration, is defined as the average number of vehicles occupying a unit length of roadway at a given instant. It is generally expressed in units of vehicles per mile. Density has not been extensively employed in the past by highway and traffic engineers to describe the traffic flow; however, it is now recommended as the basic parameter for describing the quality of flow along freeways and other multilane highways. It has also been the focus of a number of theoretical and analytical studies.

SAŽETAK

ZNAČAJKE PROMETNOG TOKA KAO KOMPONENTA TRANSPORTNOG PLANIRANJA

Poznavanje prometnih značajki korisno je u transportnom planiranju, u inženjerskom projektiranju autocesta, u predstavljanju ekonomskih analiza, pri utemeljenju kriterija geometrijskog oblikovanja, selekciji i primjeni kontrolnih mjera u prometu, te u vrednovanju pokazatelja transportnih mogućnosti.

Mjerenje i doziranje uvijek se koristilo u iskazivanju kvalitete i kvantitete prometnog toka. U ovom radu prikazane su značajke prometnog toka (brzina prijevoza, vrijeme putovanja, obujam i gustoća) kao temelja planskog oblikovanja i operacionalizacije prometa na autocestama.

REFERENCES

1 Highway Capacity Manual, Special Report 209, Third Edition Transportation Research Board, Washington, DC (1994)

LITERATURE

[1] **Baričević H.**: *Testiranje kapacitivnih rješenja ulične mreže metodom HCS (Highway Capacity Software)*, 17th Conference on Traffic Systems, Automation in Traffic (KoREMA), Osijek, Nov. 19, 1997.

[2] **Baričević H., Dundović Č.**: *Relationship between capacity and performance of the technological transport process*, International Symposium on Traffic Sciences, Fakultet za pomorstvo in promet and Slovensko društvo za znanost v prometu, Portorož 1997.

[3] **Wright H.P.**: *Highway engineering* (6th edition), Georgia Institute of Technology, 1996.

[4] Status Report, Vol.29, No.9, Insurance Institute for Highway Safety, Arlington, VA (August 20, 1994).

[5] *Traffic Flow Theory*, A Monograph, Transportation Research Board Special Report No. 165 (1975).