Small-Car Speeds and Spacings On Urban Expressways

WILLIAM D. WHITBY, Traffic Operations Research Division, U.S. Bureau of Public Roads, Washington, D. C.

•THE Traffic Operations Research Division of the Bureau of Public Roads undertook studies in April and May 1960 to provide general data on small-car speeds and their effect on highway capacity. The studies were limited in scope and were intended as a pilot study to aid in determining the need for, and the areas of, further investigations of small-car behavior.

The objectives parallel those of the Michigan study, however, the methods of obtaining and analyzing the data differ. Four locations were selected in the Washington metropolitan area on four-lane divided facilities of expressway-type design. Three locations were on near-level tangent sections, the fourth location was on a grade. The character and composition of traffic is different for each of the locations. Data for these locations were obtained using the Bureau's traffic analyzer (1) to obtain spot speeds and time spacings. The traffic analyzer automatically records on adding machine tape the speed and precise time of day each vehicle passes the point of observation. Vehicle speed is recorded as travel time in hundredths of a second over the known distance between speed detectors and the time of day is continuously measured in increments of 0.0001 hour. Vehicle classification is observed manually and the vehicle code entered on the adding machine to be printed with the automatic recording.

Table 1 gives the volume range and composition of traffic at the study locations. The total sample obtained for each of three locations was 7,000, 6,500, and 3,200 vehicles, respectively. The combined percentage of foreign and compact cars in the traffic stream was appreciably higher than for the Michigan studies—12 percent as compared to 5 percent.

Study location 1 was on the Washington-Baltimore Parkway at the District of Columbia line. This is a primary inter-urban route which also serves commuter traffic during the peak periods. In this area the posted speed limit is 45 mph and because this is a National parkway, truck traffic is prohibited. The parkway was completed about 1955.

Study location 2 was on the Shirley Highway between Ridge and Glebe Roads in Arlington County, Va. This is a primary through route serving commuter traffic during the peak periods. In the study area the posted speed limit is 50 mph for passenger cars and 45 mph for trucks. This facility was built during World War II and is now designated as an Interstate route.

Study location 3 was on the Mt. Vernon Memorial Highway between the entrances to Washington National Airport. The parkway is a major arterial link between Washington, D.C., and Alexandria, Va., and carries commuter traffic during the peak periods. The posted speed limit at the study location is 40 mph, and because this is a National parkway, truck traffic is prohibited. The parkway was constructed prior to 1940.

A fourth location was selected on the Suitland Parkway, east of Alabama Avenue, to determine the effect of grade. The study location was on a 5 percent grade approximately 1,500 ft in length. Stations were set up at the bottom of the grade, at the beginning of the vertical curve near the crest of the grade, and at a point midway between these two. Stations were operated in pairs for 12 min of a 15-min period and alternated to provide study of all stations equally during the study period. It was necessary to alternate between pairs of stations, due to the fact that the traffic analyzer only has capacity to handle a maximum of four lanes at a time. This parkway serves as an arterial between Washington and government installations in Prince Georges County and also serves

TABLE 1

VOLUME RANGE AND COMPOSITION TRAFFIC[1]

Location	Traffic Flow	Date of Test (1960)	Lane	Vol Range[2]	Traffic: Total (no)	Standard (%)	Compact (%)	Foreign (%)	Small Cars Combined (%)
Wash -Balt Pkwy	North-bound	Apr 25	1	600-1,550	3,831	90 3	4.2	4 6	8 8
			2	340-1,510	3,206	88 5	4 8	5 0	9 8
			1 + 2	940-2,990	7,037	89 5	4 4	4 8	9 2
Shirley Hwg	South-bound	Apr 26	1	620-1,700	3,038	75 6	5 3	8 1	13.4
			2	460-2,020	3,458	82 3	4 9	8.7	13 6
			1 + 2	1,090-3,560	6,496	79 2	5.1	8 4	13 5
Mt Vernon Mem. Pkwy	South-bound	May 4	1	270-820	1,688	81 5	5 1	10 2	15.3
			2	120-1,030	1,544	82 8	6 2	9.3	15.5
			1 + 2	440-1,780	3,232	82 1	5 6	9 7	15 3

[1]Percentages shown do not total 100 percent Difference, not shown, consist of other vehicle types such as trucks and motorcycles

[2]Based on 6-min counts

TABLE 2

AVERAGE SPEED BY TYPE OF VEHICLE

Location	Traffic Flow	Time Period	Volume per Hour: Lane 1	Volume per Hour: Lane 2	Average Speed (mph) Lane 1: Std	Lane 1: Compact	Lane 1: Foreign	Lane 2: Std	Lane 2: Compact	Lane 2: Foreign
Wash -Balt Pkwy	Northbound	2 42 - 4 06	731	474	43 6	44 9	44 8	51 0	50 6	52 3
		4 06 - 5 54	1,310	1,188	42 6	42 2	42 3	49 2	49 0	49 5
		5 54 - 6 30	968	872	43 5	45 3	44 6	50 1	51.7	50 0
		2 42 - 6 30	815	682	43 0	43 4	43 4	49 7	49 4	50 0
		2 42 - 6 30[a]	1,497		46 1	46 3	46 5			
Shirley Hwy	Southbound	2 30 - 3 30	725	605	44 1	42 7	45 3	52 4	52 4	51 1
		3 30 - 4 30	1,049	1,314	41 0	41 6	42.2	47 9	48.1	48 7
		4 30 - 5 00	1,594	1,908	35 1	35 2	34 6	37 7	36 2	36 2
		5 00 - 5 18	1,557	1,950	28 6	31 5	31 4	29 8	32 2	32 1
		2 30 - 5 18	1,085	1,235	38 3	38 8	38 4	43 4	41 6	41 2
		2 30 - 5 18[a]	2,320		41 0	40 2	40 0			
Mt Vernon Mem Pkwy	Southbound	2 30 - 3 30	352	203	40 3	40 0	42.0	45.4	47 3	47 1
		3 30 - 4 30	493	433	40 4	39.9	40 3	44 7	46 8	43.6
		5 00 - 6 12	703	757	40 7	39 5	41 1	45.6	45 3	45 0
		2 30 - 6 12	528	483	40 5	39.6	41 0	45 3	46 0	44 9
		2 30 - 6 12[a]	1,010		42 8	43.0	42 8			

[a]Combined average for both lanes, for the entire study period

TABLE 3

AVERAGE SPEED BY TYPE OF VEHICLE AND STATION, SUITLAND PARKWAY, WESTBOUND (5 PERCENT GRADE)

Lane	Time Period	Average Speed (mph) Station 1: Std.	Station 1: Compact	Station 1: Foreign	Station 2: Std	Station 2: Compact	Station 2: Foreign	Station 3: Std.	Station 3: Compact	Station 3: Foreign
1	7 45 - 9 00	44.9	45.8	44.4	42.4	43.6	38.6	41.2	41.8	40.0
	9·00 - 10:00	43.6	43.4	46.0	42.8	39.0	40.4	42.0	44.1	40.9
	10 00 - 11·00	44.4	45.4	40.6	42.2	41.4	43.6	41.0	42.1	35.6
	7 45 - 11:00	44.4	44.8	43.7	42.4	41.8	40.3	41.4	42.4	39.6
2	7 45 - 9.00	48.8	49 2	46 4	47 2	47 6	45 2	47.6	46.1	48.2
	9 00 - 10·00	47 6	42 6	44.8	45 7	47.1	-	45.9	44.3	46 4
	10 00 - 11 00	43.6	43 8	44.8	45 8	44.8	46.8	45.3	46.1	49.5
	7 45 - 11·00	48.0	46.2	45.8	46 7	47 2	45.8	46.7	45.3	48 2
1 + 2	7:45 - 9·00	46.4	47.5	44.9	44 2	45.1	41.2	43.6	42 5	41.4
	9.00 - 10·00	44.5	43.0	45 8	43.5	42.0	40.4	43.0	44.2	42.3
	10 00 - 11·00	44.3	45.1	41.3	43.6	41 6	45.0	41.7	42.6	42.6
	7 45 - 11 00	45.4	45.3	44 1	43.6	43.4	42 4	42.9	43 0	41.8

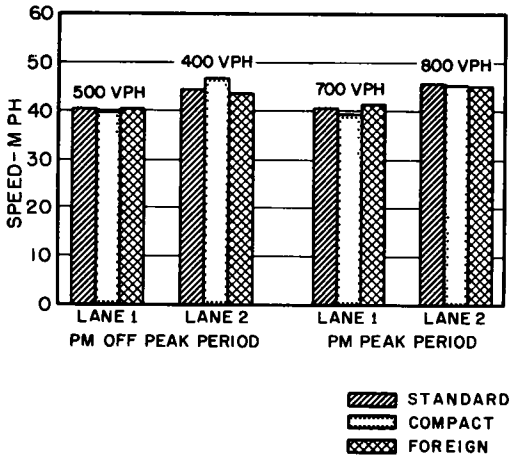

Figure 1. Average speed by type of vehicle and traffic condition, site 1, Mount Vernon Memorial Parkway southbound.

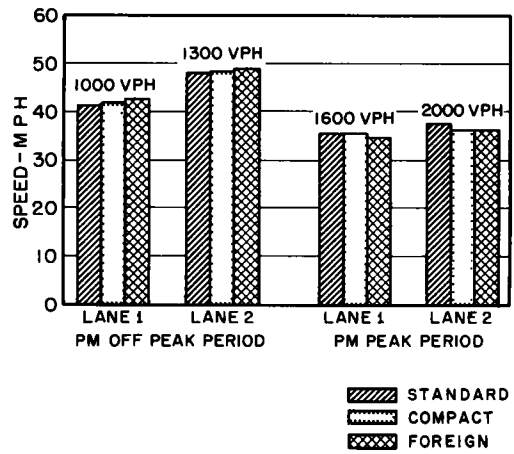

Figure 2. Average speed by type of vehicle and traffic condition, site 2, Shirley Highway southbound.

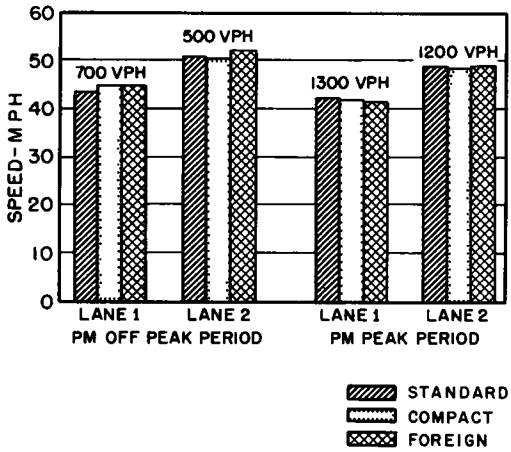

Figure 3. Average speed by type of vehicle and traffic condition, site 3, Washington-Baltimore Parkway northbound.

commuter traffic during peak periods. The posted speed limit is 45 mph and truck traffic is prohibited.

Table 2 gives the average speeds obtained at the tangent locations by vehicle type, time period, volume rate, and lane. Figures 1, 2, and 3 show a comparison of the average speeds by vehicle type for the three locations with insignificant grades. These are based on a sample of approximately 40 percent of the standard cars and all compact and foreign cars. Lane 1 is the outside or curb lane, lane 2 is the median lane.

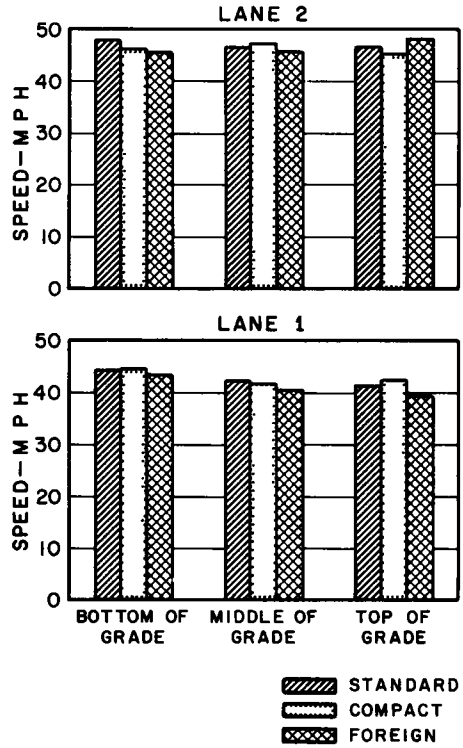

Figure 4. Average speed by type of vehicle and study location, site 4, Suitland Parkway westbound (5 percent grade).

TABLE 4

TIME-SPACING VALUES DETERMINED BY THREE METHODS FOR STANDARD AMERICAN, COMPACT AND FOREIGN PASSENGER CARS

Lane	Location	Date of Test (1960)	Time Period (PM)	Volume (vph)	Avg Speed (mph)	Spacing (sec) 1st Method (BPR) Std	1st Method (BPR) Cmpct	1st Method (BPR) Forgn	2nd Method Std	2nd Method Cmpct	2nd Method Forgn	3rd Method Std	3rd Method Cmpct	3rd Method Forgn	Uniform Spacing This Volume
1	Wash -Balt Pkwy	Apr 25	2 42 - 4 06	731	44 0	4 7	5 7	4 0	6 4	6.4	5 4	8 2	8 8	7 5	5 0
			4.06 - 5 54	1,310	42 5	2 7	2 8	2.5	4 9	5 2	4 4	5 1	5 7	4 9	2 7
			5 54 - 6 30	968	43 8	3.7	3 1	3 7	5 8	6 0	5 6	7 3	7 3	7 3	3 7
	Shirley Hwy	Apr 26	2 30 - 3 30	725	43 8	4 0	5 4	5 5	7 1	5 8	7 2	9 6	9 0	9.2	5 0
			3 30 - 4 30	1,049	41 2	2 6	4 5	4 6	5 4	5 8	6 5	6 0	6 7	7 7	3 4
			4 30 - 5 00	1,594	35 1	2 0	2 3	2 4	4 4	4 1	4 8	4 5	4 5	4 9	2 3
	Mt. Vernon Mem. Pkwy	May 4	2 30 - 3 30	352	40 5	10 0	-	11 8	8 1	7 0	9 3	12.7	8.9	13 0	10 2
			3 30 - 4 30	493	40 4	7 3	4 8	6 4	7 4	7 2	7 8	11 4	11.2	10 3	7 3
			5 00 - 6 12	703	40 7	4 2	5 8	5 6	6 7	6 7	6 7	9 9	10 0	9 2	5 1
2	Wash -Balt Pkwy	Apr 25	2 42 - 4 06	474	49 2	7 7	3 9	6 0	5 6	6 0	5 3	8 4	9 8	7 5	7 6
			4 06 - 5 54	1,188	49 2	3.0	2 7	2 4	4 5	4 5	4 2	5 4	5 9	4 9	3 0
			5 54 - 6 30	872	50 2	4 0	4 8	4 2	4 7	5 0	5 6	6 4	8 6	6 7	4 1
	Shirley Hwy	Apr 26	2 30 - 3 30	605	51 9	4 2	5 6	5 8	7 1	5 8	7 2	9 5	9 5	9.5	6.0
			3 30 - 4.30	1,314	48 1	2 6	1 9	2 8	5 4	5 8	6 5	4 9	4 6	5 2	2 7
			4 30 - 5 00	1,908	37 2	1 8	1 6	1 8	4 4	4 6	4 5	3 8	3 5	4 0	1.9
	Mt. Vernon Mem Pkwy	May 4	2 30 - 3 30	203	45 9	18 1	10 1	14 8	8 1	7 0	9 3	11 8	13 5	9 9	17 8
			3 30 - 4 30	433	44 8	8 2	7 4	6 6	7 4	7 2	7 8	10 0	9 5	10 8	8.3
			5 00 - 6 12	757	45 4	4 0	6 8	5 7	6 8	6 7	6 7	7 5	8 6	8 8	4 8

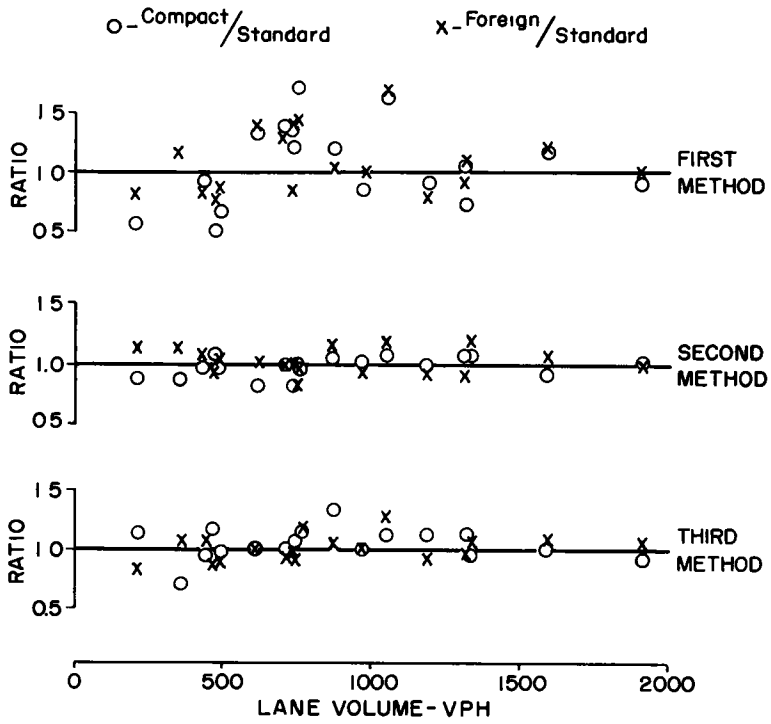

Figure 5. Ratio of time spacings, compact vehicles to standard passenger cars, and foreign vehicles to standard passenger cars, by volume.

Table 3 gives the average speed obtained at the grade location by lane, station, time period, and type of vehicle, and Figure 4 shows a comparison of the speeds by vehicle type.

TABLE 5

HEADWAYS OBTAINED FROM USING QUEUES, SHIRLEY HIGHWAY, SOUTHBOUND, APRIL 26, 1960

Time (PM)	Lane	Traffic Vol. (vph)	Uniform Spacing (sec)	Vehicle Type	Vehicle No.	Headway[1] (sec) 1	2	3	4
2:30 - 3:30	1	725	5.0	Compact	4	4.1	2.2	3.8	4.1
				Foreign	14	5.5	4.6	6.1	4.8
	2	605	6.0	Compact	12	5.7	5.3	3.7	6.3
				Foreign	19	7.3	3.8	6.2	4.6
3:30 - 4:30	1	1,049	3.4	Compact	22	2.6	3.3	2.5	2.6
				Foreign	29	2.8	3.4	4.1	3.3
	2	1,314	2.7	Compact	32	3.1	2.7	2.0	2.4
				Foreign	44	2.6	2.1	2.8	3.0

[1]Headway 1 Standard-Standard (end of queue); Headway 2 Standard-Small, ahead; Headway 3 Small-Standard, ahead; Headway 4 Standard-Standard (beginning of queue).

There appears to be no great difference in speed or consistent trend toward a higher or lower speed for compact or foreign cars as compared to standard American passenger cars at any of the locations. The tables do show the normal difference in speed associated with varying volume. There is also an expected difference in speed between lanes 1 and 2, the difference being about the same for each vehicle size.

Spacing values were calculated for the several study locatins. Three different procedures were used to determine the space occupied by the small cars in the traffic stream. The first calculation was based on the formula used by the Bureau of Public Roads for determining the passenger car equivalents of commercial vehicles. This method utilizes the complete range of time spacings, introducing a possible bias due to the large spacings at lighter volumes. The second method was used to remedy this bias. Here spaces exceeding 20 time units, approximately 6 sec, were eliminated and only those spaces involving passenger cars were used. Finally, a third analysis was made which did not attempt to determine an actual time-space value but attempted to determine the average gap used by each type. The time space ahead and behind a vehicle was tabulated and the average (a + b) value calculated for each type. The vehicle ahead and behind had to be a standard passenger car and all values exceeding 20 sec were eliminated.

Table 4 gives the time-space values, in seconds, obtained by the three methods. The volume rates and average speed for the condition under which these values were obtained is also shown. Figure 5 shows the ratio of time space for compact and foreign cars as related to the standard passenger car, obtained by the three methods at varying volume rates. A comparison of the time-spacing and time-space ratios does not show any consistent difference in spacing for the small cars. The ratios show compact and foreign car spacings to be scattered and both higher and lower than standard car spacings. There is the normal decrease in the average spacing for all vehicle types with increase in volume. However, the ratio of the space occupied by standard cars and small and compact cars remains quite uniform.

After review of the paper by Forbes and Wagner, a limited analysis based on two hours of the study on Shirley Highway was done on a comparable basis to the Michigan study. This involved determination of headways, where the small car was in the middle of a five-car queue. Table 5 gives the values obtained by using a method similar to that used by Forbes and Wagner. Again there is no apparent trend in the data to signify a difference for small cars.

The data presented here represents traffic having a higher percentage of small cars than shown in the Michigan study and the use of a larger number of vehicles in this

preliminary analysis. The data in both studies indicate that there is no significant difference between the operation of standard cars and the small cars as measured by their speed and spacing.

These studies were limited to highways that would be classed as urban expressways. It is possible that further research, where consideration is given to the effect of the small cars on city streets and on open rural highways where the average speed more nearly approaches the speed capabilities of the small cars, could yield valuable information for the determination of the over-all influence of small cars on driver behavior.

REFERENCE

1. Taragin, A., and Hopkins, R. E., "A Traffic Analyzer: Its Development and Application." Public Roads, 31:5, pp. 120-124.