EFFECT OF VEHICLE SIZE ON THE CAPACITY OF KHULNA JESSORE HIGHWAY

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ABSTRACT

This report represents the results of a study undertaken to determine the capacity of an interrupted-flow highway . The adequacy or sufficiency of existing highway networks in service to current traffic will not be known until an accurate value of basic capacity is used in capacity analysis procedures. This study was undertaken as a stepping stone towards the determination of the basic capacity of interrupted flow highway facilities in Khulna–Jessore National Highway, Bangladesh.. The study involves investigating the characteristics of the actual time headways (spacing) adopted by drivers in the traffic stream under prevailing conditions. The reciprocal of the mean time headways adopted by passenger cars under capacity flow conditions has been used in the estimation of the basic capacit. Passenger car equivalents (PCEs) for medium and large sized vehicles have been calculated. Results of the study indicated that the value of basic capacity was 712 vph or 803 passengers cars per hour per lane (pcphpl) on the basis of equivalent hourly flow rate approach and using 15-minute mean time headway the capacity was 706 vph . PCEs for medium and large sized vehicles were obtained as 1.23 and 2.05 respectively.

Keywords: *Capacity, interrupted flow, multilane highway, time headway, passenger car equivalent*

1. INTRODUCTION

After conducting extensive studies, the U.S. highway capacity manual 2000 (trb, 2000) retained the value of 2,000 passenger cars per hour per lane(pcphpl) as the basic capacity for freeways and multilane highways, and also stated that it was the representative even though higher flows of 2,300 pcphpl were obtained on a regular basis on some highways. Until an accurate value of basic capacity to the highways for a particular country is obtained, capacity analysis cannot be conducted properly and the traffic growth may result in an undesirable degree of congestion (Branston, 1977). In bangladesh, highway capacity manual has not yet developed. Moreover the vehicle mix and driving habits between Bangladesh and USA are different. Because of this, this study is conducted to determine the capacity of the khulna-jessore national highway. The data were collected between religate and fulbarigate of khulna-jessore national highway. The site was located 500 meter away from fulbarigate and very close to k.b. filling station. At the data collection site, the highway consists of two lanes. Each of the lanes serves all type of traffics.

2. METHODOLOGY

2.1 Data Collection

Due to the constraints of cost and time, only one location on the Fulbarigate of Khulna-Jessore National Highway was considered in this study. As this study involved investigating the effect of the sizes of vehicles on capacity, data was collected so as to include different periods of flow as shown in details of the data collection schedule in Table 3.1. A digital video-camera (Model: WS9) was employed to make video recordings of the traffic flow. On Wednesday, July 1, 2015 at 5.00 pm a reconnaissance survey was made to ascertain which location for the camera and the reference marks would be most appropriate. The video recording was then viewed the same day and alterations that were deemed necessary as to the angle of camera and the placement of the markers were made the next day of data recording. However ,on Monday, July 6, data were recorded at 8.00 am-10.00 am and 11.30 am-1.00 pm. On next Wednesday, July 8, 2015 data were recorded at 4.00 pm-5.00 pm and 5.05 pm-6.05 pm. The subsequent video recordings then proved to be ideal, when viewed on the computer screen , for purposes of data extraction. The times of commencement and termination were noted when the

recordings were executed. More than two-hour duration video memory card were used. Since the battery had to be replaced every hour, approximately 5 to 10 seconds were lost during each period of recording.

2.2. Time Measurement

The primary data used in this study were the average mean time headways adopted by various types of vehicles collected in the form of time headways defined as the time in seconds for the rear bumper of two successive vehicles in the same lane to pass a common reference point. Data were captured using a video camera, and later the videotape was rerecorded to dub the time in seconds with a video timer the computer was used to play the video clips. When the video clip was played, lines were precisely drawn on the television screen to connect the reference marks placed on the highway. Times taken to pass these reference lines were observed for each vehicle and the type of vehicle was visually classified. All the values were manually recorded on observation sheets. From these time of every type of vehicle following each other the headway was measured.

2.2.1 Headway Classification

For the purpose of this study, vehicles were classified into three major types: small (S), medium (M), and large (L). All passenger cars were classified as small vehicles (S); vehicles that were larger than passenger cars, such as vans and pickups having only four wheels, were classified as medium- sized vehicles (M); and all other vehicles were classified as large (L). All buses (city buses and intercity buses) were included in the large category. Nine different headway types (headway based on the sizes of leading and following vehicles involved in the headway interaction) were classified and coded:

i. Small-sized vehicle followed by small-sized vehicle (S-S).
ii. Small-sized vehicle followed by medium-sized vehicle (S-M).
iii. Small-sized vehicle followed by large-sized vehicle (S-L).
iv. Medium-sized vehicle followed by small-sized vehicle (M-S).
v. Medium-sized vehicle followed by medium-sized vehicle (M-M).
vi. Medium-sized vehicle followed by large-sized vehicle (M-L).
vii. Large-sized vehicle followed by small-sized vehicle (L-S).
viii. Large-sized vehicle followed by medium-sized vehicle (L-M).
ix. Large-sized vehicle followed by large-sized vehicle (L-L).

By using these headway passenger car eqivalents were estimated with the help of Krammes & Crowley equation.

3. ILLUSTRATION

The average headway for each vehicle types are measured as shown in table1 & table2. From these table it is seen that headway increases with the increase of vehicle sise.

A comparison of the peak 5 and 15-minute rates of flow was conducted for the four periods of observation made during the course of this study on a lane by lane basis. Previous studies (1985 hcm and roess and mcshane, 1987) have stressed that the 5-minute rates of flow were statistically unstable and hcm based its analysis procedures on 15-minutes rates of flow. The results of the comparison between 5 and 15-minute rates of flow are shown in table 3. The results show that average difference in the value of the equivalent hourly rates of flow for the left and right lanes are 7.20% and 9.57% respectively. The overall values for the combination of all the lanes is 8.38%. The results indicate that the largest variability was in the left lane with values ranging from 0.68% to 12.35%. The difference is quite substantial due to the combination of off-peak flows and flow approaching capacity. The basic capacity of the study route (Highway No.7) was determined by considering the reciprocal of the average mean headway time adopted by small vehicles following small vehicles (S-S). The analyses of the average mean headway times between these small vehicles and other types of vehicles are presented in Tables 1 & 2.So the primary variable used in the study to estimate capacity was the time headway. The difference between the average minimum time headway for peak 5 and 15-minute flow periods and a comparison of the values of capacity for the mixed traffic stream is presented in Table 4. An analysis of the average minimum time headways adopted by each type of vehicle is contained in Tables 1 & 2. From the results of this analysis, it can be seen that the average mean time headway adopted by small-sized vehicles following small-sized vehicles (SS), during the peak 15-minute period is 4.56 seconds, the reciprocal of which yields a basic capacity value of 754 passenger cars per hour. The average minimum time headway adopted by small-sized vehicles following small-sized vehicles (S-S), during the peak 5-minute period is 4.00 seconds, the reciprocal of which yields a basic capacity value of 900 passenger cars per hour. Table 5 summarizes the values of average minimum time headways adopted by small-sized vehicles following small-sized vehicles (S-S) during the peak hour of flow considered for both 5 and 15-minute periods.

Table 1: Headway analysis for 5 min flow

Time	Lane		Headway									Average headway(sec)
			S-S	S-M	S-L	M-S	M-M	M-L	L-S	L-M	L-L	
8.00 am-	Left	No.	39	3	2	3	0	0	2.00	0	0	5.80
10.00 am		H	6.18	4.33	3.00	11.0	-	-	4.50	-	-	
	Right	No.	39	3	3	4	0	0	2.0	1	0	4.34
		H	6.18	4.00	2.33	6.50	-	-	5.00	2.00	-	
11.30am-	Left	No.	41	6	4	7	3	0	3	1	0	4.70
1.00 pm		H	4.80	3.00	2.50	4.29	5.00	-	5.33	8.00	-	
	Right	No.	38	5	4	5	0	0	4	0	0	5.78
		H	5.34	7.40	7.50	3.40	-	-	5.25	-	-	
4.00 pm-	Left	No.	25	2	5	2	0	3	6	0	0	6.18
5.00 pm.		H	7.56	8.33	4.50	3.67	-	7.50	5.50	-	-	
	Right	No.	36	3	3	2	1	1	4	0	1	6.43
		H	5.39	6.33	11.00	7.50	5.00	4.00	4.25	-	8.00	
5.05 pm-	Left	No.	33	4	6	5	0	0	5	1	0	4.70
6.05 pm		H	6.12	5.75	5.50	6.40	-	-	3.40	1.00	-	
	Right	No.	48	5	6	3	0	0	5	4	0	4.18
		H	4.00	3.50	5.50	5.00	-	-	3.60	3.50	-	

Table 2 : Headway analysis for 15 min flow

Time	Lane		Headway									Average headway(sec)
			S-S	S-M	S-L	M-S	M-M	M-L	L-S	L-M	L-L	
8.00 am-	Left	No.	103	9	12	10 6.5	0	0	11	1	0	5.86
10.00 am		H	6.31	5.89	7.08		-	-	4.36	5.00	-	
	Right	No.	102	6	8	7	0	0	7	1	1	4.67
		H	4.90	3.50	6.88	4.71	-	-	4.71	2.00	6.00	
11.30am-	Left	No.	121	10	13	9	5	0	12	1	1	5.07
1.00 pm		H	5.20	3.80	5.31	4.00	5.60	-	5.67	6.00	5.00	
	Right	No.	115	10	9	11	1	0	9	1	0	6.53
		H	5.78	6.7	8.56	2.73	15.00	-	5.00	2.00	-	
4.00 pm-	Left	No.	75	7	12	8	2	1	12	2	2	6.01
5.00 pm.		H	4.20	4.43	7.00	4.88	7.50	8.00	6.42	3.65	8.00	
	Right	No.	93	6	15	7	1	1	14	1	7	6.24
		H	4.28	4.17	6.47	5.86	5.00	4.00	6.64	12.00	7.71	
5.05 pm-	Left	No.	106	7	9	8	1	0	8	1	2	5.34
6.05 pm		H	3.63	3.43	5.78	4.75	4.00	-	5.13	7.00	9.00	
	Right	No.	128	7	14	7	0	3	13	4	2	5.10
		H	4.78	4.43	6.29	5.59	-	3.45	7.69	3.50	5.00	

Table 3: Comparison of 5 and 15-Minute Rates of Flow

Time	Lane	Rate of flow (vph)		
		5 min	15 min	% difference
8.00 am-10.00 am	Left	588	584	0.68
	Right	624	568	8.97
11.30 am-1.00 pm	Left	780	688	11.79
	Right	672	624	7.14
4.00 pm-5.00 pm	Left	504	484	3.97
	Right	612	580	5.23
5.05 pm-6.05 pm	Left	648	568	12.35
	Right	852	712	16.43

Table 4 : Comparison of 5 and 15-Minute Headway and Capacity

Time	Lane	Headway (sec)			Capacity (vph)	
		5 min	15 min	% difference	5 min	15 min
8.00 am-	Left Right	5.80	5.86	1.02	621	615
10.00 am		4.34	4.67	7.07	830	771
11.30 am-	Left Right	4.70	5.07	7.30	766	710
1.00 pm		5.78	6.53	11.49	623	552
4.00 pm-	Left Right	6.18	6.01	5.36	583	599
5.00 pm		6.43	6.24	4.17	560	577
5.05 pm-	Left Right	4.70	5.34	9.96	766	675
6..05pm		4.18	5.10	18.04	862	706

Table 5: Summary of Head way Observations (S-S)

Item	Duration of peak flow	
	5 min	15 min
Mean headway (H)	4.00	4.78
Standard deviation	2.77	5.06
95 percent confidence interval for the mean	3.2 <H<4.80	3.96<H<5.60
Number of observations	48	128

From the mean headway estimated for small-sized vehicles followed by small-sized vehicles (S-S) headway type, for peak 15-minute flow on the right lane with no large vehicle present , the 95% confidence interval for the maximum volume is observed to be 909 to 643 with a mean of 776 passenger cars per hour (pcph). Similarly, for the mean headway estimated for small-sized vehicles followed by small-sized vehicles (S-S) headway type, for peak 5-minute flow on the right lane with no large vehicle present , the 95% confidence interval for the maximum volume is observed to be 1125 to 750 with a mean of 938 passenger cars per hour (pcph). In order to be on the conservative side while estimating the value of capacity, the value of capacity obtained by considering the headway for the 15-minute flow is considered to be the representative value of this study.

The passenger car equivalent was estimated depending on this formula which was given by Krammes and Crowley (1987).

$$PCE = [(1-p)(H_{L-S}+H_{S-L}-H_{S-S}) + p(H_{L-L})]/H_{S-S} \quad (1)$$

Table 6: Estimation of PCE Values

Vehicle type	PCE values (off-peak hour)		PCE values (peak hour)	
	Left	Right	Left	Right
Large	2.16	2.03	2.04	1.97
Medium	1.23	1.33	1.24	1.13

The results indicate that medium-sized vehicle slightly affect the lane capacity. If the values for two time periods considered for calculations of the PCEs were to be averaged, the resulting PCE value for medium-sized vehicles would be 1.23. This in turn suggested that the operating capabilities of medium-sized vehicles such as vans are slightly inferior to those of passenger cars. These findings also corroborate the findings made in the previous section that medium-sized vehicles are not significantly different from small vehicles.

The results also indicate that for large-sized vehicles the value of PCE, averaged for the two time periods, should be 2.05. However, it should be noted that the definition of "large" in this study includes buses, trucks, trailers,etc. Branston (1977) noted that it would not be meaningful to combine values for different commercial vehicle types to obtain a composite "heavy" commercial vehicle PCE, since its magnitude would depend largely on the different commercial vehicle types. Huber (1982) also noted that a PCE value for trucks does not adequately reflect the diverse characteristics of vehicles that may be observed in the traffic stream.

The lane use is known to affect the capacity adversely if no regulations exist as to the lanes the different types of vehicles are permitted to use. In this study site both lane was used to large sized vehicles. However, it was observed that a stubborn were still persistent in using this lane. From the lane distribution by vehicle type, obtained by considering all the vehicles observed throughout the peak and off-peak period of this study, as shown in Table 4.4 and 4.5

Table7: Lane Distribution by Vehicle Type

Vehicle type	peak hour		off-peak hour	
	Left	Right	Left	Right
Small (%)	85.91	83.28	81.43	80.19
Medium(%)	6.04	6.46	7.38	6.73
Large(%)	8.05	10.26	11.18	13.08

From the table it is clear that both peak and off-peak hour small vehicle dominant the lane use and the number of medium vehicle is very small amount. The more conservative following behavior of small and large-sized vehicles on the lanes largely explains why the average time headway of all vehicles is larger than the average time headway of small and large-sized vehicles on the lanes. It should be noted that at the time of data collection, trucks were permitted to use the lanes.

4 . CONCLUSIONS

The value of the basic capacity during a peak 15-minute interval was 706 vph based on reciprocal of minimum time headway approach and 712 vph or 803 passenger cars per hour per lane (pcphpl) adopted on equivalent hourly flow rate. The PCEs for large and medium sized vehicles are estimated as 2.05 and 1.23 respectively. From headway analysis it is seen that the capacity decreased on the increasing of large vehicle since it takes more time to pass a common reference point than small vehicle. The proportion of large vehicles in the traffic lane affects the average headways of all types of vehicles. The average headways are seen to increase with an increase in the percentage of large vehicles. This in turn leads to a reduction of the capacity of the traffic lane.

REFERENCES

Branston, D. (1977). Some Factors Affecting the Capacity of a Motorway. *Traffic Engineering and Control*, 18(6), 304-307.

Branston,D. (1974). Models of Single Lane Time Headway Distribution. *Transportation Science*, 10(2), 125-148.

Chang, M.S., and Kim, Y.K. (2000). Development of Capacity Estimation Method from Statistical Distribution of Observed Traffic Flow, *Proceedings: Fourth International Symposium on Highway Capacity*, 299-309.

Drake,J.,Schofer,J., and May,A. (1967). A Statistical Analysis of Speed Density Hypotheses. Highway research Record 154, Transportation Research Board, Washington, D.C., 53-87.

Duncan, N.C.(1979). A Further Look at Speed/Flow/Concentration, *Traffic Engineering and Control*. 20, 482-483.

Hall, F. L., Allen, B. L., and Gunter, M. A. (1986). Empirical Analysis of Freeway FlowDensity Relationships. *Transportation Research A*, 20(3), 197-210.

Highway Capacity Manual, (2000), Transportation Research Board, Washington, D.C.

Highway Capacity Manual, Special Report 87 (1965), Transportation Research Board, Washington, D.C.

Highway Capacity Manual, Special Report 87 (1985), Transportation Research Board, Washington, D.C.

Huber, M. J. (1982). Estimation of Passenger Car Equivalents of Trucks in Traffic Stream. Transportation Research Record 869, *Transportation Research Board*, National Research Council, Washington, D.C., 60-70.

Japanese Highway Capacity Manual (1984). Japanese Road Association.

Krammes, R.A., and Crowley, K. W. (1987). Passenger Car Equivalents for Trucks on Level Freeway Segments. *Transportation Research Record 109*, Transportation Research Board, National Research Council, Washington, D.C., 10-16.

Murata, T., and Hashimoto, K. (1987). Characteristics of Traffic Flow on Basic Segments of the Tomei Expressway (in Japanese). *Expressways and Automobiles*, 30(2), 20-30.

Norman, O. K., and Walker, W. P. (1949). Highway Capacity: Practical Applications of Research. *Public Roads*, 25(10), 237-277.

Pignataro, L. J. (1973). *Traffic Engineering Theory and Practice*. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Radwan,A.E., and Kalevala, S. A. F. (1986). Investigation of the Effect of binge in Vehicular Characteristics on Highway Capacity and Level of Service. *Transportation Research Record 1005*, TRB, National Research Council, Washington,D.C., 65-71.

Roess, R.P., and McShane, W.R. (1987). Capacity and Level of Service Concepts in the Highway Capacity Manual. *ITE Journal*, 57(4), 27-30.

Schofield, M. (1986). Speed, Flow and Capacity on the M6 Motorway. *Traffic Engineering and Control*, 27(10), 509-513.

Walpole, R.E., and Myers, R.H. (1978). *Probability and Statistics for Engineers and Scientists*. Macmillian Publishing Co. Inc., New York.

Wasilewski, P. (1974). The Semi-Poisson Headway Distribution Model. *Transportation Science*, 8, 237-247.