The Phenomenon of High-Speed-Car-Following on Chinese Highways

M. GUO and Z. WU

ABSTRACT

Traffic videos were taken from four Chinese highways and the high-speed-car-following phenomenon was studied. The impacts of location, lane and vehicle classification were analyzed. Two types of high-speed-car-following and the relation with lane-changing were indicated.

INTRODUCTION

Traffic flow is of complicated nonlinearity. It is well known that the nonlinearity mainly manifests as the stop-and-go phenomenon under high density, while the relationship between speed and density is linear under low density. However we find that the nonlinearity also exists under low density, which manifest as the high-speed-car-following (HSCF) phenomenon. This phenomenon is defined as some vehicles running fast with considerably low headway when the traffic is smooth in general. Thus the traffic flow alternate between denseness and sparseness intermittently.

A number of important research achievements of traffic flow are based on the actual measurement data, such as three-phase traffic theory [1]. In recent years, Next Generation Simulation (NGSIM) trajectory data collected from traffic videos have been playing an important role [2-5]. With the same thinking, we have taken about 200 hours traffic video from urban expressways in four cities and 100 hours from four intercity highways in China. The results of measurement on urban expressways have been published [6-7]. This paper discusses the HSCF on the intercity highways.

DATA SETS

The detailed information of the data samples are listed in Table I. Two of the highway segments are near the urban area (NU), while the other two are far away from the urban area (FU). The sampling method from traffic video and error estimation are referred to [7]. All the data constitute seven samples. In sample 6, only one representa-

Mingmin Guo, Department of Mechanics and Engineering Science, Fudan University, Shanghai, China.

TABLE I. DATA SAMPLES.

Sample No.	Highway	Shooting location	Number of lanes	Shooting time	Number of vehicles	Speed (m/s)	Headway (m)
1	G2	West of Shanghai Jiangqiao toll gate (NU)	4	2012/04/03 14:45-16:12	4284	26.6	33.8
2	G2			2012/05/04 15:06-16:36	4914	26.0	36.1
3	G2			2012/06/06 07:47-11:49	11588	24.5	38.4
4	G15w	On both sides of Jiaxing Xiangxian Bridge (FU)	2	2012/03/28 08:01-09:43	1387	25.6	37.3
5	G15w			2012/09/08 08:08-09:59	1652	26.0	35.3
6	G45	North of Beijing Shaoyaoju subway station (NU)	2	2011/07/07 15:43-17:55	----	16.8	40.9
7	G60	South of Jiaxing Wangdian service area (FU)	4	2011/07/26 14:14-18:12	4357	26.3	39.9

TABLE II. NUMBER OF CARS AND TRUCKS.

Sample No.	Car		Truck	
	Number	Proportion	Number	Proportion
3 (09:37-11:24)	3596	77.15%	1065	22.85%
4	950	68.49%	437	31.51%
7	3269	75.03%	1088	24.97%

tive vehicle in each image frame was collected, while in the other six samples, all the vehicles in each image frame were collected.The average speeds of all the samples except for sample 6 are significantly greater than our results from urban expressways [6] and the results of NGSIM data in references [2-5], which means the traffic situations in this study are different from those studies.

The vehicle classifications were collected as well in sample 3 (09:37-11:24), 4 and 7, where the vehicles are categorized into cars or trucks, as listed in Table II. The proportion of trucks is higher than 22% at least. There were few trucks in sample 6, due to this segment is very close to the urban area and can be treated as an urban expressway. The proportions of heavy vehicles in I-80 and US-101, the frequently-used NGSIM data, are 2.2% and 3.8% respectively [4], which are much less than sample 1-5 and 7, maybe close to sample 6.

RESULTS AND ANALYSIS

Time headway (h_t) is the time difference between two successive vehicles passing the same location. In this paper, the ratio of space headway to speed can be considered as an approximation of h_t. Table III lists the number of total vehicles, the number of vehicles with small time headway and the corresponding ratios. The percentages of $h_t \leq 2$s and $h_t \leq 1$s are remarkable for all the four locations, even though the flow rate of sample 7 is only 274 veh/hr/lane. The percentages of $h_t \leq 2$s and $h_t \leq 1$s of NU samples are usually greater than those of FU samples due to the higher flow volume. As to sample 6, because of the sampling method, the statistics is based on the data size instead of the number of vehicles. Two qualitative conclusions can still be drawn: the vehicles with small h_t are not rare, higher than FU samples definitely; the percentage of $h_t \leq 2$s is much greater than that of $h_t \leq 1$s, which indicates that the drivers are more inclined to follow the leading vehicle tightly in this segment due to the high density and low speed.

TABLE III. TIME HEADWAYS OF EACH SAMPLE

Sample No.	Total number of vehicles	Time headway ≤ 1		Time headway ≤ 2	
		Number of vehicles	Proportion	Number of vehicles	Proportion
1	4284	498	11.62%	1348	31.47%
2	4914	429	8.73%	1403	28.55%
3	11588	899	7.76%	2413	20.82%
4	1387	80	5.77%	289	20.84%
5	1652	115	6.96%	322	19.49%
6	14402	948	6.58%	6598	45.81%
7	4357	122	2.80%	394	9.04%

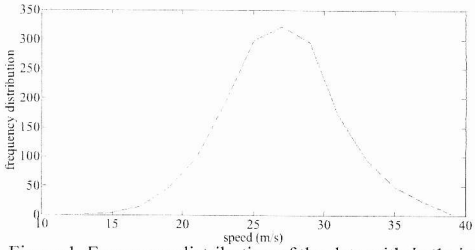

Figure 1. Frequency distribution of the data with $h_t \leq 1$s in sample 3 for different speed range.

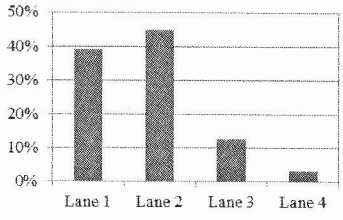

Figure 2. Proportion of the vehicles with $h_t \leq 1$s in sample 3 for each lane.

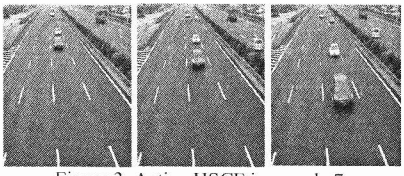

Figure 3. Active HSCF in sample 7.

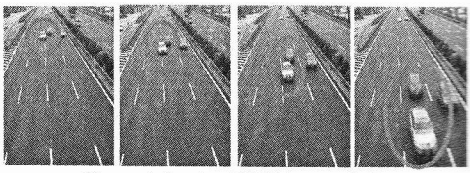

Figure 4. Passive HSCF in sample 7.

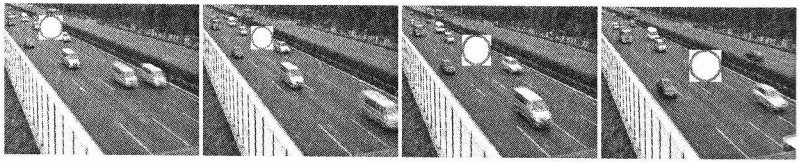

Figure 5. Four consecutive image frames from sample 3.

The frequency distribution of the data with $h_t \leq 1$s in sample 3 for different speed range is shown in Figure 1. It has a single peak, similar to the normal distribution. Most data are distributed at the speed higher than 20m/s, and the peak is located between 25m/s and 30m/s. So the small time headways are relevant to the driving behavior of high speed and small spacing. That's why we call it high-speed-car-following. This high-risk behavior on Chinese intercity highways cannot be ignored.

The distribution of HSCF vehicles on each lane in sample 3 is shown in Figure 2. Over 86% of the vehicles with $h_t \leq 1$s occur in lane 1 and 2, while only 3.45% in lane 4. On the intercity highway, cars run mainly in the fast lanes and trucks run mainly in the slow lanes. Therefore Figure 2 indicates that most of the HSCF vehicles are cars. Between 09:37 and 11:24 in sample 3, 258 cars with $h_t \leq 1$s were observed; at the same time only 13 trucks were observed to have $h_t \leq 1$s. Furthermore, HSCF cars

basically follow cars rather than trucks. Among the 258 HSCF cars, only 2 of them followed trucks. However, among the 13 HSCF trucks, 7 of them, travelled after cars.

The HSCF can be roughly classified into two types: active HSCF and passive HSCF. Figure 3 gives an example of active HSCF. The car highlighted by a red circle, whose speed was 32m/s, kept the HSCF state with h_t less than 0.7s. Figure 4 gives an example of passive HSCF, which was caused by lane-changing and overtaking. The speed of the rear highlighted car was higher than 30m/s, while its h_t was even less than 0.4s in the last two images. The HSCF often makes the rear vehicle's driver take a lane-changing maneuver as well, as shown in Figure 5. The highlighted car with speed of 29m/s and h_t of 0.5s, changed from lane 1 to lane 2. So we believe that the HSCF is closely related to the lane-changing behavior, and this disturbance enhances the non-linearity of traffic flow.

CONCLUSIONS

The high-speed-car-following phenomenon on four Chinese highways was investigated on the basis of time headways which were calculated from the traffic videos. The HSCF, such a dangerous driving behavior, has a relatively high frequency of occurrence. It happens more often in NU than in FU. And most of the HSCF vehicles are cars instead of trucks, which mainly run in the fast lanes. The HSCF can be classified into active type and passive type. The latter type is caused by lane-changing, and HSCF may also cause the lane-changing maneuver.

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