Operational Characteristics of Weaving Sections in China

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ABSTRACT

The efficiency of traffic operation in highway weaving sections is a key factor to the capacity of the whole highway system, hence highway system planners, designers and engineers are concerned mostly on the design, analysis or operation management of weaving sections. The capacity and level of service of weaving sections are the issues frequently discussed in transportation analysis. In order to establish a Chinese Highway Capacity Manual, an effort as part of the work has been started to develop an analysis/ design procedure of highway weaving sections in China. However, the complex and tense lane-change maneuver in the section causes the traffic operation very different from other components of highway system, so the characteristics of the operation must be studied first in order to analyze or conduct problems of highway weaving sections. Sponsored by the Ministry of Communication of PRC, an operational study effort was conducted. The authors present the field data collection process and the results in this paper. The field data includes measurements such as traffic volume, travel speed, lane distribution of volume, acceleration and deceleration and so on. According to the field data, the authors analyze the operational conditions and situation in weaving sections in China.

Keywords: Traffic Operation, Weaving Sections, Highway Capacity, Level of Service

1. INTRODUCTION

Weaving area always occurs when two or more vehicle streams, driving in the same direction, cross each other. Vehicles in the area are classified as weaving vehicles and nonweaving vehicles. Weaving is the cause of disturbance in traffic stream, because weaving vehicles must take lane changes within the length of weaving section. Hence, weaving section must be of turbulence, great time headway and low capacity, and as a result, come to be a bottleneck of road system. Research on issues of weaving sections is important either to traffic administration or to facility design and plan, especially to enhancing the efficiency and safety of road system.

Analysis on operational characteristics of facilities is the key process of facility treatment. The important characteristics should be the basis of analytical methods of facilities.

Since 1996, the communication ministry of China has sponsored a research project named *Research on Highway Capacity* as one of the important national technological projects during "the Ninth Five Years." As part of the work, traffic studies have been conducted about weaving sections in China, and the data collected have been analyzed. Some results are generalized. Here, this paper presents some conclusions on operational characteristics of weaving sections.

It should be noted that the traffic rates are all data of 5 minutes period in this paper, which are directly obtained from field data.

2. DATA COLLECTION

The field data of operation in weaving sections are collected on July 29, 1999, and October 22, 1999, at two sites. The two sites are both located at eastern expressway of third ring road of Beijing City, the first is the weaving section from Jinsong Bridge to Shuangjing Bridge and the second is from Changhong Bridge to Nongzhan Bridge. Both sites are on level grade and straight segments. Table 1 shows the general conditions of the two sites. Detectors and video camera are used in data collection (Futian et al., 1987). The arrangement of these instruments is shown in Figure 1. Among these, the location of the video camera should be a high enough position to record the whole situation of weaving section (Baojie, 1994).

Data collected has 50,000 and 40,000 data points at each study site respectively, which includes the AM peak hour and the PM peak hour. Figure 2 shows the match of the flow rates between the entry cross section and the exit cross section at the first study site. It reveals that the flow rates of the two cross section vary basically the same trend, namely, the instruments worked well and there is no data leak during the process of data collection.

TABLE 1 General Conditions of the Two Subjected Weaving Sections

Weaving section	Length	Number of lanes			Curve	Grade	Affected by signal?	
		mainstream	entry/exit	within section			entry	exit
1	≈ 290 m	3	1	4	R=□	level	No	No
2	≈ 100 m	3	1	4	R=□	level	No	No

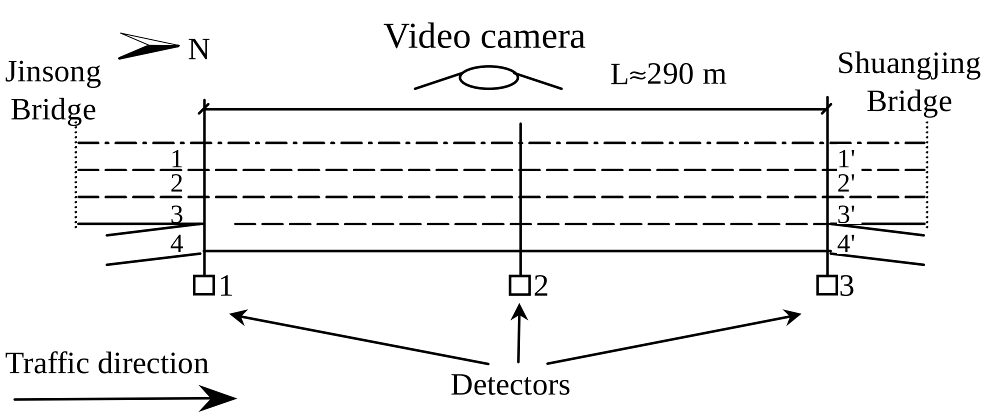

FIGURE 1 The arrangement of instruments at study site.

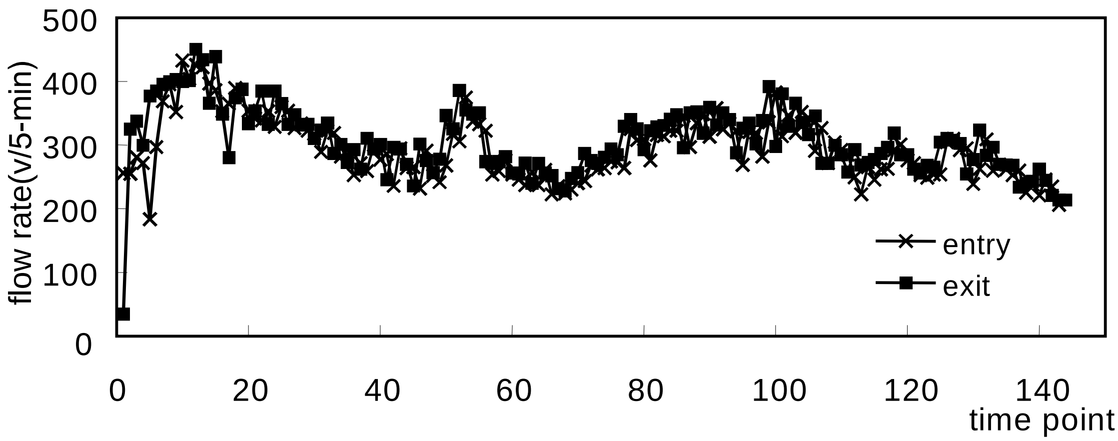

FIGURE 2 The match of flow rate data at two sections.

3. OPERATIONAL CHARACTERISTICS

Based on the field collecting data, this paper presents the characteristics of operation on speed, relationship between speed and flow rate, lane changing, lane distribution and time headway.

3.1 Speed

The first and third cross section in data collection of weaving sections, respectively, signifies the entry and exit cross section, and the second section is a median cross section in the weaving section. Table 2 gives the vehicle speed on each of the four lanes and at each section.

Vehicle speed of the lane 1 approximately signifies the speed of nonweaving vehicles and the average of speed of lane 3 and lane 4 approximate that of weaving vehicles. The difference between speed of two type vehicles is great, as much as 24.62 km/h at entry section, 12.58 km/h at exit section and 13.57 km/h at median section. The variance of speed at median section is the least, meaning that interaction among vehicles is great when they are driving within the weaving section.

Figure 3 is the statistical data of speed, thereinto, (a) is speed at higher flow rate and (b) is at lower flow rate.

From Figure 3 we can see that either on lane 1 and lane 2 or on lane 3 and lane 4, where weaving maneuvers are conducted, vehicles decelerate significantly. But because affected little by weaving on lane 1 and lane 2, deceleration there is smaller than that of lane 3 and lane 4. At lower flow rate on the other hand, vehicles on lane1, 2, and 3 suffer the effect of weaving much low and decelerate little, but vehicles on lane 4 accelerate apparently. This is because the high vehicle speed on the main stream and relatively low speed on the auxiliary lane at lower flow rate. Vehicles on auxiliary lane must accelerate from entry to exit so as to match the speed of main stream.

TABLE 2 Speed of Vehicles on Lanes of Each Cross Section

Section	Item	15% Speed [km/h]	50% Speed [km/h]	85% Speed [km/h]	Mean Speed [km/h]	Variance
First [Entry]	Lane1	49.34	61.95	72.08	60.79	13.13
	Lane2	41.30	51.18	62.57	51.70	12.10
	Lane3	37.30	48.15	59.69	48.90	15.52
	Lane4	30.10	36.51	43.92	37.15	8.00
	Section average	36.61	51.65	66.50	51.85	15.02
Second [Median]	Lane1	44.27	59.80	70.90	58.22	13.71
	Lane2	38.87	50.09	62.23	50.61	12.35
	Lane3	37.64	48.15	58.66	48.44	11.32
	Lane4	35.74	45.68	55.99	45.98	10.23
	Section average	38.56	51.22	65.15	51.72	13.11
Third [Exit]	Lane1	45.81	59.04	70.15	58.41	12.95
	Lane2	27.00	40.59	51.89	41.58	15.17
	Lane3	37.54	47.91	58.63	47.80	12.77
	Lane4	34.04	45.01	57.87	45.11	12.25
	Section average	40.52	53.91	67.08	53.68	14.17

3.2 Relationship Between Speed and Flow Rate

Figure 4 is the variation trends between speed and flow rate (TRB, 1975), among which, (a) is the trend of mean speed and (b) is the data plots of speed-flow rate. In order to show the variation trend, (a) is simple and clear, however, (b) not only shows the trend by the

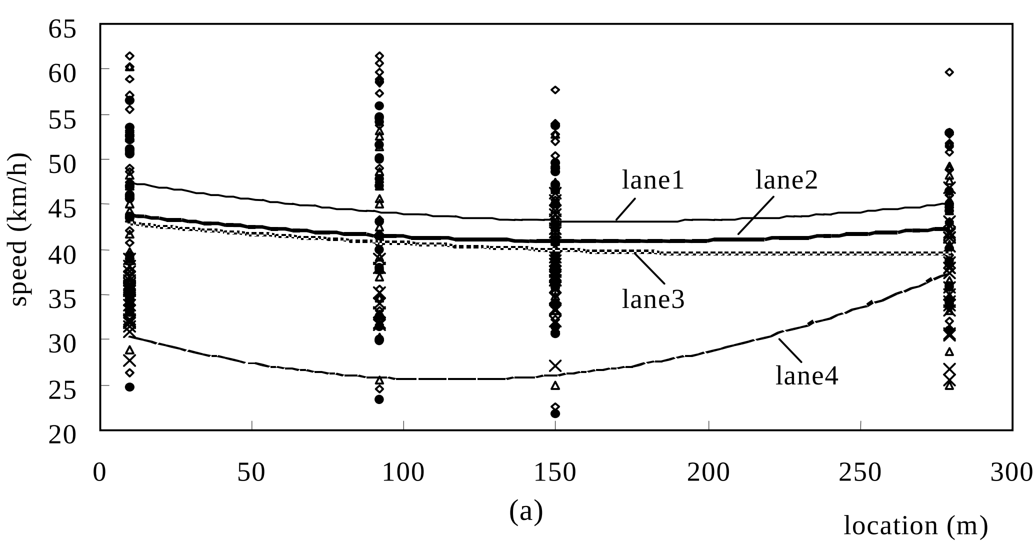

FIGURE 3(a) Lane speeds at different locations within weaving sections: higher flow rate.

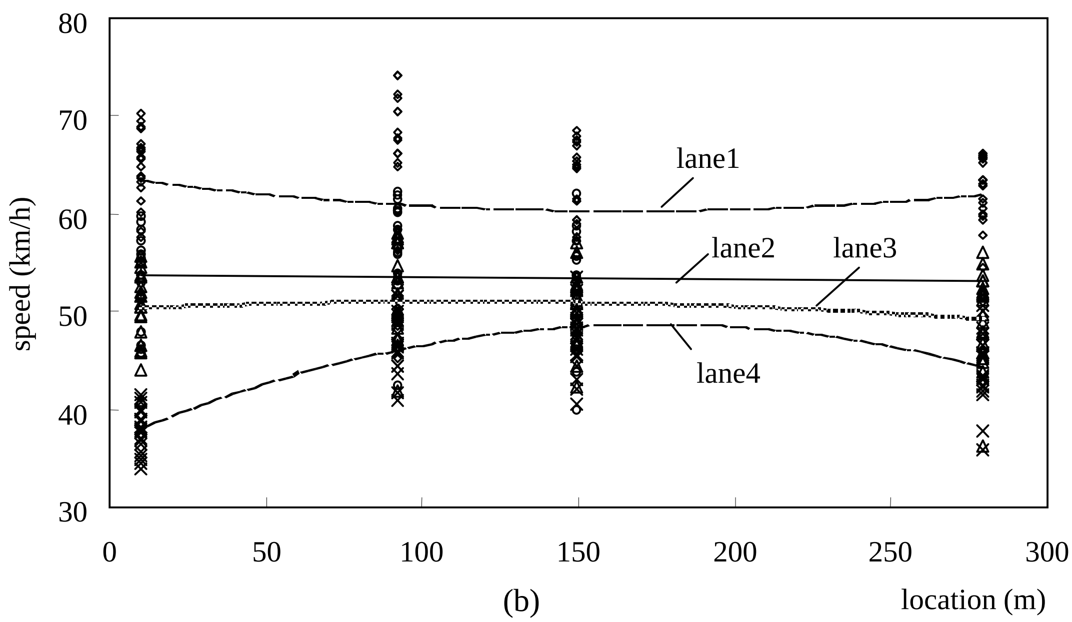

FIGURE 3(b) Lane speeds at different locations within weaving sections: lower flow rate.

trend line but also shows the data variances at each 5 minutes period. It shows that with the increase of flow rate, speeds on each lane decrease. For each lane, variance of speed decreases with the flow rate increase. Further more, variance of speed on inner lanes is greater than that on outer lanes.

As the flow rate increase, weaving maneuvers become more difficult and complex, which leads into the decrease of speed. But the interaction among vehicles becomes greater as the flow rate increases, which causes the smaller variance of speed. That interaction intensification is the same reason for speed variance of inner and outer lanes.

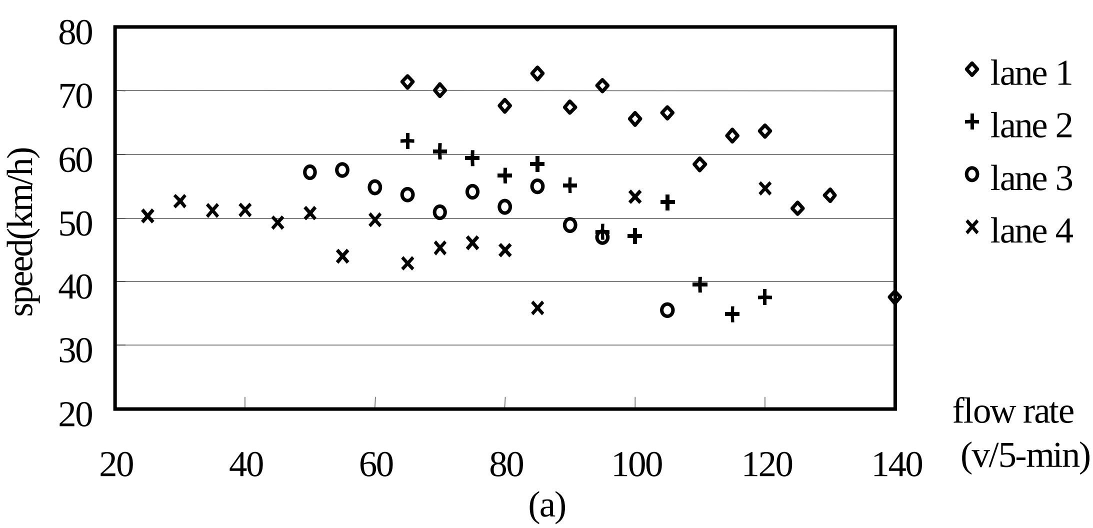

FIGURE 4(a) Speed variation with flow rate in weaving section: trend of mean speed.

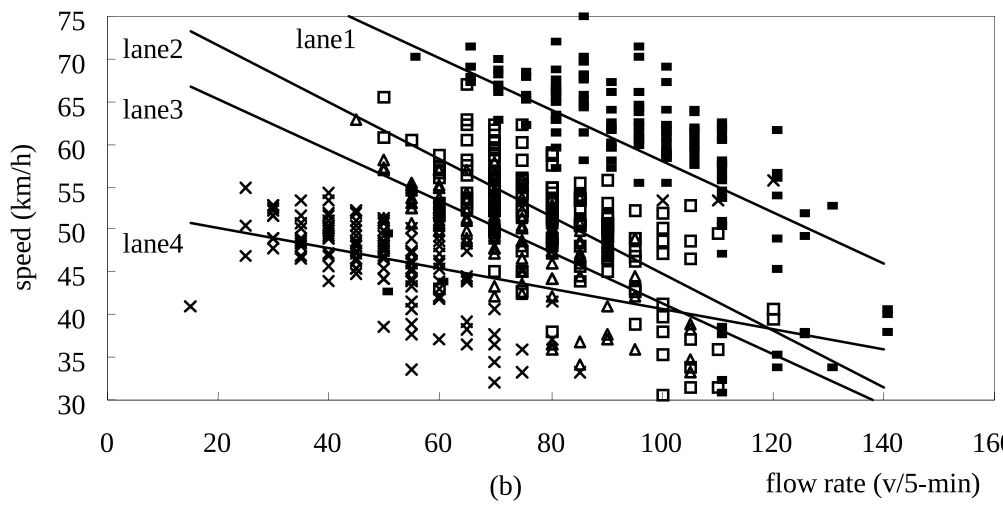

FIGURE 4(b) Speed variation with flow rate in weaving section: data plots of speed flow rate.

3.3 Lane Distribution

The distribution of traffic among lanes is another important results analyzed in this paper. The lane distribution point plot is shown in Figure 5 with traffic flow rate from low to high. The data scale covers all lanes and all observed 5 minute period flow rates. The y-axis indicates the ratio of traffic volume on a given lane to the sum of the four lanes. From the shoulder lane to middle lane, the ratio increases which means that there are more and more vehicles driving on it. This is partly because there is little influence by weaving on inner lanes and the capacity there is higher than outer lanes. From the trend of distribution varying with different flow rate, it can be concluded that the percentage of traffic volume on each lane is basically stable.

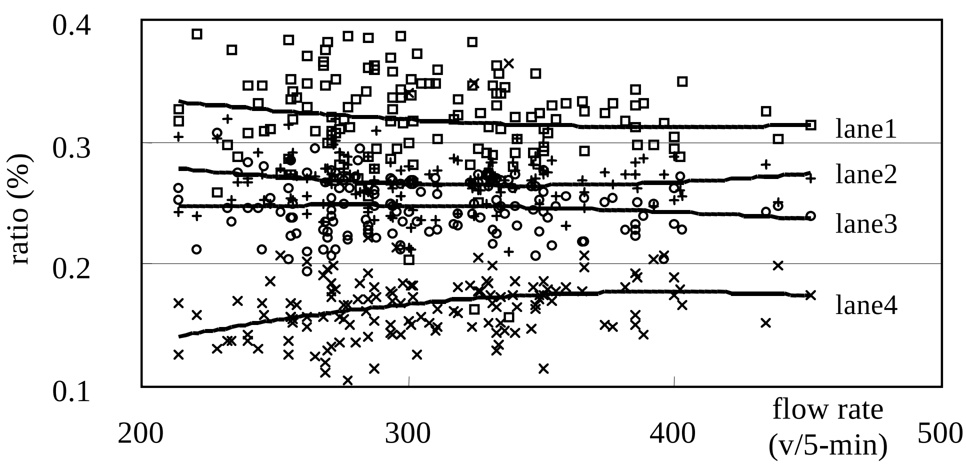

FIGURE 5 Traffic distribution among lanes.

3.4 Lane Changing

Lane changing is the radical factor in weaving sections and affects the operational characteristics essentially (Fazio, 1988). From the videotape, some results about lane changing are obtained. Before entering the weaving section, 95 percent of weaving vehicles have already changed to the lane adjacent to the auxiliary lane to prepare for weaving to the desired exit lane, and most nonweaving vehicle aggregate to the inner lanes to avoid the influence of weaving. After the half point of weaving section length, 90 percent of vehicles from the expressway can change onto the auxiliary lane. But weaving vehicles on the auxiliary lane are merging into the expressway lanes as long as the whole weaving section.

3.5 Large Vehicles

Composition of vehicle types is an important factor for traffic operation. Different time headways held by different vehicle types has been analyzed in Figure 6. It shows the mean time headway of different vehicle types generalized from 5 minutes period statistics. Figure 6 also shows that large vehicles always drive on the outer lanes, and that the mean time headway for each type generally increases from the middle lane to the shoulder lane. So the traffic rates of outer lanes is often lower compared to inner lanes and the influence of large vehicles on traffic operation usually is considered by a PCE (passenger car equivalent) factor.

Figure 7 shows the time headway exceeding 8 seconds on each lane for each vehicle type. Generally, 8 seconds is treated as the limiting time headway for free flow vehicles. Since at high traffic rates, vehicles which can follow previous a vehicle effectively always sustain a shorter time headway, so time headway exceeding 8 seconds may indicate the poor following of a vehicle holding it. From Figure 7, we can see that there are more vehicles on outer lanes with time headway exceeding 8 seconds than inner lanes, and that there are more large vehicles with time headway exceeding 8 seconds than any other vehicle types. This fact says that on inner lanes the vehicles present a stable and effective following drive, and on outer lanes, probably large vehicles have a poor following drive because of their limited decelerating and accelerating abilities.

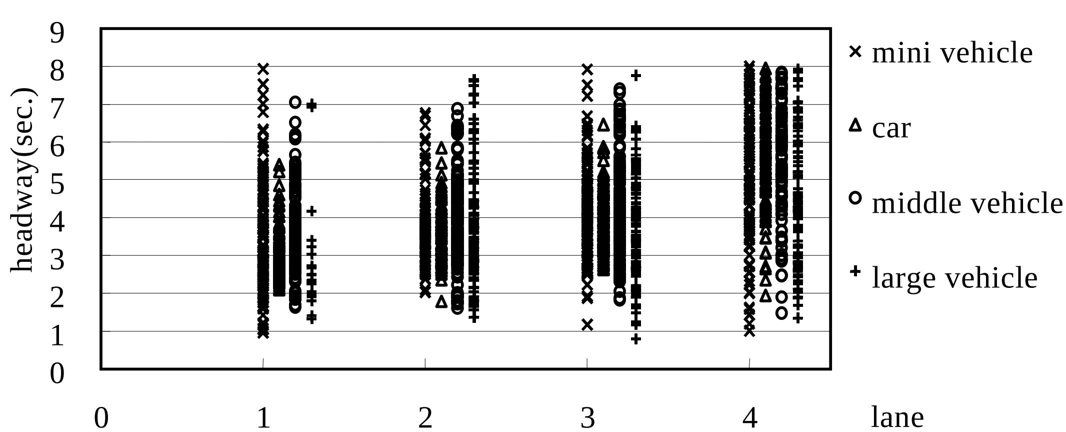

FIGURE 6 Headway of each vehicle type on each lane.

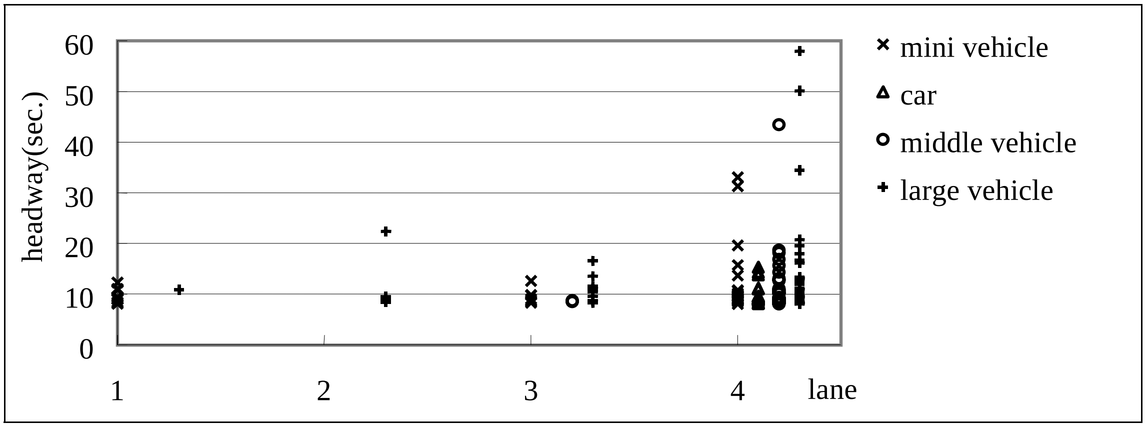

FIGURE 7 Headway exceeding 8-second plots of each vehicle type on each lane.

4. CONCLUSION

From the results of the field data, this paper presents some conclusions as follows:

1. Speeds of different vehicle types and on different lanes at different sections vary too much and have some relationship with traffic flow rate. With the increase of the traffic flow rate, vehicle speed generally decreases. Speed of inner lanes is higher than that of outer lanes and with a higher speed variance than outer lanes.
2. The lane-changing maneuver may cause turbulence in weaving sections. To avoid the effect of weaving, most nonweaving vehicles always aggregate to the inner lanes to obtain a little more higher through speed. For the weaving vehicles at the main stream of the expressway, the middle point of the weaving section is the completing lane change point, but for the weaving vehicles at the auxiliary lane, lane change may occur within the whole length of the weaving section.
3. Large vehicles in traffic stream often hold greater headway than other vehicle types and always drive on the outer lanes partly because the poor following drive and partly because of the traffic administration regulations, which results the lower capacity at outer lanes. With the analysis on the headway exceeding 8 seconds, the effect of large vehicle on capacity is recognized.
4. The traffic volume distribution among lanes is basically stable with traffic flow rate varies from low to high.

5. FUTURE RESEARCH

Work described in this paper is an effort to study the operational characteristics of weaving sections in China. Based on the field data collected and the operational characteristics of weaving sections, factors affecting traffic greatly will be analyzed and, furthermore, a theoretical model for weaving section analysis will be developed. However, the field data still need enriching and operational characteristics not noted here still need verifying. The future research will concentrate on the cause of disturbance to weaving section operation.

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