Vehicle Classification for Expressway Capacity Analysis in China

RONG JIAN
LIU XIAOMING
REN FUTIAN
Transportation Research Center
Beijing Polytechnic University, China 100022

ABSTRACT

A new vehicle classification is given in this paper for expressway capacity analysis in China, because the existing vehicle classification causes some problems, such as the vehicle-types whose sizes are the same have different performance characteristics. The new vehicle classification is principally based on free-flow speed together with the characteristics of vehicle configuration and wheelbase frequency. According to this principle, dynamic cluster is used to combine the existing vehicle-types into three new vehicle-types, which are labeled passenger car, heavy vehicle, and unidentified, respectively. After analysis of the performance characteristics of new vehicle-types and validation of local data, the new vehicle classification is proven and applied successfully in expressway capacity analysis in China.

1. INTRODUCTION

In China, ideal capacity is analyzed by the relationships of speed flow under 100% standard vehicles condition. Vehicle classification and PCE's of non-standard vehicle-types must be solved in advance. Although vehicle classifications exist in China and other motorized countries, two reasons exist that the vehicle classification is deficient for expressway capacity analysis in China. First, the existing vehicle classification in China has been used for mixed traffic capacity analysis. It was based on wheelbase and vehicle configuration; this results in approximately 10 vehicle-types. However, the vehicle-types travelling on expressways are different from those in mixed traffic. The existing vehicle classification does not naturally befit expressways. Second, the criterion of vehicle-types in motorized countries is rigorous and uniform. Further vehicle classification is unnecessary because vehicles are always classified regularly into 3 types: passenger car, truck, and bus. The unique traffic conditions exist in China. Some vehicles whose sizes and configurations are the same have different performance characteristics. Traffic composition is more complex and varies much from the condition of motorized countries. A need existed to study the vehicle classification for expressway capacity in China. The issue has three parts: 1) the existing vehicle classification is used in analyzing data from the Guang-Fo Expressway and some problems are found in the process; 2) the principle of new vehicle classification for expressway capacity analysis is formulated. It should be principally based on free-flow speed together with the characteristics of vehicle configuration and wheelbase frequency. According to the principle and the thoughtway of dynamic cluster, three new vehicle-types labeled passenger car, heavy vehicle, and unidentified, respectively, are obtained by combining the existing vehicle-types; and 3)

the new vehicle classification is used to analyze the same data from the Guang-Fo Expressway. Its accurate performance in expressway capacity analysis was shown. Through the validation using local data, one can successfully apply the new classification in expressway capacity analysis in China.

2. ANALYSIS DATA

The data were observed in Guangdong, Beijing, Sichuan, and Henan province from September 1997 to July 1998. The data from the Guang-Fo Expressway are used to explain the limitations of the existing vehicle classification and good characteristics of new vehicle-types in detail, because it contained traffic characteristics with higher volume. The other data are used to validate the applicability of new vehicle classification.

3. LIMITATIONS OF EXISTING VEHICLE CLASSIFICATION IN CHINA

The existing vehicle classification in China is a local one, which is formulated in the study of highway capacity in Hebei and Henan (Institute of Traffic Planning and Design of Hebei and Institute of Transportation Research of Henan, 1996).

The existing classification is classified by wheelbase and vehicle configuration, along with experts' experiences in highway capacity analysis. It includes 10 vehicle-types, whose critical parameters are listed in Table 1.

According to the criterion in Table 1, the data from the Guang-Fo Expressway are analyzed. The 85th percentile free-flow speed, standard deviation of general speed and traffic composition in each direction are calculated, respectively, where free-flow vehicle indicates the vehicle whose time headway is more than 8 sec. Figures 1, 2, and 3 show the results. Here, the 85th percentile free-flow speed in Figure 1 and standard deviation of general speed in Figure 2 are used as indexes of performance characteristics. If the both parameters of any vehicle-types are equal, their performance characteristics are thought to be same.

From Figures 1, 2, and 3, the limitations of the existing vehicle classification are shown:

1) Some different vehicle-types have similar free-flow speeds and standard deviations of general speed. In Figures 1 and 2, the free-flow speeds and standard deviations of general speed of vehicle-types 3 and 4 are almost same. From Table 1, their wheelbases and configurations are very close. These vehicles that have the same performance characteristics belong to different vehicle-types in the existing vehicle classification. It will mislead the results of its following capacity analysis.

TABLE 1 The Critical Parameters of Existing Vehicle Classification in China

Type No.	Label of Vehicle Type	Description	No. of Axles	Typical wheelbase range, m (ft)			
				Axle 1-Axle 2	Axle 2-Axle 3	Axle 3-Axle 4	Axle 4-Axle 5
1	Motorcycle		2	0.90-1.60 (2.95-5.25)			
2	Mini-bus	Buses that can carry less than 25 person	2	1.61-1.95 (5.26-6.40)			
3	Van		2	1.96-2.25 (6.41-7.38)			
4	Mini-vehicle		2	2.26-2.40 (7.38-7.87)			
5	Passenger Car		2	2.41-2.90 (7.88-9.51)			
6	Light Vehicle		2	2.91-3.50 (9.52-11.48)			
7	Medium Vehicle	Trucks that can load 2.5~7t	2	3.51-4.65 (11.49-15.25)			
			3	3.00-7.00 (9.84-22.96)	0.30-1.80 (0.98-5.90)		
			3	3.00-7.00 (9.98-22.96)	1.80-9.99 (5.90-32.80)		
8	Large Vehicle	Trucks that can load more than 7t, Buses that can carry more than 25 person	2	4.66-7.00 (11.50-22.96)			
			3	4.65-7.00 (11.49-22.96)	4.50-9.99 (11.76-32.80)		
			3	3.00-7.00 (9.98-22.96)	0.30-1.80 (0.98-5.90)		
9	Trailer	Semi-Trailers, Full-Trailers	4	3.00-5.50 (9.98-18.04)	3.50-5.00 (9.98-16.40)	2.00-4.00 (6.56-13.12)	
			4	3.00-6.00 (9.98-19.96)	4.00-6.50 (13.12-21.32)	2.50-4.00 (8.20-13.12)	
			4	3.00-7.00 (9.98-22.96)	0.30-5.00 (0.98-16.40)	0.30-5.00 (0.98-16.40)	
			5	3.00-7.00 (9.98-22.96)	0.30-2.00 (0.98-6.56)	1.80-9.99 (5.90-32.80)	1.80-9.99 (5.90-32.80)
10	Unidentified	Others					

2) A certain vehicle-type has unstable 85th percentile free-flow speed and standard deviation of general speed in two directions, under the same conditions of road and traffic. In Figure 1, the difference, which is between the 85th percentile free-flow speeds of the vehicle-type 1 in direction 1 and direction 2, is up to 30.0 km/h (18.7 mph). Figure 2 shows that the standard deviation of general speed of vehicle-types 1, 7, 9 in the two directions are different. The maximum difference is up to 22.2 km/h (13.8 mph). A certain vehicle-type in the existing vehicle classification has unstable performance characteristics, as is opposite to the common conception.

3) The percentages of some certain vehicle-types are too small to analyze expressway capacity. Figure 3 shows that the percentages of the vehicle-types 1, 2, 3, 9, 10 is less than 5%. These small percentage vehicle-types resulted in some problems, as item 2) described above, and the confused performance characteristics, as Section 4.3.1 mentioned below.

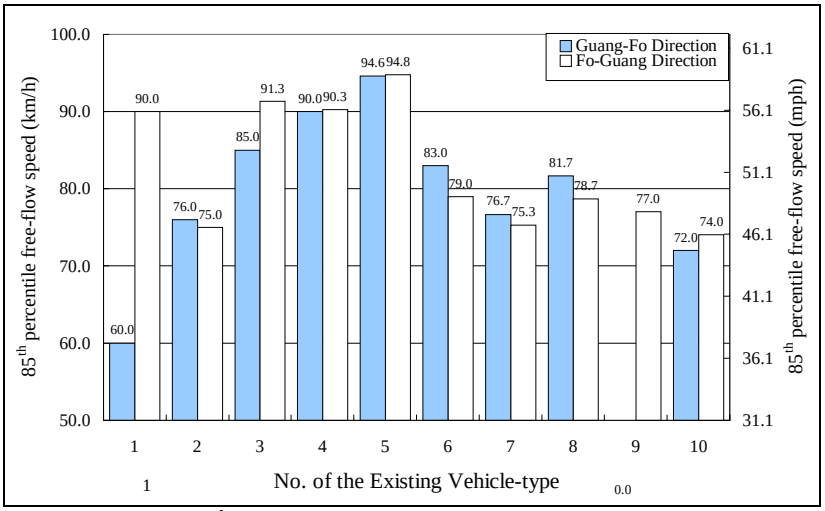

FIGURE 1 85th percentile free-flow speed of each vehicle-type in the two directions of the Guang-Fo Expressway.

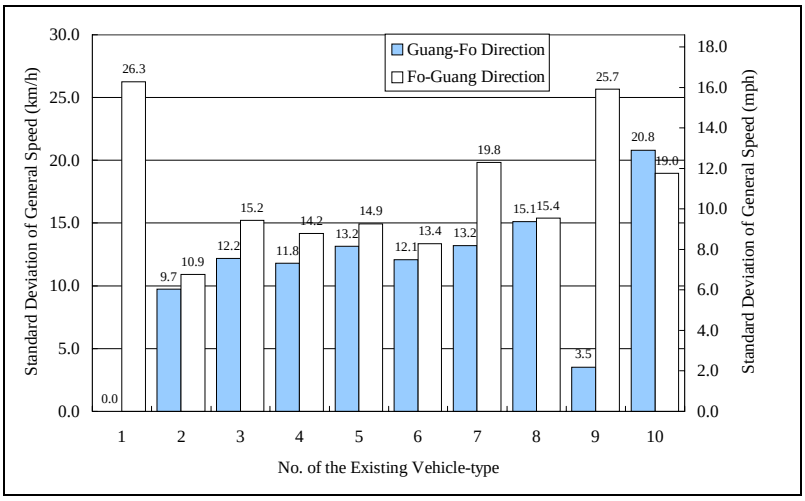

FIGURE 2 Standard deviation of general speed in the two directions of the Guang-Fo Expressway.

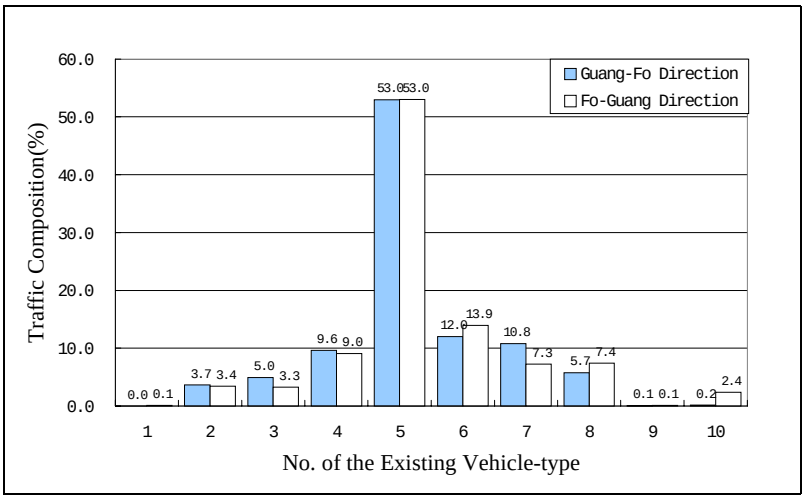

FIGURE 3 Traffic composition in the two directions of Guang-Fo Expressway.

In addition, capacity analysis of mixed traffic is addressed in China because its mixed traffic is rather serious. In mixed traffic, medium vehicle always occupies the highest percentage, so it is selected as the standard vehicle-type in capacity analysis. With motor industry growth, traffic conditions have changed. The percentage of passenger cars has increased rapidly, especially on expressways. Figures 4 and 5 reveal that the percentage of the vehicles whose wheelbases are 2.5 m (8.2 ft) to 3.0 m (9.8 ft) is approximately 53%. Passenger car has already become the main vehicle-type on expressways.

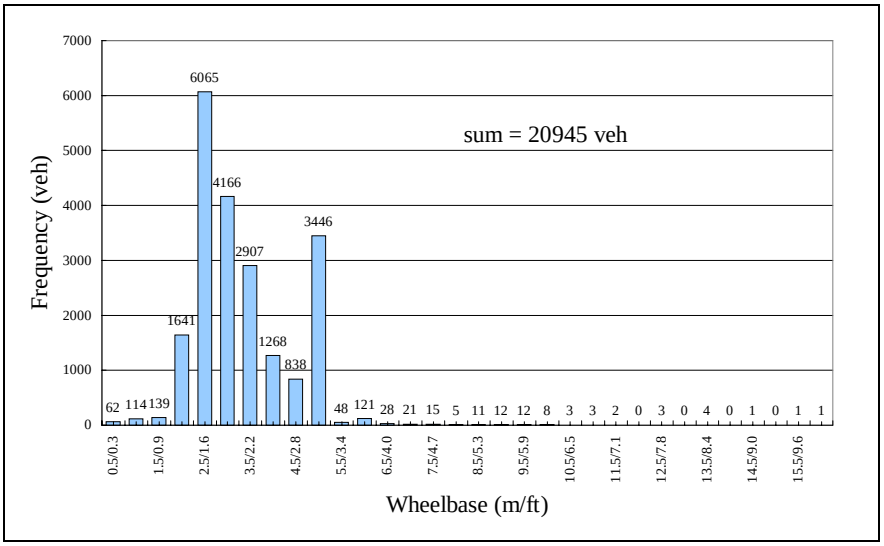

FIGURE 4 Wheelbase frequency in the Guangzhou to Foshan direction.

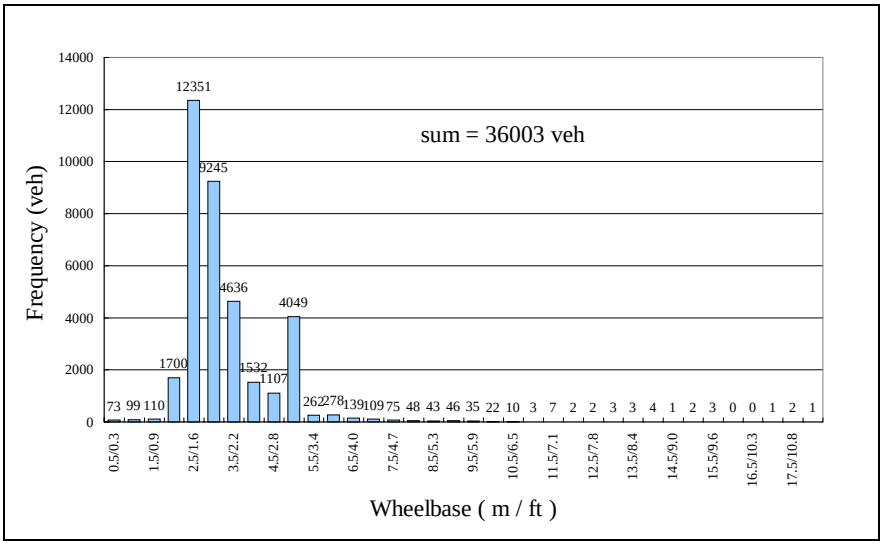

FIGURE 5 Wheelbase frequency in the Foshan to Guangzhou direction.

Considering these above limitations of the existing vehicle classification, a new method for classifying vehicle-types on expressways is formulated that is principally based on the performance characteristics of vehicles, together with vehicle configuration and wheelbase frequency. The following characteristics of new vehicle-types are expected: 1) the performance characteristics between various vehicle-types are rather different, 2) the performance characteristics of same vehicle-type are stable under a certain conditions, and 3) traffic composition is consistent in a certain region and each vehicle-type often appears in the prevailing traffic flow.

4. VEHICLE CLASSIFICATION FOR EXPRESSWAY CAPACITY

4.1 Criterion of New Vehicle Classification

The aim of vehicle classification for capacity analysis is to classify the vehicles that have the same performance characteristics into one vehicle-type, in order to simplify PCEs (passenger car equivalents) calculation and other capacity analysis. The performance characteristics of vehicles should be defined as the principle criterion of vehicle classification. In theory, free-flow speed can measure the performance characteristics of vehicles, because it is the spot speed at which the vehicle travels under a free condition. It is only related with the operational characteristics of vehicles and driving habits of drivers. In practice, the criterion is not only free-flow speed but also vehicle configuration and wheelbase frequency because of some real issues.

4.2 Methodology of Clustering Vehicle-Types

In order to avoid that the different vehicle-types have the same performance characteristics, the new vehicle classification is constructed by combining the existing ones. According to the thoughtway of dynamic cluster, mentioned by He, Zhao, and Li (He, Z.X., Zhao, Z.Y., and Li, J.W., 1992), the Euclidean Lengths calculated as Equation (1) are used to measure the variances between various clusters. The average free-flow speed of passenger car is defined as the initial cluster center. When the Euclidean Length 10 is chosen to be the maximum interval between any two new vehicle-types, the existing vehicle-types are combined into four types as Figure 6 and Table 2 show.

$$R_i = \sqrt{(x_i - x_0)^2} \tag{1}$$

where: R_i = Euclidean Length between average free-flow speed of vehicle-type i and passenger car;
x_i = the average free-flow speed of vehicle-type i;
x_0 = the average free-flow speed of passenger car.

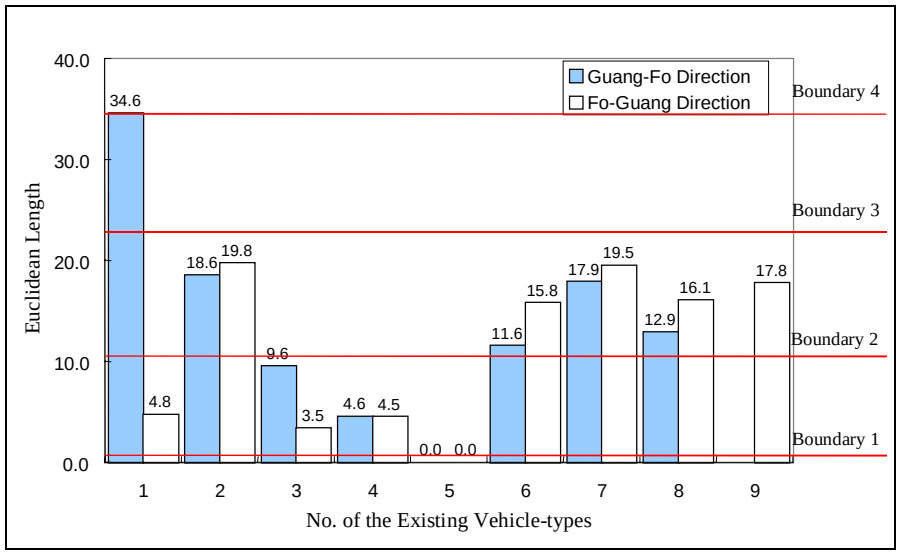

FIGURE 6 Euclidean lengths between the average free-flow speed of each vehicle-type and passenger car in the Guang-Fo Expressway (the existing vehicle classification).

TABLE 2 Result of Clustering the Existing Vehicle Classification

No. of Cluster Center	Including the Vehicle-Type Number and Labels of the Existing Vehicle Classification
1	5, passenger car
2	3, 4, Van and Mini-vehicle
3	2, 6, 7, 8, 9, Mini-bus, Light Vehicle, Medium Vehicle, Large Vehicle, and Trailer
4	1, Motorcycle

*The unidentified vehicle is not considered in the cluster process, because it includes various vehicles that the traffic counter cannot recognize.

Together with the vehicle configuration and wheelbase frequency, vehicle-types 1, 2, 3, 4 and 5, and 6, 7, 8 and 9 are combined into passenger car and heavy vehicle, respectively, in order to prevent obtaining some vehicle-types of too small percentage. The new vehicle-types are obtained as Table 3 described.

TABLE 3 New Vehicle Classification for Expressway Capacity Analysis

Labels of the New Vehicle-Type	Description of the New Vehicle Classification
Passenger Car	Motorcycles, Mini-buses, Jeeps, Vans, Passenger Cars, Light Vehicles, and Microbuses, etc.
Heavy Vehicle	Carrying Trucks, Large Buses, Heavy Vehicles, Semi-Trailers, and Full-Trailers, etc.
Unidentified	Others

4.3 Characteristics of New Vehicle-Types

In this section, the performance characteristics of the new vehicle-types are analyzed based on the same data used in Section 3.

4.3.1 Speeds of every new vehicle-type

Figure 7 indicates that the variance of free-flow speeds between any two new vehicle-types is fairly distinct. The minimum variance is approximately 10 km/h (6.2 mph). The initial conclusion can be drawn that the performance characteristics of each vehicle-type are different.

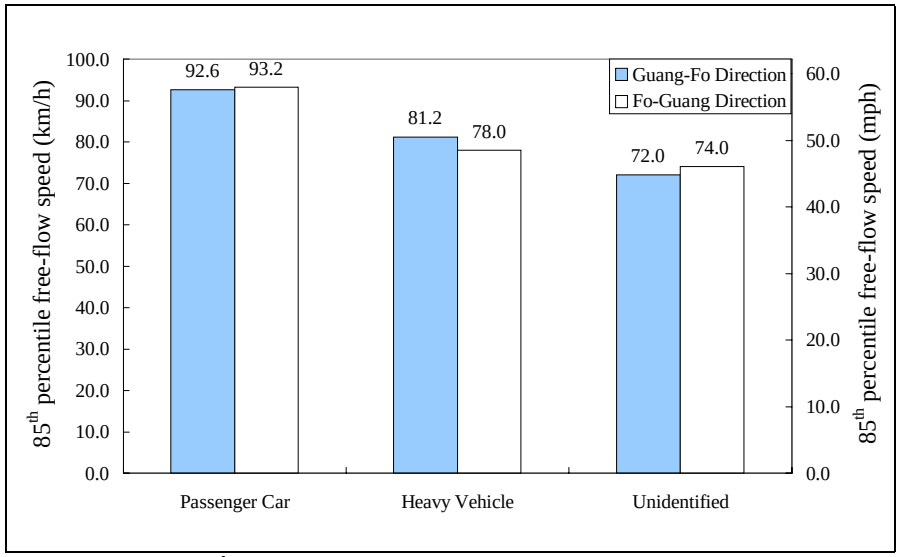

FIGURE 7 85th percentile free-flow speed of each new vehicle-type in two directions of Guang-Fo Expressway.

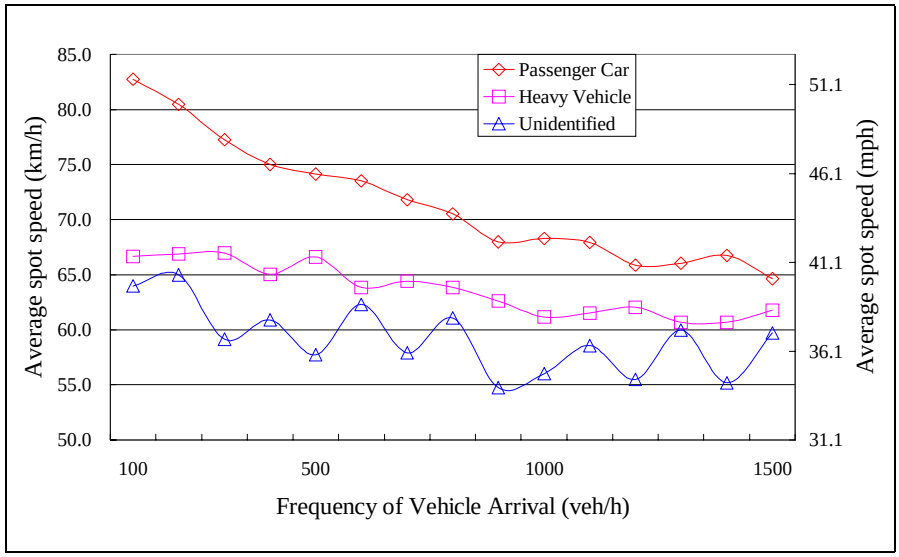

FIGURE 8 Average spot speed of every new vehicle-type at given frequency of vehicle arrival.

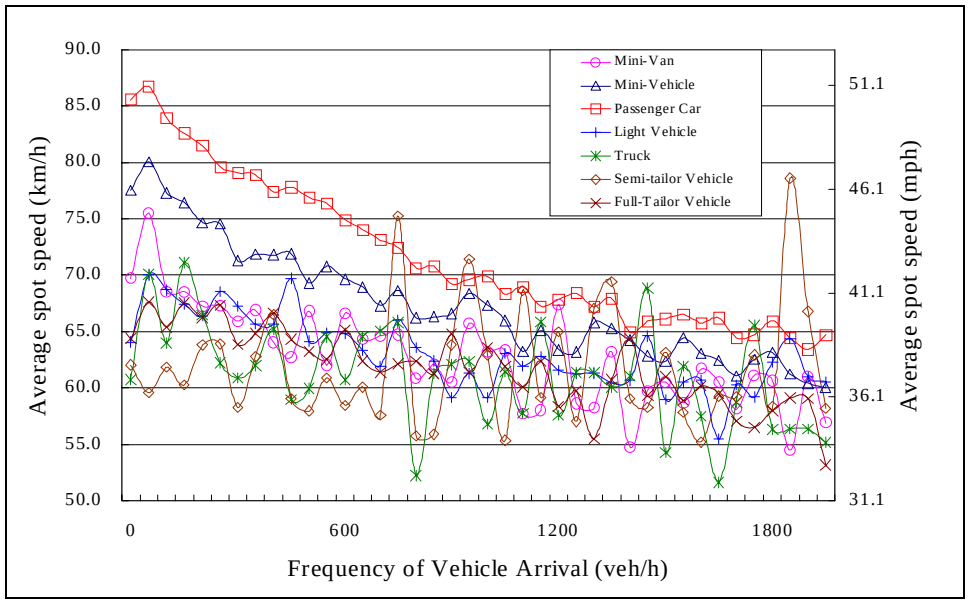

FIGURE 9 Average spot speeds of various existing vehicle-types at given frequency of vehicle arrival.

Further, the average spot speeds of each vehicle-types are compared under a series of frequency of vehicle arrival, as Figures 8 and 9 show. In Figure 8, the three speed trend lines are clear, but the nine lines in Figure 9 are blended together. Now based on the analysis of the 85th percentile free-flow speed and speed trend, the clear conclusion is drawn that the performance characteristics of each new vehicle-types are obviously different on the Guang-Fo Expressway.

4.3.2 Standard deviations of general speeds of every new vehicle-type

The standard deviations of general speed of each new vehicle-type in two directions of the Guang-Fo Expressway are showed in Figure 10. The standard deviations of general speed in the two directions are almost the same. From Figures 7 and 10, the maximum variances of free-flow speed and standard deviation between two directions are only 3.1 km/h (1.9 mph) and 2.5 km/h (1.6 mph). It is much smaller than 30.0 km/h (18.7 mph) and 22.2 km/h (13.8 mph) that are the same indexes of the existing vehicle-types mentioned in Section 3. The analysis indicates that the performance characteristics of new vehicle-types are more stable than the existing ones on the Guang-Fo Expressway.

4.3.3 Traffic composition

The traffic composition of new vehicle-types is shown as Figure 11. From it, the percentages of every new vehicle-type in the two directions are almost same and each of new vehicle-types occupies fairly percentage in the whole traffic except unidentified vehicles. That means the whole traffic composition is stable and every new vehicle-type can often appear in the prevailing traffic flow in the Guang-Fo Expressway.

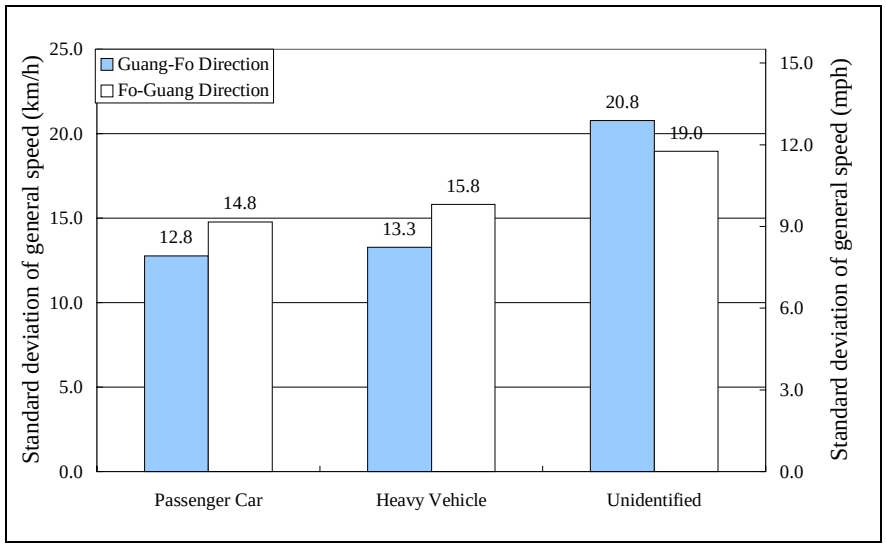

FIGURE 10 Standard deviation of general speeds of every new vehicle-type in the two directions of the Guang-Fo Expressway.

4.4 Typical Regions Validation

Using the new vehicle classification data from Beijing (Jing-Shi Expressway), Sichuan (Cheng-Mian Expressway), and Henan (Zheng-Kai Expressway) are analyzed. These data represent three traffic conditions from the Beijing, Zhongyuan, and Xinan region. Tables 4, 5, and 6 list the average free-flow speed, standard deviation of general speed, and traffic composition in these three regions.

From Tables 4, 5, and 6, the performance characteristics of every new vehicle-type in typical regions are similar with that of the Guang-Fo Expressway. The new vehicle classification is suitable for expressway capacity analysis in these regions at least.

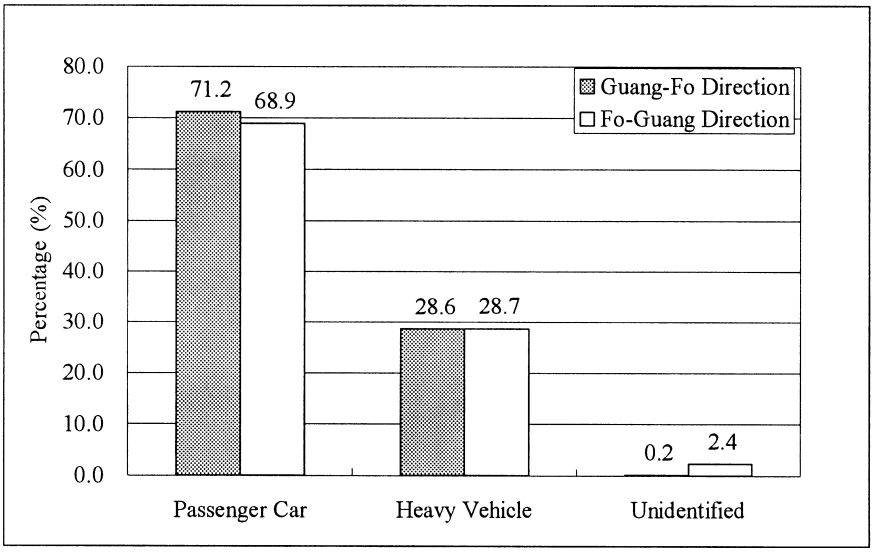

FIGURE 11 Traffic composition in the two directions of the Guang-Fo Expressway.

TABLE 4 Average Free-Flow Speed in Each Typical Region (km/h, mph)

Vehicle-type	Zheng-Kai		Jing-Shi		Cheng-Mian	
	Dir 1	Dir 2	Dir 1	Dir 2	Dir 1	Dir 2
Passenger Car	94.3, 58.6	100.7, 62.6	80.4, 50.0	80.1, 49.8	117.8, 73.3	111.5, 69.3
Heavy Vehicle	63.6, 39.6	68.8, 42.8	62.8, 39.1	61.1, 38.0	92.6, 57.6	90.2, 56.1
Unidentified	0.0, 0.0	69.8, 43.4	26.1, 16.2	60.0, 37.3	0.0, 0.0	0.0, 0.0

TABLE 5 Standard Deviation of General Speeds in Each Typical Region (km/h, mph)

Vehicle-type	Zheng-Kai		Jing-Shi		Cheng-Mian	
	Dir 1	Dir 2	Dir 1	Dir 2	Dir 1	Dir 2
Passenger Car	18.3, 11.4	19.1, 11.9	16.3, 10.1	14.8, 9.2	20.8, 12.9	19.3, 12.0
Heavy Vehicle	13.3, 8.3	12.1, 7.5	19.8, 12.3	17.9, 11.1	22.4, 13.9	20.3, 12.6
Unidentified	2.5, 1.6	13.9, 8.6	42.3, 26.3	34.0, 21.1	0.0, 0.0	0.0, 0.0

TABLE 6 Traffic Composition in Each Typical Region (%)

Vehicle-type	Zheng-Kai		Jing-Shi		Cheng-Mian	
	Dir 1	Dir 2	Dir 1	Dir 2	Dir 1	Dir 2
Passenger Car	51.8	41.1	72.6	74.7	79.9%	85.7
Heavy Vehicle	38.7	44.6	27.2	25.2	20.1	14.3
Unidentified	9.5	14.4	0.2	0.1	0.0	0.0

5. CONCLUSIONS

Through the above analysis, the conclusions are drawn:

1. In expressway capacity study, the existing vehicle classification in China has some limitations, such as some vehicle-types have the same performance characteristics. It produces misleading results.

2. The new vehicle classification is obtained by the methodology that is based on free-flow speed, together with vehicle configuration and wheelbase frequency. It includes three new vehicle-types. They are labeled “passenger car,” “heavy vehicle,” and “unidentified,” respectively.

3. The new vehicle classification has the following strong points and advantages: 1) the performance characteristics between various vehicle-types are different, 2) the performance characteristics of the same vehicle-type are stable, and 3) the traffic composition is consistent and every vehicle-type often appears in the prevailing traffic flow.

4. After validation the applicability in typical regions in China, such as Guangdong, Beijing, Sichuan, and Henan, the new vehicle classification scheme is suitable for expressway capacity analysis based on the filed data from these typical regions.

ACKNOWLEDGMENTS

The authors thank the Institute of Highway Research of Ministry of Communication, the Institute of Highway Research of Guangdong Province, the Jingchuan Co. in Sichuan Province, and the Institute of Highway Research of Henan Province for their providing the traffic data.

REFERENCES

The Study of Highway Capacity in Hebei and Henan: Progress Report 1. Hebei: Institute of Traffic Planning and Design of Hebei and Institute of Transportation Research of Henan, 5. pp. 15–17, 1996.

He, Z.-X., Zhao, D.-Y., and Li J.-Wen. *Fuzzy Mathematics and its Deriving Decision Method* (Chinese). Railway Press of China, Beijing, 1992.