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THE BEHAVIOR ANALYSIS ON A NEW TYPE WEAVING SECTION

Hsun-Jung Cho
Professor
Department of Transportation Technology and Management, National Chiao Tung University.
1001 Ta Hsuch RD., Hsinchu, Taiwan 300, R.O.C.
886-3-5712121 EXT 57217 Taiwan
FAX. 886-3-5720844
E-Mail: hjcho@cc.nctu.edu.tw

George C.P. Tsai
Ph.D. Candidate
Department of Transportation Technology and Management, National Chiao Tung University.
5FL., NO. 1, LANE 1, Hoping E. RD., SEC. 3, Taipei 106, Taiwan, R.O.C.
886-2-27017891 Taiwan
FAX. 886-2-27017872
E-Mail: geogtsai@ms.taneeb.gov.tw

Abstract: The purpose of this research, it is analytically the interrelations between the traffic flow characteristics that include traffic density, rate of flow, and speed (k, q, and u) into completely congestion traffic conditions. This study investigates the macroscopic models of traffic flow characteristics on a new weaving section on the Taiwan National Freeway Systems, focusing on the interrelations between the traffic speed, density, and rate of flow of the congestion traffic conditions. The analysis based on these driver behaviors includes 100% lane-changing and 65.22% weaving activities. The results for this study show the fundamental interrelation of traffic flow characteristics on the completely congestion traffic flow condition similar to Greenshield model and showing no influence on lane changing and weaving activities. These regression models concludes that the critical density is 55.74 vehicles per kilometer, the speed is 34.29 kilometer per hour, and the maximum rate of flow (capacity) is 1854 vehicles per hour per lane, respectively. These results represent that the value of traffic speed and rate of flow are same the Highway Capacity Manual (HCM) and the traffic density is more then the HCM.

Key Words：Traffic Flow Characteristics, Density, and Speed, Rate of Flow.

1. INTRODUCTION

Three types of weaving configuration were defined on the basis of the lane changes required of weaving vehicles. Type A weaving sections require that each weaving vehicle make one lane change in order to execute the desired movement. Two critical characteristics distinguish Type B weaving sections from all others, 1. One weaving movement may be accomplished without making any lane changes, and 2. The other weaving movement requires at most one lane change. Type C weaving section are similar to Type B sections in that one or more “though lanes” are provided for one of the weaving movement. The distinguishing feature between Type B and Type C weaving sections is the number of lane changes required for the other weaving movement. The Type C weaving section is characterized by: 1. One weaving movement may be accomplished without making any lane changes, and 2. The other weaving movement requires two or more lane changes (HCM, 1985 and 2000). A typical new weaving section is call separated connecting collector-distributor (C-D) roadway weaving section of cloverleaf interchanges. This type defined in the 1965 HCM as requiring “The dual-purpose weaving section on the compound weaving section can be arranged to separate weaving traffic from non-weaving traffic, this type call the separated weaving section. While the two flanking sections is devoid of weaving and carry the other flow only. Such a separated weaving section, with only on outer roadway provided is characteristic of introduced section of collector-distributor road along a freeway, which thus removes weaving from the through roadway”(HCM, 1965). This type of separated connecting C-D roadway weaving section is not to describe and to discuss again in HCM 1985 and 2000. Furthermore, in recent the study and analysis of traffic characteristics and capacity for this type are very lacking. But, in the view of traffic safety and interference of traffic flow on the main line of freeway, this type of separated weaving sections is better then other types. Therefore, this type applied on the freeway systems in Taiwan is very popular. On the other hand, this type needs the right-of-way (R.O.W) is more then other types, especially, in the urban area is to avoid using this type.

2. LITREATURE REVIEW

Studies at weaving sections on the freeway traffic flow characteristics are few in number. The recently studies are focus on the comparison with existing analytical procedures and predicting weaving area operations (Skabardonis, Cassidy, May, and Cohen, 1989; Roess, 1987), or discussed the capacity and level of service (L.O.S) on the weaving sections (Roess and Ulerio, 2001; Cassidy and May, 1991). Other studies are presentation the methodology by revision to level D methodology of analyzing the relationship of length and freeway to freeway weaving percentages on weaving sections at near-capacity traffic conditions (Windover and May, 1994). Other study proposed analytical technique the fundamental traffic flow characteristics on the non-congestion type A weaving section on frontage roads, that results of this research shows the fundamental relationship of speed, rate of flow and density, respectively, has a high degree scatter among the data, speed appears to be insensitive to flow. These data sets plot as front in diagram, it is not completely (Fredericksen and Ogden, 1994). These papers use the methodologies including two theories. One collected field data of weaving flows on the weaving sections, applied statistic analysis (Roess, 1987), and established regression models (Fredericksen, 1994 and Cassidy, Skabardonis and May, 1989) to forecast the capacity and volume on the weaving sections (Kwon, Lau, and Aswegan, 2002). These studies are using the macroscopic and/or microscopic model analysis that discussed and predicted the relationship of average speed, rate of flow, and density, or discussed the operations, capacity and L.O.S of freeway weaving sections. In this paper, the study is focusing on the macroscopic analysis for the fundamental relationships of traffic speed, rate of flow, and density, respectively. These fundamental relationships of traffic speed, rate of flow, and density are in the completely congestion traffic conditions on the separated connecting C-D roadway weaving section. Second, it is to compare the result by Fredericksen research (1994), the result is on the non-congestion traffic condition in the type A weaving sections on frontage roads and to compare by Greenshield’s hypothesis of a linear speed-density relationship.

3. DATA COLLECTION

Data for this study was collected to consist of the data used to formulate the regression models.

3.1 Data Requirements

Data collection activities for this research included traffic volume, vehicle classification, lane changing activity, traffic speed, density, and weaving section geometry. Personnel at the Taiwan National Freeway Bureau used the video-recording equipment of ATMS and collected all operational data. The weaving section geometry was obtained from freeway plans and field measurements.

3.2 Study Site Selection

The field data of the operation in weaving section was collected on November 15, 2001, and May 20, 2002, from 7:00to 9:00 a.m. at one site. The site is a level grade and straight segment. The configuration of this site is indicated in Figure 1, and Table 1 shows the general conditions of this site.

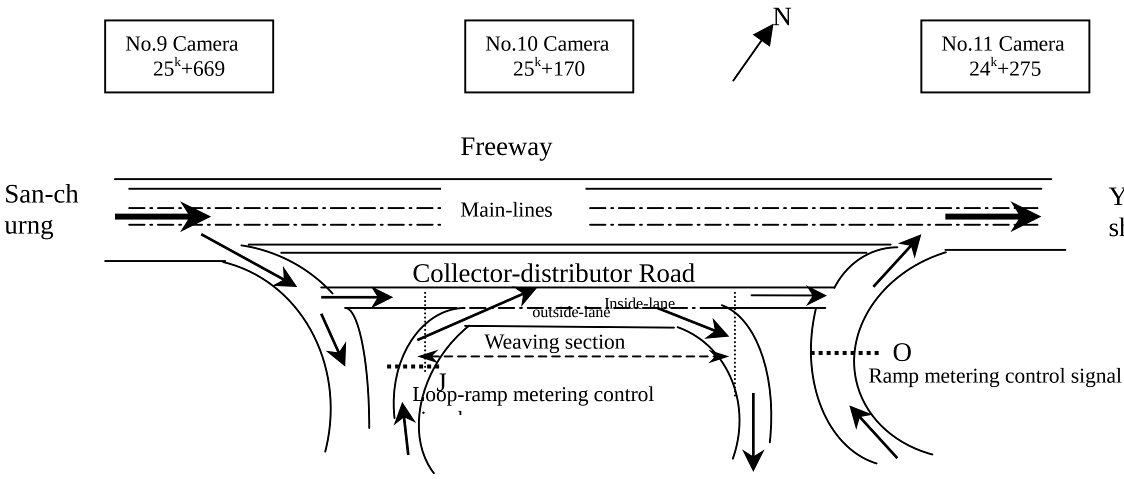

Figure1 the configuration of C-D road weaving section on the Taipei interchange

Table 1 general Conditions of the Study Weaving Section

Study section	Length (m)	Number and width (m) of Lanes				Curve (m)	Grade (%)	Affected by Signal	
		Main-Stream		Entry/ Exit				Entry	Exit
Main-line	≈1015	3	3.75	-	-	R=0	Level	No	No
C-D Road	≈806	2	3.75	1	3.75	R=0	Level	No	No
Weaving Area	≈72	2	3.75	-	-	R=0	Level	No	No
On-Ramp	≈402	-	-	1	4.5	R=300	+6.0	Yes	-
Off-Ramp	≈534	-	-	2	3.75	R=500	-1.32	-	No
On-Loop ramp	≈259			1	4.5	R=35	+5.52	Yes	-
Off-Loop ramp	≈270	-	-	1	4.5	R=45	-5.96	-	No

These video cameras were used in the ATMS system component to do the data collection. These cameras should be in a high enough position to record the whole situation and maneuver of the weaving section.

3.3 Results of Data Collection

Once the required traffic data was collected, the appropriate operational data was extracted directly from the videotape documentary. This data was summarized in 1-minute intervals. This time interval was used to increase the sample size.

Traffic flows of entering the weaving section and traffic flow of weaving vehicles were measured from the videotaped data. Densities were also obtained directly from the videotapes by counting the number of vehicles in a weaving section at a given unit length. We used pausing to the videotape every 3 seconds, recorded the densities for each lane, and averaged the readings to obtain a density value for each 1-munite period. Average speeds using the television timer determined the time it took a vehicle to travel a known distance. All lane changes within the entire weaving section were counted and summed for each 1-minute period; these values were then converted to lane changes per hour per kilometer per lane. The length of the weaving section length was measured between the painted gore points.
The traffic flow on the study site was rather high, total flows was 5066 vehicles, that includes in inside lane was 1212 vehicles and outside lane was 3854 vehicles. The total average traffic speed was 27.36 km/hr., in inside lane was 25.91 km/hr., and in outside lane was 28.88 km/hr. The total average traffic density was 66.82veh/km., in inside lane was 58.21 veh/km., and in outside lane was 75.43 veh/km., respectively. The lane change activity was 100 percentages, and weaving activity was 65.22 percentages. These other traffic flow characteristics as shows in Table 2.

Table 2 traffic maneuvers of the study weaving section

Location / Variables	Inside lane	Outside lane	All section	Average
Volumes (veh)	1212	3854	5066	2533
Rate of flows (veh/hr)	1214.91	1854.56		1558.07
Densities (veh/km)	58.21	75.43		66.82
Speeds (km/hr)	25.91	28.88		27.39
Headways (seconds)	4.82	2.94		3.88
Occupancy rate (%)	51.96	80.08		61.02
Weaving frequency (percentage)			65.22	

Remake: 1.veh = vehicles
2.veh/hr = vehicles per hour
3.veh/km = vehicles per kilometer
4.km/hr = kilometers per hour

4. FUNDAMENTAL RELATIONSHIPS ANALYSIS

Before a regression model was built and developed for analyzing weaving section performance, the empirical relationships between traffic speed, rate of flow and density were examined to gain a better understanding of the operational characteristics of weaving sections. An important behavioral characteristic of traffic flow is the hypothesized relationship between the speed and density of traffic at equilibrium, called the fundamental diagram (Sanwal, Petty, Walrand and Fawaz, 1996). The basic relationships among the three traffic measures are usually represented by typical curves plotted together (HCM, 1985). In order to ensure the suitability and the valid range of the data, the 1-minute interval rate of flow, density, and speed for the weaving section of freeway are plotted together; this includes the rate of flow versus speed, the rate of flow versus density and density versus speed etc.

4.1 Speed-Rate of Flow Relationships

Relationships between speed and rate of flow were studied initially. Average flow rates per lane were used to normalize the weaving section flows, and space mean speeds were obtained from the videotaped field data by calculating speeds from the travel space and travel time data. A scatter-plot of average speed versus average flow is illustrated in Figure 2. Aggregated 1-minute observation data from the study site was used to construct the scatter plot.

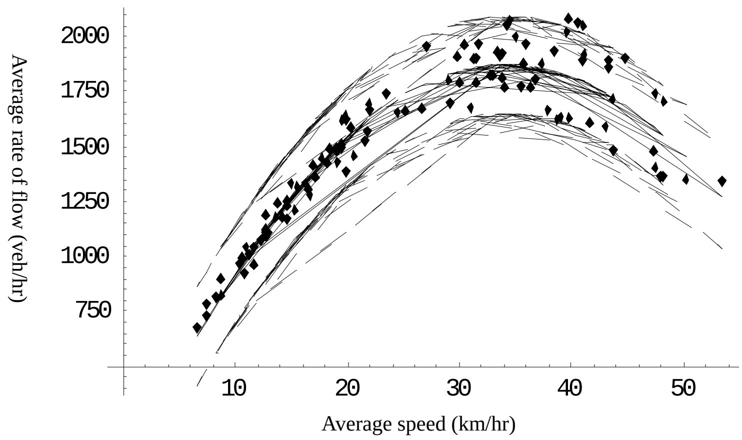

Figure 2 result of regression for average speed versus average rate of flow

Figure 2 reveals a high degree of scatter among the data. Speed appears to be sensitive to flow for the flow rates measured, e.g., fewer then 1854 vehicles per hour per lane. There are more scatters at high flows; indicating that speed is sensitive to flow as it nears capacity. From the data collected, an obvious relationship between speed and flow was found. The average speed is 34.29 kilometer per hour.

4.2 Density-Rate of Flow Relationships

Relationships between density and rate of flow were also examined. Densities were measured directly from the videotaped field data over the length of weaving section. Figure 3 illustrates the density-rate of flow relationship using average densities and average rate of flow for 1-minute periods. Flow appears to be sensitive to density, although the scatter increases at lower densities (e.g., fewer then 56 vehicles per kilometer), and the scatter decrease at higher densities (e.g., more then 56 vehicles per kilometer).

There is a conceptual flow in the relationship between density and traffic flow, however. For a given weaving section, the average speeds are nearly constant until traffic flows approach the

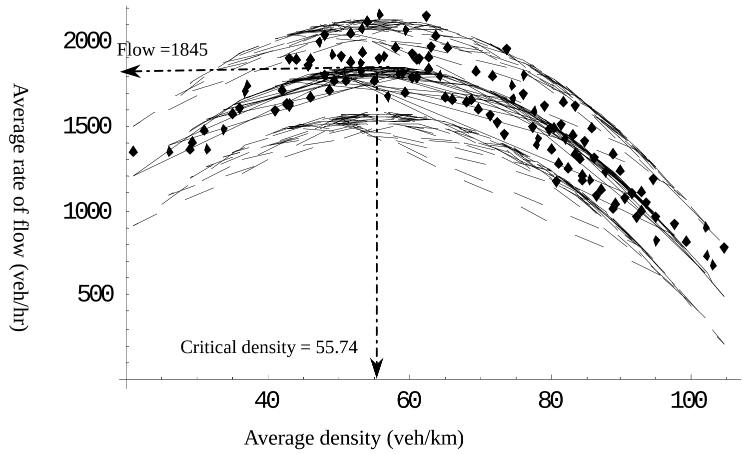

Figure 3 result of regression for average density versus average rate of flow

capacity level. In some studies, traffic flows for the weaving section studies did not approach capacity. This resulted in density values consisting of volumes divided by essentially constant speed (Fredericksen and Ogden, 1994). In this study, the plot of density versus rate of flow is the same as speed versus rate of flow, which would obviously be a strong linear relationship at low traffic flows (e.g., less then 1854 vehicles per hour per lane). It was determined that a model for predicting densities on the basis of flow would be the most effective procedure for predicting traffic operations in the weaving sections on separated connecting C-D roadways.

4.3 Speed-Density Relationships

Relationships between speed and density were also examined. Speeds and densities were measured directly from the videotaped field data over the length of the weaving section. Figure 4 illustrates the speed-density relationship using average speeds and average densities for the 1-minute periods. Density appears to be sensitive to speed, although the scatter decreases at higher speeds.

Mainly for illustration, Figure 4 presents the relationships among the average speed and average density over the observed periods. This it significantly from most speed-density models in which the average speed generally decreases linearly or nonlinearly with the increase of density (Chang and Kao, 1991). However, in this case the average speeds in these regions of the higher densities region or lowers densities region appears to be a nonlinear relationship, which in medially region would obviously be a strong linear relationship.
Those figures show reasonable agreements with the typical curves as far as the range of the data allows. The curves support the fact that the overall level of service of the traffic from which this data was collected ranges from the level of service C to the critical point, i.e., the level of service E.

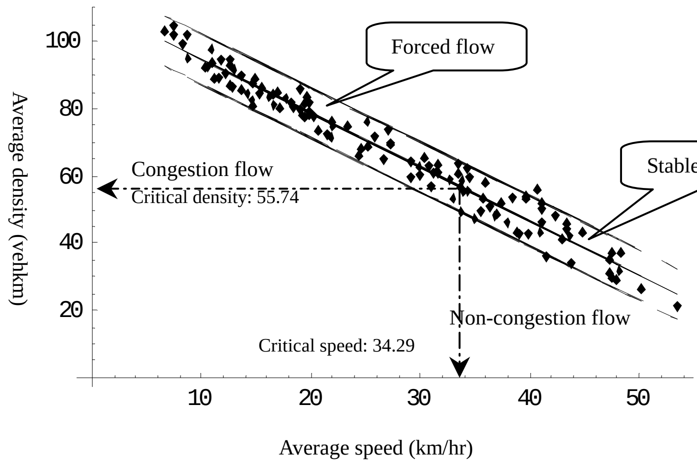

Figure 4 result of regression for average speed versus average density.

In this study, fundamentals of the data were studied. A detailed description of the data is presented and the time interval for the traffic conditions study is selected. In addition, procedures for computing traffic flow measures are explained. Finally, traffic conditions of the data and the relationships among the traffic condition parameters are studied.
Based on the 1-minute interval traffic conditions on the weaving section of the C-D roadway, the average rate of flow ranged from 1357 to 4328 vehicles per hour per lane; the average traffic density ranged from 42 to 209 vehicles per kilometer; and the average travel speed ranged from 6.6 to 53.48 kilometers per hour. The rate of flow and density increased with time during the study period whiles the speed decreased. The pair-wise relationship curves among the rate of flow, density, and speed closely matches the basic relationship curves among these three parameters within the range of the data. The result supports the adequacy of the data. The level of service of the traffic during the hour ranges from C to E.

5. ANALYSIS RESULTS AND DISCUSSION

The purpose of this study and analysis for weaving traffic maneuvers is to build up the regression model of the correlation of traffic speed, rate of flow, and density, and predict the trend of traffic flow characteristics.

5.1 Results of analysis

5.1.1 Density versus Speed

The model of the result of regression for density versus speed is indicated as follows:

$$k = 110.879-1.60814\ u \qquad \text{---(1)}$$

where: k = average traffic density, vehicle per kilometer, and
u = average traffic speed, kilometer per hour.

The coefficient of correlation (R^2 = 0.965338) and the t value of constant is 131.837 (greater than t_{test} value is 1.686 with 95% confidence), and of the x variable (density) is –57.3264 (absolute value greater than t_{test} value), the density variable is the significance of the speed. In this case, it is explained by the variability of the dependent variable, the average density in this case. The adjusted R^2 value for Equation (1) is 0.965044. The result of regression for average traffic density versus average traffic speed equation is shown as Figure 4. This model indicates when the critical density at maximum flow (capacity) equals to 55.74 vehicles per kilometer per lane. Then coincides with the speed 34.29 kilometers per hour at that point of capacity of bottleneck, and the rate of flow is 1845 vehicles per hour per lane. The jam density equals to 110.879 vehicles per kilometer and then the traffic rate of flow and speed equals to zero. The results are shown as Figure 4 and 3.

5.2 Density versus Rate of Flow

The model of the result of regression for the density versus rate of flow is indicated as follows:

$$q = 149.567+61.7085k-0.558381k^2 \quad \text{--(2)}$$

where: q = average rate of flow, vehicle per hour, and
k = average traffic density, vehicle per kilometer.

The coefficient of correlation (R^2 = 0.845873) and the t value of constant are 1.17393 (the value lesser than t_{test} value is 1.686 with 95% confidence); of the x variable (density) is 15.1115 (greater than t_{test} value); and of the x^2 variable (density) is –18.09 (absolute value greater than t_{test} value). The density variable is significant to the rate of flow. In this case, it is explained by the variability of the dependent variable, the average rate of flow in this case. The adjusted R^2 value for Equation (2) is 0.843239. The result of regression for the average traffic density versus the average rate of flow equation is shown as Figure 3. The model indicated that the critical density is 55.74 vehicles per kilometer, which coincides with the rate of flow at 1854 vehicles per hour per lane (capacity).

5.3 Speed versus Rate of Flow

The model of the result of regression for the speed versus rate of flow is indicated as follows:

$$q = 108.87u-1.58715u^2 \quad \text{--(3)}$$

where: q = average rate of flow, vehicle per hour per lane, and
u = average traffic speed, vehicle per hour per lane.

The coefficient of correlation (R^2 = 0.904596) and the t value of x variable (speed) are 24.8847 (greater than t_{test} value is 1.685 with 95% confidence), and of the x^2 variable (speed) is –20.7316 (absolute value greater than t_{test} value). The speed variable is significant to the rate of flow. In this case, it is explained by the variability of the dependent variable, the average rate of flow in this case. The adjusted R^2 value for Equation (3) is 0.902779. The result of regression for the average traffic speed versus the average rate of flow equation is shown as Figure 2. The model indicated the critical speed is 34.29 kilometers per hour, which coincides with the rate of flow at 1845 vehicles per hour per lane.

5.4 Discussion

In the previous research of this study, first, the linear speed-density regression model is $k = 110.879 – 1.60814\,u$, where the coefficient of the correlation R^2 = 0.965338. The regression model form and trend are similar to Greenshield's Linear Speed-Concentration model. The models are $u = 34.17 - 0.2124\,k$ (on inside lane) and $u = 38.05 - 0.2416\,k$ (on outside lane), where these coefficients of correlation R^2 = 0.96 and 0.97. This model is simple to use and several investigators have found good correlation between the model and field data. Those regression models, which show results found by Huber (Gerlough, Huber, 1975), are compared to these models in Figure 5.

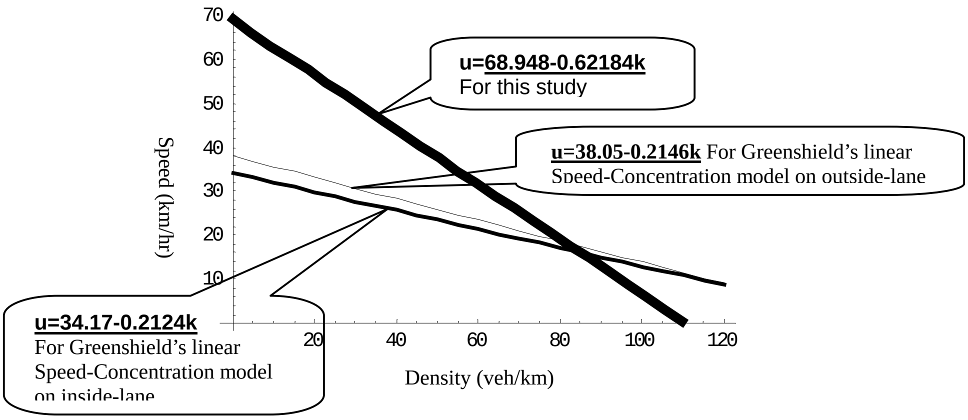

Figure 5 the compared of traffic speed versus traffic density

Second, the flow-density regression model is q = 61.7085 k – 0.558381 k^2 + 149.567, where the coefficient of correlation R^2 = 0.845873. The regression model form and trend are similar to the special flow-density model for three lanes of a freeway that the model described as q = 65.5 k – 0.179 k^2 – 80. Whereas most stream flow models are used to describe one-lane flows, it is possible to develop models describing the total flow on one roadway of a freeway. These models are seen in Figure 6.

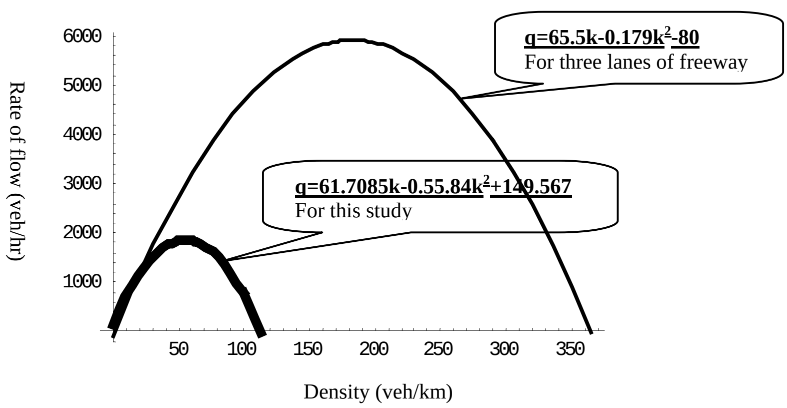

Figure 6 the compared of traffic density versus traffic flow

Third, the flow-speed regression model is q = 108.87 u – 1.58715 u^2, where the coefficient of correlation R^2 = 0.904596. The regression model form and trend are similar to the Greenshield's speed-flow function that was fitted to the Chicago Data (Drake et al. 1967). The model is q = 126.02 u – 2.15 u^2, which shows the speed-flow function resulting from Greenshield's hypothesis of a linear speed-density relationship. These models are compared to one another in Figure 7.

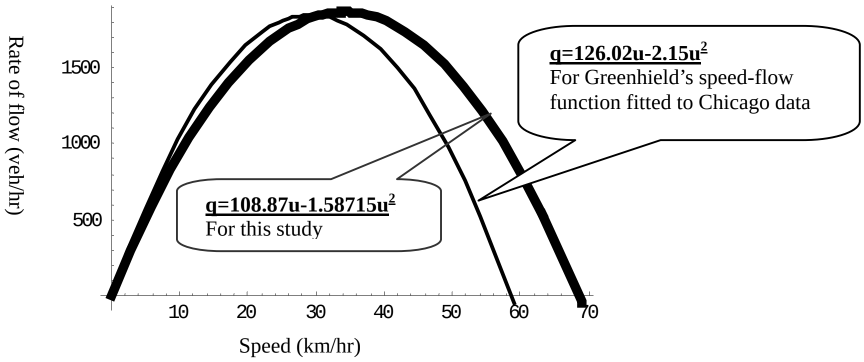

Figure 7 the compared of traffic speed versus traffic flow

6. CONCLUSION

The general objective of this research is to study the traffic flow characteristics of weaving vehicles in a freeway weaving section. Efforts are focused on analyzing the interrelation of traffic flow characteristics, as traffic speed, density, and traffic rate of flow.

In this research, the traffic flow characteristics of weaving traffic in a separated connecting C-D roadway on the freeway weaving section and on congested traffic flow conditions is studied by analyzing the three basic factors as traffic density, traffic speed, and traffic rate of flow characteristics of weaving vehicles. On the basis of the statistical analysis results, the following major conclusions were drawn:

1. The general form and trend of regression models in the fundamental traffic flow characteristics (includes traffic rate of flow, density, and speed) of weaving vehicles appear to be similar to Greenshield model. The results are showing the basic traffic flow pattern that pattern is no influence on increases with the lane changing and weaving activities, that is to be similar to the between of traffic in basic freeway sections. However, specific values obtained for weaving traffic such as the critical density, which is 55.74 vehicles per kilometer; the result is the higher then the HCM of Taiwan. The traffic speed is 34.29 kilometer per hour; and the maximum rate of flow (capacity) is 1854 vehicles per hour per lane. These results represent that the value of traffic variables including the traffic speed and rate of flow are same the Highway Capacity Manual (HCM) and the traffic density is more then the HCM.

2. The previous research the traffic flow characteristics in the weaving section was focusing on the frontage roadway facilities with ramp onto non-congestion traffic conditions. In this study investigates the macroscopic models of traffic flow characteristics on the weaving

section of a separated connecting C-D roadway on the Taiwan National Freeway Systems, focusing on the fundamental interrelations between the traffic speed, density, and rate of flow of the congestion traffic conditions, the results are more completely.

3.Traffic density and traffic speed appear to be better parameters for describing the behavior of weaving traffic than traffic rate of flow. The results of the regression analysis appear to be the constant coefficients of regression models that coefficients of constant indicate no significance with the 95% confidence difference observed between the traffic rate of flow versus the traffic density and traffic speed. However, the coefficients of the first (x) and secondary (x^2) variables (density or speed) appear higher, which is significant with the 95% confidence. Generally, the R^2 values for these regression models are very high, which ranges from 0.845873 to 0.965338. It implies that a considerable portion of the correlation of traffic flow characteristics such as traffic density, traffic speed, and rate of flow are excessively influenced by these factors considered in the regression variables.

ACKNOWLEDGEMENTS

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