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A Model to Predict Speed Rates in Weaving Sections (Case Study: Tehran Principal Arterials)

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ABSTRACT

Due to a strong need for lane changing, in weaving sections a type of turbulence creates a traffic flow and as a result the speed and the capacity of the weaving section decreases. Therefore, investigation of in this regard seems to be very essential. However, because of the lack of manual control for urban principal arterials, calibration of these models is necessary as well. One of these models that are used to evaluate the level of the weaving sections service is Speed Rates Model which will be elaborated in this paper. The required data have been collected in nine Tehran principal arterials. Then, two models for prediction of weaving and non-weaving speed rates have been developed. Validations also confirm the accuracy of the developed models. The investigation of weaving speed rates reveals that, speed rates for weaving vehicles reduce by increasing weaving density and rates. Also the research on non-weaving speed model shows the speed rates for non-weaving vehicles reduce by increasing weaving density and lane changing rate. Moreover, comparison of the developed model and HCM 2010 for similar condition reveals that the developed models have the predictability more than that of HCM 2010 model.

Keywords: weaving speed rates, non-weaving speed rates, weaving section, speed, lane changing

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INTRODUCTION

Weaving section means the conflict of two or more traffic flows which are moved through specific routes without using any control instruments (Windover & May, 1994) Weaving sections usually occur when merge and diverge zones are approximately close to each other (Ostrom, Lannon, & May, 1994). In weaving sections, drivers for finding a way need lane-changing. In this case, drivers for finding a way need the required maneuvers. Then, we may face agitation in comparison with other parts of the highways which leads to a specific operation in traffic volume and decreases the capacity. That is why investigation of weaving section plays a vital role (NCHRP, 2011). There are some codes such as HCM2010 which are used for external roads, (TRB, 2010) but for internal roads there is no reference available; therefore, calibration of existing models is essential and should be taken into account. One other issue which should be considered is finding a model for predicting of speed rates in weaving and non-weaving sections.

LITERATURE REVIEW

First studies on weaving sections had been done in HCM1965; using two approaches on freeways specified the length of weaving sections. The first model which was developed by Leisch and Norman included some curves using weaving volume and weaving length (Normann, 1957).

In HCM1965, the volume of non-weaving or its flow was not taken into account and for specifying the number of lane changing in weaving sections just an algorithm was utilized. TRB in 1970 tried to calibrate the curves which were used in HCM1965 (Pignataro, 1973). The first and most important study about weaving section is NCHRP, done by NCHRP, FHWA for developing HCM1985. Then, a model for predicting capacity of freeway in 1970 was developed by Roess and Mcshanne and published in TRB. This model is more complicated and the basic model is divided to discrete steps (L. J. Pignataro, Mc Shane, & Roess, 1975). In the middle of studying by NCHRP and FHWA, Leisch developed one more model like HCM1965 but FHWA used these documents as its financier and published in TRB212 (Leisch, 1983). Since 1980 various methodologies have been applied to survey on weaving sections. In 1981 JHK developed a third model for HCM developed by Reilly and this algorithm was used in HCM2000. In 1985, (Reilly, Kel, & Johnson, 1984)Fazio developed a model based on Reilly algorithm and added lane changing parameter to it (Fazio, 1985).

In HCM 2000, prediction of speed convert to density and level of service calculation based on density. But in HCM 2010, methodology had changed and at the first it predicted the number of lane changing and based on this, speed calculated and converted to density (TRB, 2010). Then, based on these issues, level of service of weaving sections specified. Comparing the estimation of the capacity of Type B weaving sections to the HCM2000 procedures demonstrate that the HCM2000 procedures suffer from four significant drawbacks. First, the procedures can only consider relatively long weaving sections (longer than or equal to 150 m). Second, the HCM procedures fail to capture the impact of the distribution of weaving flows between freeway and on-ramp demand on the capacity of weaving sections, which is demonstrated to be as an important factor in the analysis weaving section capacities. Next, the procedures do not ensure that the capacity of a weaving section reverts to the basic freeway capacity when the volume ratio is zero (no weaving flows) regardless of the weaving section length. Finally, the HCM procedures do not guarantee consistency between the weaving and merge/diverge procedures at boundary conditions (Rakha & Zhang, Aug 2015). Then there were some surveys on the criteria which are effective in this issue. In another survey which is done for TRB the researchers quantify the interactions between vehicles during lane change in congested weaving 5 sections and try to incorporate them into vehicles' (merging vehicles, their putative leaders (PL) 6 and putative followers (PF) acceleration-deceleration models (Wan, Jin, Yang, & Ran, 2014). There was also a survey on analysis of lane changing behavior at a freeway weaving section that illustrated under heavy congested traffic conditions the weaving vehicles tended to change lane as soon as possible after the beginning of the weaving section. When the traffic conditions are fluid, the lane changing positions are more dispersed along the first part of the weaving section (Marczak, Leclercq, & Buisson, Feb 2015). By identifying some key driving characteristics of vehicles in the weaving section, it reveals that 25.25% of the weaving movements took place in the first 50-100 meters from the point of merge and around 30% of the total traffic involved in one lane-changing movement (kaKusuma, Ronghui, Choudhury, & Montgomery, 2014)

A theoretical weaving section is considered at the macroscopic level as the superposition of two merges and two diverges. The model endogenously incorporates the capacity drop related to the weaving lane changes. It only depends on six parameters: three parameters of the fundamental diagram (the free-flow speed, the jam density, and the wave speed in congestion), the vehicles' acceleration, the relaxation factor, and the length of the anticipation zone (Marczak et al., Feb 2015). This paper used as a basis for HCM2010 in order to predict speed (TCTTS, 2014).

DATA COLLECTION

For predicting the speed in weaving sections, nine sections in Tehran highways were selected and the required data were collected. Data were collected for 4 hours (from 9 to 130) and in 5 minute intervals. Table 1 shows the process. Moreover, Figure 1 illustrates the location of these sections on Tehran map (TCTTS, 2014).

Table1. Highway sections for data collection

Highway name	Entrance ramp	Existing ramp	number of lane	length of section(m)
Hemmet	Shariati	Haghani	5	413
Hakim	Chamran	Bahaii	4	352
Imam Ali	Janbazan	Resalat	4	155
Sadr	Kamranieh	Niaiesh	4	115
moddares	Arash	Dastgerdi	3	194
Niaiesh	Chamran	Seol	4	135
Niaiesh	Yadegar	Ashrafi	4	165
Yadgar	Hakim	Marzdaran	5	160
Rey	Karimi	Salman Farsi	4	232

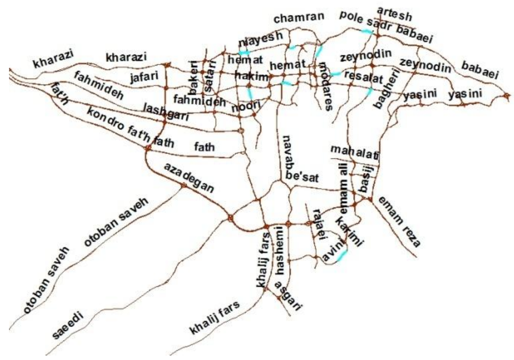

Fig1. Tehran principal arterial's sections for survey

COLLECTION OF SPEED DATA IN WEAVING SECTIONS

For the collection of speed, the researchers have used space that means speed. In weaving sections we have four kinds of traffic flow which is shown in Figure 2, from ramp to ramp $V_{RR,}$ from ramp to highway $V_{RF,}$ from highway to ramp V_{FR} and from highway $V_{FF,}$ from entrance section to exit one. Moreover data collection was done in 3 sections which are shown in Fig 2 (Kittelson & Associates, 2008).

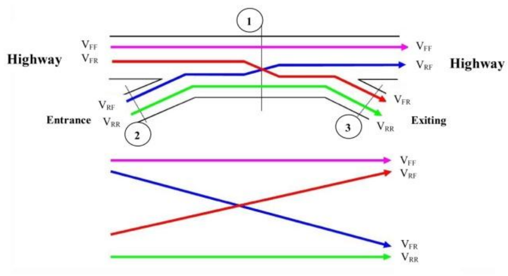

Fig2. Various kinds of traffic flow in a section

1. Measuring travel time from ramp to ramp t_{RR}, from ramp to highway t_{RF}, from highway to ramp t_{FR} and from highway t_{FF}, from entrance section to the exiting one respectively in weaving sections. Situations of these parameters are shown in Fig 2.
2. Specifying the length of weaving section (LB). With using Eq 1, we may estimate space mean speed for various situations.

$$S_k = \frac{L_B}{\sum_{i=1\ to n} \frac{t_i}{n}} = \frac{L_B}{\sum_{1\ to n} t_i} \quad (1)$$

Here S_k is space mean speed for flow K (km/h) , L_B is weaving section length from entrance section to exit one, t_i is time travel for vehicle i in L_B and n is the number of vehicles which travel time surveyed for them.

PROCESSING OF WEAVING SECTION MODEL

In previous studies about speed, one of the most important criteria was density in weaving sections that some features like weaving volume to total volume ratio (VR), total volume to number of lane (V/N) and length of weaving sections were introduced (NCHRP, 2011; TRB, 2010). But in the current survey, the researchers have used the number of lane changing in weaving sections rather than VR and (V/N). In this paper, the most critical parameter of speed for weaving vehicles in a waving section is the ratio of total lane changing to the length of weaving section (LC_{all}/L_R) and indicates density in the weaving section (TCTTS, 2014). Investigating the speed changes, it shows that speed changes for weaving vehicles versus density is descending which means that by increasing the speed the density of weaving vehicle will reduce.

SUGGESTED MODEL FOR SPEED OF WEAVING VEHICLE

The logical assumption in speed modelling is maximum speed which is equal to free flow speed (FFS), and because of the conflict in highway sections, speed of vehicle in proportion to the density will reduce. Regarding existing data, minimum speed of vehicle in weaving sections is assumed 15 (km/h). After calibration of model, equations number (2), (3) suggested for the speed of weaving vehicles.

$$S_w = 15 + [\frac{FFS-15}{1+W_w}] \quad (2)$$

$$W_w = a + [\frac{LC_{all}}{L_B}]^b \quad (3)$$

Here FFS is free flow speed in highway (km/h), LC_{all} is the total number of lane changing in weaving section (Lc/h) , L_B is length of weaving section (m) and W_w is density factor. Table 2, shows coefficient and statistical index for the suggested model of speed of weaving vehicles after calibration.

Table 2. Coefficient and statistic index for the suggested model of weaving vehicles speed

Coefficient	Coefficient value	t	R^2
a	0.279	1.177	0.5
b	0.715	2.29	

SUGGESTED MODEL FOR THE NON-WEAVING VEHICLE SPEED

In this paper a different method has been used for modelling, because in comparison with HCM2010 by this assumption R^2 for evaluation of model is much higher and being more acceptable (TRB, 2010). The researchers have assumed speed in weaving sections that is equal to free flow speed in highways, but because of the conflicts, it will reduce. Moreover, in previous studies minimum number of lane changing (LC_{min}) has been used with the proportion of volume section to number of lane (NCHRP, 2011; TRB, 2010). But the survey on Tehran shows that, it is better to use (LC_{all}/L_R)So the researchers have applied a similar equation for non-weaving speed like weaving speed and in this model the effective parameter is (LC_{all}/L_R) that indicates density in weaving sections on highways. The investigation shows speed changes for non-weaving vehicles versus density that is descending and by increasing density, speed of weaving vehicle will reduce. Surveying on HCM2010, indicates a model for estimating one for non-weaving vehicles having similar structure as weaving vehicles. Just constant value of calibration varies. Equation 4 shows speed model for non-weaving vehicles.

$$S_{NW} = 15 + [\frac{FFS-15}{1+W_w}] \quad (4)$$

$$W_{NW} = a + [\frac{LC_{all}}{L_B}]^b \quad (5)$$

In this equations, FFS is free flow speed in highway (Km/h), LC_{all} is number of total lane changing in non-weaving section , L_B as length of non-weaving section (m) and W_{NW} is density factor. Here Table 3 indicates coefficient and statistical index for the suggested model of non-weaving vehicles speed after calibration.

Table3. Coefficient and statistical index for the suggested model of non-weaving vehicles speed

Coefficient	Coefficient value	t	R^2
a	0.054	0.738	0.463
b	1.109	2.268	

EVALUATION OF MODEL FOR SPEED IN WEAVING SECTIONS

Evaluation of weaving speed

To compare observed and predicted speed, the researchers have used spot scattering which is shown in Figure 3. Although the rate of correlation coefficient is 0.34, it is acceptable. Moreover the standard deviation rate for the observed and predicted speed is 4.93(km/h), (TCTTS, 2014) which is acceptable in comparison with the model of HCM2010 which estimated it 7.2(km/h) and by $R^2 = 0.614$ (TRB, 2010).

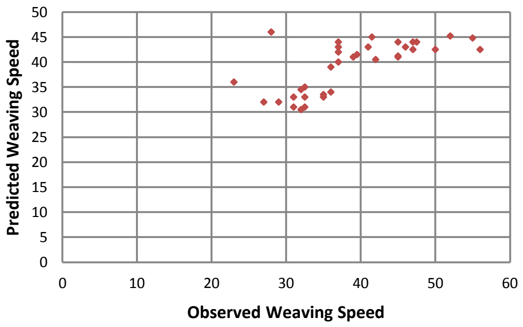

Fig3. Observed weaving speed versus predicted weaving speed

Evaluation of model for speed in non-weaving sections speed

Figure 4 shows the comparison of observed and predicted one in non-weaving sections. The standard deviation rate is about 7.55 (km/h), (TCTTS, 2014) which is acceptable, which is acceptable in comparison with the model of HCM2010 which estimated it 8.4(km/h) and by $R^2 = 0.25$ (TRB, 2010).

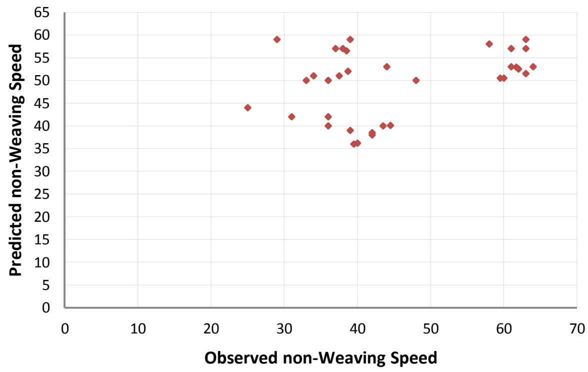

Fig4. Observed weaving speed versus of predicted non-weaving speed

CONCLUSION

A survey on weaving sections due to the agitation in traffic flow and reduction in speed and capacity is essential. Because there is no reference and code for weaving section in internal roads and because the HCM2010 is related to weaving section on freeways, this survey is done. Using other references and calibration of models, speed in weaving and non-weaving sections may be predicted. To do so nine sections in Tehran highways were selected and the required were data collected and 2 models for predicting the speed were evaluated. The investigation of weaving speed rates reveals that speed rates for weaving vehicles reduce by increasing weaving density and rates. Also the research on non-weaving speed model shows the speed rates for non-weaving vehicles reduce by increasing weaving density and lane changing rate. Moreover, the comparison of the developed model and HCM 2010 for similar conditions reveals that the developed models have the predictability more than that of HCM 2010 model.

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