

Predicting Average Vehicle Speed in Two Lane Highways Considering Weather Condition and Traffic Characteristics

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Abstract. Analysis of vehicle speed with different weather condition and traffic characteristics is very effective in traffic planning. Since the weather condition and traffic characteristics vary every day, the prediction of average speed can be useful in traffic management plans. In this study, traffic and weather data for a two-lane highway located in Northwest of Iran were selected for analysis. After merging traffic and weather data, the linear regression model was calibrated for speed prediction using STATA12.1 Statistical and Data Analysis software. Variables like vehicle flow, percentage of heavy vehicles, vehicle flow in opposing lane, percentage of heavy vehicles in opposing lane, rainfall (mm), snowfall and maximum daily wind speed more than 13m/s were found to be significant variables in the model. Results showed that variables of vehicle flow and heavy vehicle percent acquired the positive coefficient that shows, by increasing these variables the average vehicle speed in every weather condition will also increase. Vehicle flow in opposing lane, percentage of heavy vehicle in opposing lane, rainfall amount (mm), snowfall and maximum daily wind speed more than 13m/s acquired the negative coefficient that shows by increasing these variables, the average vehicle speed will decrease.

1. Introduction

Analysis of vehicle speed with different weather conditions and traffic characteristics is very effective in traffic planning. Since the weather condition and traffic characteristics is so various in everyday, so the average vehicle speed modelling can be useful in traffic management. Based on the research purpose, the focus of this literature review will be on weather effects on the traffic characteristics.

The effects of weather conditions on travel speed and traffic congestion is significant in the winter (Rakha, [1]). The relationship between speed and volume was studied on freeway sections using the data (RTMS) and atmospheric conditions. The empirical relationships between speed and traffic volume are analyzed by atmospheric conditions (clear, rain, fog and snow), surface conditions (dry, wet, icy) and the percentage of heavy vehicles in traffic. The rainy weather reduces the vehicle speed by 8 to 12 percent and the capacity by amount 7 to 8 percent. In addition, the wet surface reduces the speed by amount of 6 to 7 percent and the light snows also affected on the demand and reduce the traffic volume, [2]. Cold and snowy weather is affected on rate of hourly and weekly traffic flow. The snowfall at



temperatures above zero degrees, reduce 1 to 2 percent of traffic volume. The volume was reduced between 1 and 31 percent in the days without rainfalls according to cold sever. Average traffic volume was reduced by about 30 percent in degrees of below 25°C, [3]. Traffic volume is reduced by about 16% to 47% in the winter weather conditions, temperatures in below freezing temperatures and snowfall at higher intensity of 0.51 cm/h [4, 5]. Under slight snowfall, free-flow speed is reduced to 3 km/h (8 km/h at heavy level traffic 2400 veh/h) and under heavy snowfall, free-flow speed reduced 38 km/h to 50 km/h, [6]. Light snow, will result to reduction in free-flow speed to (96 km/h), in contrast, heavy snow will result to reduction in speed to 37 to 41.8 km/h [7]. The traffic volume is reduced 20 % on snowy days with low wind speed conditions. Also, it is reduced by nearly 80 percent on snowy days when visibility is less than 1/4 mile and the wind speed is high (above mph 40) [8].

The relationship between rain and other weather variables was researched on traffic volume in urban arteries at Melbourne, Australia. Regression model of combined traffic data, weekdays, holidays and weather conditions was offered. The traffic volume reduced 1.35 percent in wet days in winter and reduced 2.11 percent in spring. The greatest reduction volume is 3.43 percent for rainfall to amount 2 mm to 5 mm, [9]. A slight of rainfall reduces free-flow speed by amount 2 km/h and at the maximum flow (2400 veh/h) is reduced averagely 13 km/h in comparison with clear weather conditions, [6]. Speed reduction under rainfall is about 3 to 5 percent, [5]. Reduction of performance speed under light rainfall in the free flow conditions is 1.9km/h and in the capacity conditions is 6.4 to 12.9 km/h. Reduction of performance speed under heavy rainfall in the free flow conditions is 4.8 to 6.4 km/h and in the capacity conditions is 12.9 to 16 km/h [7]. Heavy rainfall is effective on speed and headway time. Also, the heavy rainfall reduces traffic speed and increases the headway time.

Multi-state prediction models by linear regression analysis, investigates traffic characteristics under rainfall. Finally, it was suggested a procedure for determining the speed adjustment factor for traffic under rainy conditions [10]. Ru Wang et al., [14] studied the relationship between weather conditions and traffic flow characteristics in urban road by using a fixed detector data, video data and weather data. Nonlinear regression was used to estimate the capacity and traffic speed. The results indicated that the snow conditions and especially rainy conditions influence free-flow speed in highways and arterial roads [10].

Yang et al used a hierarchical method to investigate the effects of driving in foggy conditions on drivers of risk: base speed response for low risk level, and quickly dynamic response for medium risk level and critical speed response for high risk level. Driving simulation experience indicated that drivers for reduce the risk of driving in foggy conditions at all three levels of risks they are willing to reduce speed [11]. In the other study on 75km of suburban freeway sections, reducing the average speed was 8 km/h and 19.2 km/h for foggy and snowy conditions respectively [12]. In another study, Padget et al [13] studied relationship between speed and weather conditions with passenger vehicles, USV and pickup truck at arterial urban streets in Iowa during the winter from 1999 to 2000. The results showed that speed of all three types of vehicles is clearly less than normal speed in normal conditions. They also concluded that speed variation, increased between types of vehicles in winter weather conditions and the difference of speed [13, 14].

Compared to previous studies, our study applied the two-lane highways factors such as traffic flow and heavy vehicle percentage in the opposite lane. These factors can be effective on passing performance and average vehicle speed in two lane highways. Also, this study considered the different weather condition.

2. Data collection

In this study, traffic and weather data for a two-lane highway located in the Northwest of Iran was gathered for analysis. This 110-kilometer long highway with mountainous terrain and average annual daily traffic equal to 14000 veh/day is considered as one of major highways in east Azerbaijan province rural network. The study area is shown in Figure.1.

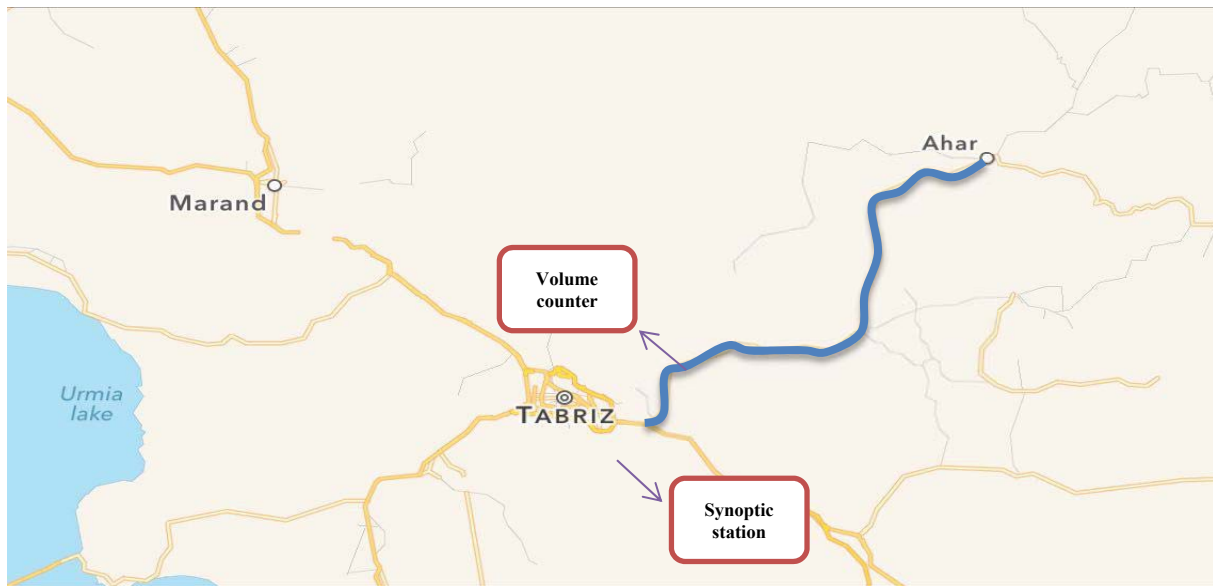


Figure 1. Study area

Two types of data needed for this study: traffic flow data and meteorology data. Volume counter located in 25 kilometres from Tabriz city for collection of traffic flow data. The counter location is in tangent section of highway so that no vertical and horizontal curve is not located in 2 kilometre radius of the volume counter. This counter recorded 496 daily data from 2012 to 2013. Table 1 shows the summary statistics information of traffic flow variables. Meteorology data have been collected from the Tabriz synoptic station. Table 2 shows the summary statistics information of meteorology data variables.

Table 1. Summary statistics information of traffic flow variables

Variable	Mean	Standard error	Minimum	Maximum
Average vehicle speed (km/h)	68.63	4.10	51.39	80.40
Traffic flow (veh/day)	7673.20	2858.13	891	20368
Heavy vehicle percent (%)	12.68	6.98	2.53	49.21
Traffic flow in opposite lane (veh/day)	6049.99	1916.60	171	16623
Heavy vehicle percent in opposite lane (%)	11.66	3.56	3.40	42.67

3. Methodology

In this study, a linear regression model was applied for predicting average speed. Traffic and weather data selected for modelling. Traffic data include traffic flow in each direction of highway and weather data include rainfall, snowfall, humidity, temperature and wind speed. Eq.1 shows the overall structure of the model.

$$S_F = \sum_i A_i V_i + \sum_j B_j Vop_j + \sum_k C_k W_k + d \quad (1)$$

Where S_F : average speed in two lane highway; A_i : Coefficient of traffic flow factor i in the analysis direction; V_i : traffic flow factor i in the analysis direction; B_j : Coefficient of traffic flow factor j in the opposing direction; Vop_j : traffic flow factor j in opposing direction; C_k : Coefficient of weather condition factor k ; W_k : Weather condition factor k ; d : Model constant.

Table 2. Summary statistics information of meteorology data variables

Variable	Mean	Standard error	Minimum	Maximum
Daily temperature average (°C)	15.58	9.54	-5.12	33.95
Maximum daily temperature (°C)	21.85	10.36	-3.20	41.00
Minimum daily temperature (°C)	10.01	8.74	-12.40	28.20
Rainfall amount (mm)	0.87	2.65	0.00	19.00
Daily humidity average (%)	48.97	16.97	16.00	93.75
Maximum daily humidity (%)	68.32	18.30	23.00	99.00
Minimum daily humidity (%)	30.26	15.97	5.00	86.00
Daily wind speed average (m/s)	3.94	1.69	0.87	10.12
Maximum daily wind speed (m/s)	8.75	3.85	2.00	20.00

After the modelling, the sensitivity analysis is used to describe variables. Sensitivity analysis is very useful when attempting to determine the impact the actual outcome of a particular variable will have if it differs from what was previously assumed. Sensitivity analysis uses the elasticity parameter for describing the continuous variables and the semi elasticity parameter is used to describe the binary variables [16]. Eq. (2) and (3) show the elasticity parameter and the semi elasticity parameter.

$$E_x = \frac{\partial y}{\partial x} * \frac{x}{y} \quad (2)$$

where E_x : change in the average speed for a percentage change in the independent variable x; y: average vehicle speed; x: amount of independent variable.

$$E_x = \frac{y_{1x} - y_{0x}}{y_{0x}} \quad (3)$$

where E_x : change in the average vehicle speed for change in the independent variable x from 0 to 1; y_{1x} : the independent variable x that be 1 in average vehicle speed; y_{0x} : independent variable x that be 0 in average vehicle speed.

4. Modelling

Before the modelling, traffic data and meteorology data should be merged. In other words, meteorology data related to daily traffic data should be achieved. This merging is done by visual basic program and STATA12.1 (Statistical and Data Analysis) software is used for modelling in this study. Also, 95% confidence level was considered for significance of each variable. Table 3 shows the final model with 7 independent variables: traffic flow in analysis direction, percentage of heavy vehicle, traffic flow in opposing lane, percentage of heavy vehicle in opposing lane, rainfall amount(mm), snowfall and maximum daily wind speed more than 13m/s. Variables of snowfall and maximum daily wind speed more than 13m/s is the discrete variable and the others are continuing variables.

Table 4 shows the analysis of variance (Anova) for final model. Ratio of treatment mean square to residual mean square is 16.76 in this analysis. This ratio is more than total mean square (16.72). In other words, the null hypothesis of variable coefficients is rejected. Also R^2 is 0.1941 for final model. This amount of R^2 is not inappropriate because this model is considered just traffic and meteorology condition while many other factors influence on the average vehicle speed.

Table 3. Model output

Dependent variable (average vehicle speed)						
Variable	Coefficient	Stand. error	Z	P > Z	95% Confidence interval	
Traffic flow (veh/day)	0.00027	0.00006	4.28	0.000	0.00014	0.00039
Heavy vehicle percent (%)	0.211	0.0256	8.24	0.000	0.160780	0.261488
Traffic flow in opposite lane (veh/day)	-0.00064	0.00009	-6.66	0.000	-0.00083	-0.00045
Heavy vehicle percent in opposite lane (%)	-0.1434	0.0499	-2.87	0.004	-0.2415	-0.0453
Snowfall *	-3.219	1.1071	-2.91	0.004	-5.394	-1.0436
Rainfall amount (mm)	-0.1300	0.0655	-1.98	0.048	-0.2589	-0.00119
Maximum daily wind speed more than 13m/s *	-1.151	0.4944	2.33	0.020	-2.1282	-0.1797
Model Constant	69.746	0.907	76.90	0.000	67.963	71.528

* Discrete variable

Table 4. Anova analysis

Source	Partial SS	DF	MS	F(7.487): 16.76 Prob > F: 0.00
Treatment	1603.28	7	229.04	R-squared: 0.1941 Adj R-squared: 0.1825 Root MSE: 3.69
Residual	6657.25	487	13.66	
Total	8260.53	494	16.72	

After the evaluation and analysis of the model, the variable coefficient was interpreted. These coefficients should be rational for average vehicle speed estimated. The positive coefficient 0.00027 and 0.211 is related to traffic flow and percentage of heavy vehicle. This shows that if traffic flow and heavy vehicle present increase on the day, average vehicle speed will increase. Since none of the hourly traffic flows were more than capacity in 496 days, this result can be rational.

Negative coefficient -0.00064 and -0.1443 is related to the traffic flow and heavy vehicle present in opposite lane. These coefficients show that if traffic flow and heavy vehicle present in opposing lane increase on the day, average speed will also decrease. In other words, if the passing chance in the opposite lane decreases, average speed will decrease too.

Snowfall amount (mm) was not significant in the model but the dummy variable of this variable is significant with p-value of 0.004. Coefficient of this variable is -3.219 and shows that snowing day decreases the average vehicle speed. Rainfall amount with coefficient -0.130 was significant. It shows that if the rainfall amounts increase, average vehicle speed is decreased.

Wind speed coefficient is -1.151 it shows that if wind speed be more than 13 m/s per day, average vehicle speed will decrease. After the modelling, the sensitivity analysis was used to describe variables. Because of the regression model in this study, differential of average vehicle speed ratio to independent variable equal with variable coefficient in final model. Final model has 5 continuous variables and 2 discrete variables; describe this two groups of variables is different. For example, in continuous variable, differential of heavy vehicle present in opposite lane is -0.1434. It means that if the heavy vehicle presents in opposite lane increase 1%, average vehicle speed decrease 0.14%. Also in discrete variable, differential of snow fall variable is -3.21. This differential indicates that if snow on the day, average vehicle speed will be 3.21% less than other days.

5. Conclusion

In this study, traffic and weather condition for Tabriz-Ahar two-lane highway located in the Northwest of Iran were selected for analysis. A linear regression model was used for modelling. In summary, the following conclusions can be noted:

- Variables of traffic flow, heavy vehicle percent, traffic flow in opposite lane, heavy vehicle percentage in opposite lane, rainfall amount (mm), snowfall and maximum daily wind speed more than 13m/s were obtained significant variables in the final model.
- Variables of snowfall and maximum daily wind speed more than 13m/s are the discrete variables and the other variables are continuing variable.
- Variables of traffic flow and heavy vehicle percentage acquired the positive coefficient that shows increase these variables increasing the average vehicle speed. Other variables acquired the negative coefficient that shows increase these variables decreasing the average vehicle speed.
- In this study, variables of weather condition such as rainfall, snowfall and wind speed similar to previous studies reduce the average vehicle speed.
- All the variables have a significant level more than 95%. Statistical tests indicate that the final model is acceptable model consider with traffic and weather conditions.

6. References

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