EXPERIMENTLA ANALYSIS OF CAR FOLLOWING PARAMETERS BASED ON RTK GPS DATA*

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1. Introduction

In past few decades, several mathematical models have been developed to describe interaction between successive vehicles. The stimulus-response concept, which is regarded as a fundamental concept in many car following models, was developed by General Motor's researchers in late fifties and early sixties[1),2)3)]. Although a great deal of investigation works was performed to calibrate and validate this model, it has very limited use for simulation purposes nowadays. The inconclusiveness associated with the behavior of this model might have contributed significantly for the decline in its use, as a large numbers of contradictory findings were proposed to correct the values of its model parameters[1),4)5)6)7)]. Besides these general drawbacks, it has been noticed that the validation works conducted by previous researchers have several limitations in terms of number of vehicles used in experiments and quality of data.

This study aims to analyze the microscopic traffic flow behavior in light of more reliable experimental data. The purpose is to clarify the inconclusiveness associated with the stimulus-response model through identification of sensitivity parameters l and m for different traffic conditions. The optimum values estimated for these parameters are analyzed and compared with previous findings to reach to a consensus.

2. Stimulus-Response Concept

The concept was initiated by Chandler et al.[1)], subsequently followed by a series of investigations[2),3)4)5)6)].

$$a_n(t+T) = \lambda \; \Delta v(t) \tag{1}$$

Gazis et al.[6)] proposed a generalized model, incorporating speed and headway in the formulation.

$$\lambda = \alpha \; x \; \frac{v_n(t+T)^m}{\Delta x(t)^\ell} \tag{2}$$

Combining equation (1) and (2),

$$a_n(t+T) = \alpha \; x \; \frac{v_n(t+T)^m}{\Delta x(t)^\ell} \Delta v(t) \tag{3}$$

where l and m are sensitivity parameters. A wide range of values were proposed for these parameters based on investigations conducted by previous researchers[1),4)5)6)7)]. May and Keller[7)] proposed l = 3, m = 1as optimal integer solutions while Cedar et al. [9),10)] estimated l = 2.4 and m = 0.6 as the optimum values using traffic stream model. They acknowledged that the data fit was better in case of two-regime approach compared with single-regime approach and proposed l = 3 and m = 0 for the uncongested driving conditions and l = 0 - 1 and m = 0 for congested driving conditions. Later, Easa et al.[11)] developed nomographs to obtain these parameters for different driving conditions. Brackstone et al.[12)] has presented summary of investigations proposing values of sensitivity parameters.

Gurusinghe[13)] estimated these parameters by linear correlation method based on equation (3). He found that the optimum values were not so stable. More seriously, the correlation coefficients obtained were very low. This method

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needs reaction time T to be determined first. Conventionally, the reaction time is considered as a constant and estimated by cross correlation method. However, Castello[14] suggested that the reaction time might not be constant; rather it may have some relationship with traffic density in macroscopic flow. Ozaki[15] suggested that the reaction time might have some relationship with headway, speed and leader acceleration. Gurusinghe et al.[16] have proposed a graphical method to estimate time variant reaction time. Suzuki et al.[17] have analyzed the variations in the time variant reaction time estimated by graphical method for different driving conditions. Ranjitkar et al.[18] have proposed an algorithm to estimate sensitivity factor λ based on time variant reaction time, using Lissajou's diagram between acceleration and relative speed.

3. Methodology

Sensitivity parameters are calibrated using two different approaches:

(a) Direct Approach: Sensitivity factor λ is estimated from acceleration and relative speed data using Lissajou's diagram and then sensitivity parameters l and m are estimated based on equation (2) by linear regression method. The time variant reaction time estimated automatically, using computer program is used.

(b) Indirect Approach: Traffic stream model, given by Cedar et al. [9),10)] is used for estimation of sensitivity parameters. This model is a transformation of the stimulus-response model to Greenberg[19] macroscopic model and its formulation is as follows:

$$v = v_f \left[1 - \left(\frac{k}{k_j} \right)^{l-1} \right]^{\frac{1}{1-m}} \tag{4}$$

where v, v_f, k and k_j are speed, free flow speed, density and jam density respectively. Genecop, a non-linear optimization technique is used to estimate these parameters efficiently.

4. Data Collection

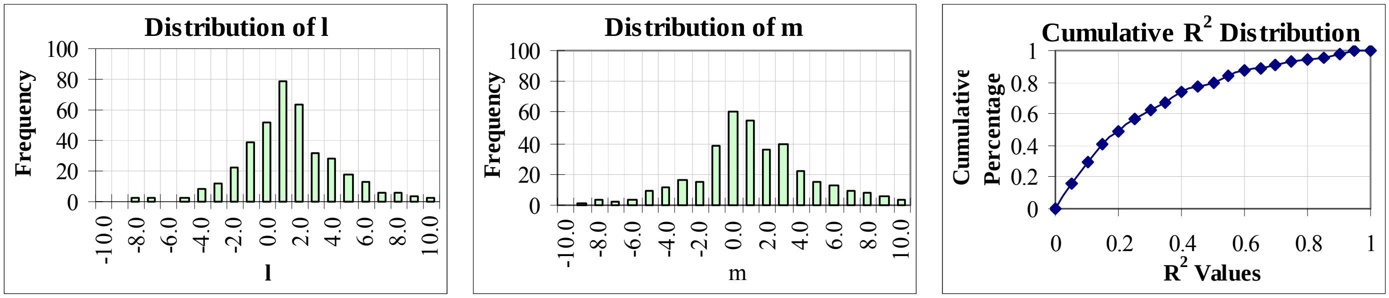
The experiments conducted in a test track of Civil Engineering Research Institute of Hokkaido, Japan involved ten passenger cars, equipped with RTK GPS receivers. The test track consists of two 1.2 km long straight sections connected by two 0.3 km long semicircular curves. We have conducted two types of experiments, first car following experiment that generally represents steady state driving conditions and second, intersection experiment that covers a wide regime of traffic conditions i.e. from congested to free flow or, steady state. In car following experiment, various speed patterns were tested for the lead car including four sinusoidal, four constant and a random speed patterns. In intersection experiment, one intersection point was installed on each of the straight sections of the test track. The RTK GPS receivers used in this experiment output position and speed data at every 0.1 sec interval with 10mm+2ppm position accuracy and less than 0.2 km/h speed accuracy. Gurusinghe et al.[16] has examined the accuracy of these data sets and confirmed that these data are accurate enough.

5. Analysis and Results

In total, 94 data sets are used for analysis including 47 sets of car following data and another 47 data sets of intersection data. Each of these data sets contains data from a single run in the test track. The extracted data from the receivers that include time, position and speed data are processed to estimate other variables such as acceleration, headway, relative speed and density etc. The acceleration is calculated by differentiation of speed data by polynomial fitting technique. The headway and relative speed is estimated from the position and speed data of successive vehicles respectively.

(a) Direct Approach: As the time variant reaction time and sensitivity factor are estimated from peak points in relative speed and acceleration data, this analysis is based on only peak point data. The data point with poor correlation between acceleration and relative speed are not considered in this analysis.

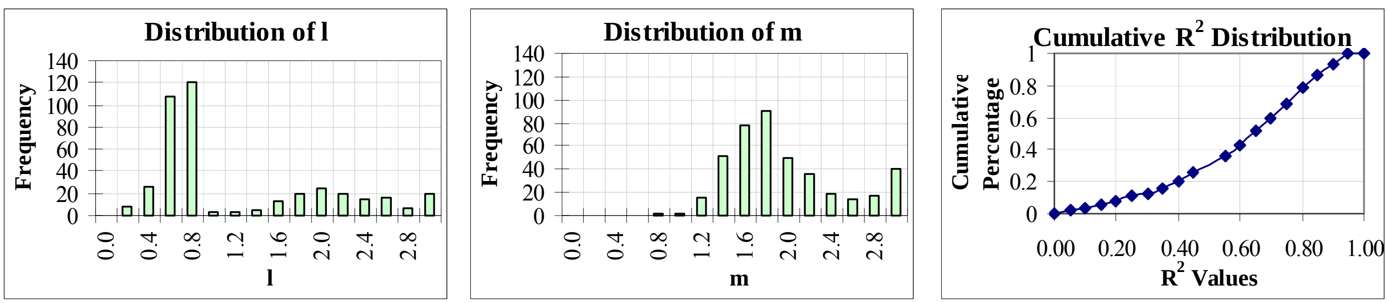
Fig. 1 presents distribution of optimum values for parameter l, m and cumulative R^2 percentile for all drivers estimated by direct approach using car following data. **Fig. 1a** and **Fig. 1b** show that parameter l and m is distributed over a wide range of values from +10 to –10. **Fig. 1c** shows that the correlation coefficient obtained is not satisfactory although this it is comparatively better than the results obtained by previous researchers.



a. Distribution of parameter l   b. Distribution of parameter m   c. Cumulative R^2 percentile distribution

Fig. 1 Distribution of sensitivity parameters and R^2 cumulative percentile using car following data

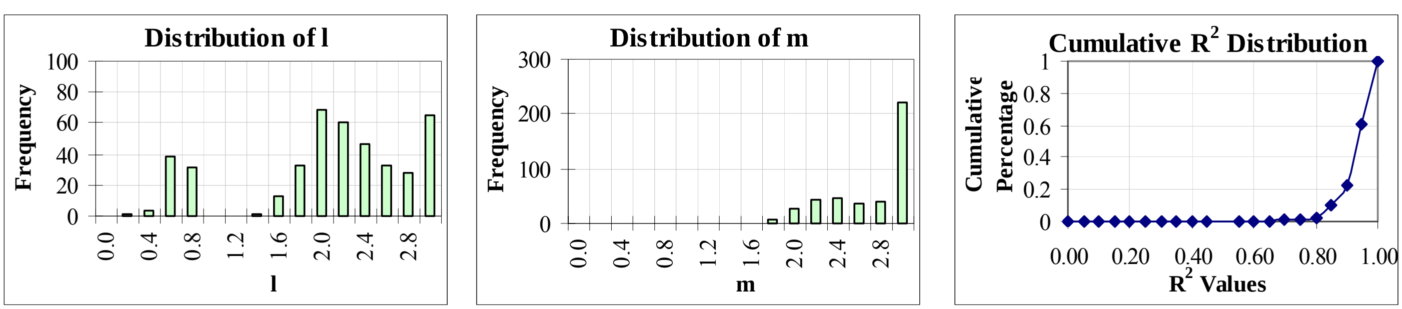
(b) Indirect Approach: Fig. 2 presents the distribution of optimum values for parameters l, m and cumulative R^2 percentile for all drivers estimated by indirect approach using car following data. The optimum value obtained for parameter l is distributed with in the range of 0.2-3 while the same for parameter m is distributed with in the range of 1.2-3.0 as shown in **Fig. 2a** and **Fig. 2b**. These range are relatively narrow compared with the previous results obtained using direct approach. The correlation coefficient also gets improved as shown in **Fig. 2c**.



a. Distribution of parameter l   b. Distribution of parameter m   c. Cumulative R^2 percentile distribution

Fig. 2 Distribution of sensitivity parameters and R^2 cumulative percentile using car following data

Fig. 3 presents the distribution of optimum values for parameters l, m and cumulative R^2 percentile for all drivers estimated by indirect approach using intersection data. The optimum value obtained for parameter l is distributed with in the range of 0.6-3 while the same for parameter m is distributed with in the range of 2.0-3.0 as shown in **Fig. 3a** and **Fig. 3b**. These range are relatively narrow when compared with previous results obtained using direct approach. A distinct improvement in correlation coefficient can be observed from **Fig. 3c**.



a. Distribution of parameter l   b. Distribution of parameter m   c. Cumulative R^2 percentile distribution

Fig. 3 Distribution of sensitivity parameters and R^2 cumulative percentile using intersection data

Besides other reasons for improvement in the results, obtained using indirect method, one reason might be the use of intersection data that covers a wide regime of traffic flow conditions from congested to steady state.

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