Freeway Traffic Volume Prediction Based on Improved Cell Transmission Model

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ABSTRACT

The traditional cell transmission model (CTM) requires that all cell lengths must be equal. In order to improve the applicability of CTM model and make the prediction result more accurate, improved CTM was proposed. In the improved CTM, the length of the cell cannot be equal, so it is more suitable for the prediction of different length sections on the highway. The simulation results show that the improved CTM model meets the requirements of freeway traffic flow forecasting.

INTRODUCTION

CTM was first proposed by Daganzo in 1994. The model is consistent with the hydrodynamic model. It can well describe the process of vehicle queue formation and dissipation. CTM can describe the traffic status of saturated or unsaturated sections accurately, and can simulate traffic flow propagation in the network. It is an effective tool to study the traffic flow rules. Compared with urban roads, freeway traffic is relatively simple, so it is very suitable to use CTM model to predict traffic volume.

CELL TRANSMISSION MODEL

The CTM model divides the road into homogeneous section, and divides the time into equal length intervals. The lengths of the cells are the distances traveled in light traffic within one time interval. CTM model satisfies :

\[ n_i(t + 1) = n_i(t) + y_i(t) - y_{i+1}(t) \]  \hspace{1cm} (1)

\[ y_i(t) = \min \{ n_i(t), Q_i(t), \omega / v \} \left[ N_i(t) - n_i(t) \right] \]  \hspace{1cm} (2)

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Where:
\[ n_i(t), \text{the number of vehicles in cell } i \text{ at time } t; \]
\[ y_i(t), \text{the number of vehicles entering the cell } i \text{ from the cell } i-1, \text{ at the time } t \text{ to } t+1; \]
\[ Q_i(t), \text{the capacity flow into } i \text{ for time interval } t; \]
\[ N_i(t), \text{the maximum number of vehicles that can be present in cell } i; \]
\[ \omega, \text{free flow speed}; \]
\[ v, \text{backward wave speed}; \]

According to the principle of CTM, the length of a cell is equal to the distance traveled at one time interval when the vehicle is at free speed. It is difficult to simulate the traffic flow of ordinary section and ramp section on Freeway.

If the fixed cell length is used, the two ramp distances are easy to lead to the existence of two ramps on one cell, which cannot simulate the traffic between the ramps. In order to display the input and output of traffic flow on freeway better, it is necessary to improve the CTM model when the ramp is arranged in the appropriate cell.

**IMPROVED CELL TRANSMISSION MODEL**

In the improved CTM, the cell length may different, but must be greater than travel distance within a time interval. With the help of Matlab software, the improved CTM could build. According to the traffic flow parameters at the entrance of the section, the traffic volume of each cell in each moment could predict. Inputting the same traffic flow parameters into the Vissim software, and the detectors are installed in each cell to obtain the flow data of each cell. Based on the cellular data obtained by Vissim, the reliability of the traffic volume data of each cell predicted by the improved CTM will evaluate.

Simulate a freeway with a length of 14k. The ramp position is shown in Figure 1.

The improved CTM divides the main section into 18 cells, and the cell length is between 500–1000 meters. The free speed is equal to 90km/h. The time step is equal to 10s. The traffic volume of each step at the entrance of the road is input into the improved CTM. Then the traffic flow of each cell will obtain. In the model, input unsaturated flow and saturated flow are analyzed respectively. The result is shown in Table I and Table II.

![Figure 1. Simulation section of improved CTM.](image-url)
**TABLE I. ANALYSIS OF THE CELL VEHICLE NUMBER PREDICTION UNDER CONDITION OF 2500PCU/H.**

| Cell | predicted value(pcu) | Simulation value(pcu) | Relative error (%) |
|------|-----------------------|-----------------------|--------------------|
| 1    | 2503                  | 2549                  | 1.80               |
| 2    | 2503                  | 2549                  | 1.80               |
| 3    | 2502                  | 2548                  | 1.80               |
| 4    | 2500                  | 2549                  | 1.90               |
| 5    | 2376                  | 2416                  | 1.70               |
| 6    | 2371                  | 2416                  | 1.80               |
| 7    | 2369                  | 2416                  | 1.90               |
| 8    | 2032                  | 2076                  | 2.10               |
| 10   | 2030                  | 2075                  | 2.20               |
| 11   | 2107                  | 2167                  | 2.80               |
| 12   | 2105                  | 2167                  | 2.80               |
| 13   | 2102                  | 2168                  | 3.00               |
| 14   | 2100                  | 2166                  | 3.10               |
| 15   | 2097                  | 2166                  | 3.20               |
| 16   | 2095                  | 2164                  | 3.20               |
| 17   | 1619                  | 1672                  | 3.20               |
| 18   | 1652                  | 1705                  | 3.10               |

**TABLE II. ANALYSIS OF THE CELL VEHICLE NUMBER PREDICTION UNDER CONDITION OF 4600PCU/H.**

| Cell | predicted value(pcu) | Simulation value(pcu) | Relative error (%) |
|------|-----------------------|-----------------------|--------------------|
| 1    | 4248                  | 4567                  | 7.00               |
| 2    | 4248                  | 4566                  | 7.00               |
| 3    | 4248                  | 4565                  | 6.90               |
| 4    | 4248                  | 4566                  | 7.00               |
| 5    | 4048                  | 4322                  | 6.30               |
| 6    | 4049                  | 4318                  | 6.20               |
| 7    | 4050                  | 4318                  | 6.20               |
| 8    | 3613                  | 3849                  | 6.10               |
| 10   | 3613                  | 3849                  | 6.10               |
| 11   | 3734                  | 3979                  | 6.20               |
| 12   | 3734                  | 3979                  | 6.20               |
| 13   | 3734                  | 3980                  | 6.20               |
| 14   | 3734                  | 3979                  | 6.20               |
| 15   | 3735                  | 3980                  | 6.20               |
| 16   | 3735                  | 3801                  | 1.70               |
| 17   | 2930                  | 2847                  | 2.90               |
| 18   | 3002                  | 2903                  | 3.40               |
In the last table, the maximum relative error under saturated traffic is 7%, and the maximum relative error under unsaturated traffic is 3.2%. According to the relative error, the prediction error of the CTM will increase when the traffic volume increases, but whether the flow is saturated or not, the relative error is less than or equal to 7%. The results meet the requirements of the prediction accuracy of the highway, and the prediction results are satisfactory.

**CONCLUSION**

The improved CTM can choose the appropriate cell length according to the specific condition. The cell length cannot be equal, which makes the model more applicable. Compared with the prediction results and simulation results, the prediction results obtained by the improved CTM are in good agreement with the actual ones. The error is small and the fitting result is good, and the traffic flow of the expressway can be well predicted.

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